Noeuds de noeuds

> Sur un tore vont être découpées deux lanières (Rouge et Bleue) : chacune fait 2 fois le tour du "trou extérieur" et 3 fois le tour du "trou intérieur"

Quand le tore disparaît on rétrécit la lanière Rouge sur le cercle des centres du tore, et on tient l'ensemble par cette lanière : la lanière Bleue tombe et pend. On a la Bleue qui fait 3 fois le tour de la (double) Rouge, ce qui nous dit que les deux courbes sont 6 fois entrelacées ... mais en regardant le résultat, il est "impensable" que ce soit la Rouge qui fasse 3 fois le tour de la Bleue alors qu'au départ leur positions étaient symétriques

```
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```

> *Le présent fichier est* "lavé" : *j'ai enlevé les traces d'erreurs*
"fin_16_08_demo_pneu_UPS" *est correct en gardant les traces d'erreurs*

```
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```

L'image de départ

```
> restart;with(plots):with(plottools):
```

R et r = les rayons des cercles "extérieur" et "intérieur" du tore T, P = le point générique de T

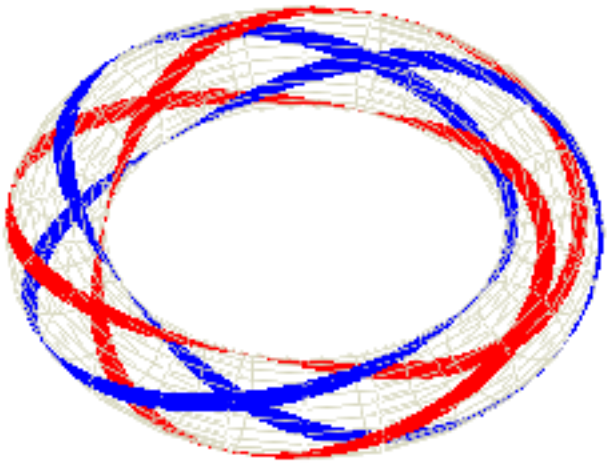
```
> R:=5:r:=1:
> P:=(theta,alpha)->[(R+r*cos(alpha))*cos(theta),(R+r*cos
  (alpha))*sin(theta),r*sin(alpha)]:
> pneu:=plot3d(P(theta,t),theta=0..2*Pi,t=0..2*Pi,style=
  wireframe,color=wheat):
> # display(pneu,scaling=constrained,view=[-R-r..R+r,-R-r..R+r,
  -R-r..R+r]):
```

NB : la formule pour le premier noeud, bandeB : l'objet graphique noeudB (B = Bleu)

```
> NB:=(u,v)->P(2*u,3*u+v):
> bandeB:=plot3d(NB(u,v),u=0..2*Pi,v=-0.2..0.2,color=blue,
  style=patchnogrid,grid=[100,4]):
> # display(pneu,bandeB,scaling=constrained,view=[-R-r..R+r,-R-
  r..R+r,-R-r..R+r]);
```

NR : la formule pour le second noeud, bandeR : l'objet graphique noeudR (R = Rouge)

```
> NR:=(u,v)->P(Pi/3+2*u,3*u+v):
> bandeR:=plot3d(NR(u,v),u=0..2*Pi,v=-0.2..0.2,color=red,style=
  patchnogrid,grid=[100,4]):
> display(pneu,bandeB,bandeR,scaling=constrained,view=[-R-r..R+
  r,-R-r..R+r,-R-r..R+r]);
```



```
>
>
```

La bande rouge se contracte

> *Le rayon r devient un ρ variable, ce paragraphe finit par la première animation*

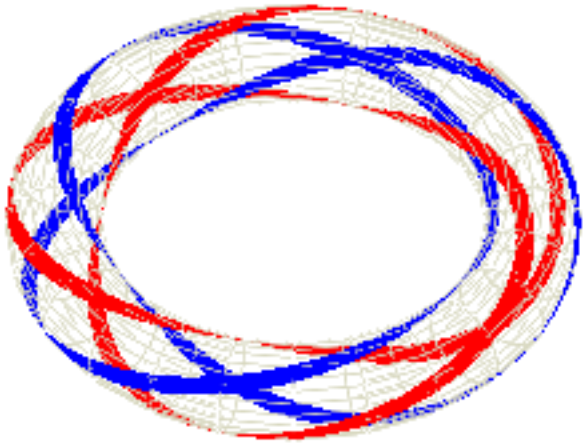
Le rayon devient un ρ variable, ce paragraphe finit par la première animation **(2.1)**

$$> \ Prho := (\theta, \alpha, \rho) \rightarrow [(R + \rho * \cos(\alpha)) * \cos(\theta), (R + \rho * \cos(\alpha)) * \sin(\theta), \rho * \sin(\alpha)] :$$

```
> NRrho:=(u,v,t)->Prho(Pi/3+2*u,3*u+v,t):
```

```
> bandeRrho:=t->plot3d(NRrho(u,v,1-t),u=0..2*Pi,v=-0.2..0.2,
  color=red,style=patchnogrid,grid=[100,4]):
> # display(pneu,bandeB,bandeRrho(0.5),scaling=constrained,
  view=[-R-r..R+r,-R-r..R+r,-R-r..R+r]):
> animate(bandeRrho, [t], t = 0 ..0.8, background = display(pneu, bandeB), scaling
      = constrained);
```

$$t = 0.$$



La bande bleue traverse le trou : première moitié

> La bande bleue est divisée en : un morceau bleu qui ne bougera pas, un jaune qui ne bougera pas, un morceau noir qui va se déplacer pour donner le vert. Quand on regarde sous les angles -95,88 on "voit" pourquoi ce mouvement ne va pas rencontrer bandeRrho(0.8) (preuve dans la partie texte)
>
> Au début les bandes mobiles sont de couleurs différentes : cela aide à débugger

```
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```

```
> tord1a := plot3d(NB(u, v), u = 0 .. π/3, v = -0.2 ..0.2, color = blue, style = patchnogrid, grid
      = [100, 4]) :
  tord1b := plot3d(NB(u, v), u = 2 ·π/3 .. 2·π, v = -0.2 ..0.2, color = yellow, style
      = patchnogrid, grid = [100, 4]) :
  tord1cfin := plot3d(P(2· π - 4· u, 3·u + v), u = π/3 .. 2·π/3, v = -0.2 ..0.2, color = green,
      style = patchnogrid, grid = [100, 4]) :

> tord1cdebut := plot3d(NB(u, v), u = π/3 .. 2 ·π/3, v = -0.2 ..0.2, color = black, style
      = patchnogrid, grid = [100, 4]) :

> display(bandeRrho(0.9), tord1a, tord1b, tord1cfin, tord1cdebut, view = [-R-r-2 ..R + r
      + 1, -R-r-2 ..R + r + 1, -R-r-1 ..R + r + 1], scaling = constrained, orientation = [0,
      0]) :

> tordbouge := t→ plot3d(NB(u, v)·(1 - t) + P(2· π - 4· u, 3·u + v)·t, u = π/3 .. 2 ·π/3, v
      = -0.2 ..0.2, color = brown, style = patchnogrid, numpoints = 800) :

> #animate(tordbouge, [t], t = 0 ..1, background = display(bandeRrho(0.9), tord1a, tord1b,
      view = [-R-r-2 ..R + r + 1, -R-r-2 ..R + r + 1, -R-r-1 ..R + r + 1], scaling
      = constrained, orientation = [0, 0])) ;

> Tout est réécrit en pur bleu
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> tord1a := plot3d(NB(u, v), u = 0 .. π/3, v = -0.2 ..0.2, color = blue, style = patchnogrid, grid
      = [100, 4]) :
  tord1b := plot3d(NB(u, v), u = 2 ·π/3 .. 2·π, v = -0.2 ..0.2, color = blue, style
      = patchnogrid, grid = [100, 4]) :
  tord1cfin := plot3d(P(2· π - 4· u, 3·u + v), u = π/3 .. 2·π/3, v = -0.2 ..0.2, color = blue,
      style = patchnogrid, grid = [100, 4]) :

> tord1cdebut := plot3d(NB(u, v), u = π/3 .. 2 ·π/3, v = -0.2 ..0.2, color = blue, style
      = patchnogrid, grid = [100, 4]) :
```
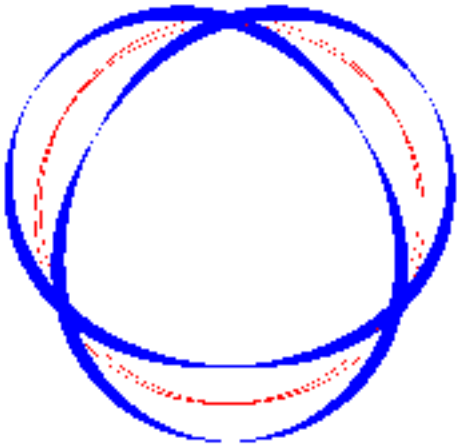

```
>
> tordbouge1 := t→ plot3d( NB(u, v)·(1 − t) + P(2·π − 4·u, 3·u + v)·t, u = π/3 .. 2·π/3, v
      =−0.2 ..0.2, color = blue, style = patchnogrid, grid = [100, 4] ) :
> animate(tordbouge1, [t], t = 0 ..1, background = display(bandeRrho(0.9), tord1a, tord1b,
      view = [ −R−r−2 ..R + r + 1, −R−r−2 ..R + r + 1, −R−r−1 ..R + r + 1], scaling
      = constrained, orientation = [0, 0]) );
```

$t = 0.$



```
>
```

La bande bleue traverse le trou : seconde moitié

> La bande bleue est divisée en :
FAB (bleu) qui ne bougera pas
CDE (orange) qui ne bougera pas
un jaune qui ne bougera pas (c'est le final du mouvement précédent)
un morceau noir qui va se déplacer pour donner le vert. Quand on

regarde sous les angles -95,88 on "voit" pourquoi ce mouvement ne va pas rencontrer bandeRrho(0.8)

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> $tord2a := plot3d\left(NB(u,v), u = -\frac{\pi}{3} .. \frac{\pi}{3}, v = -0.2 .. 0.2, color = blue, style = patchnogrid, grid = [100, 4]\right):$

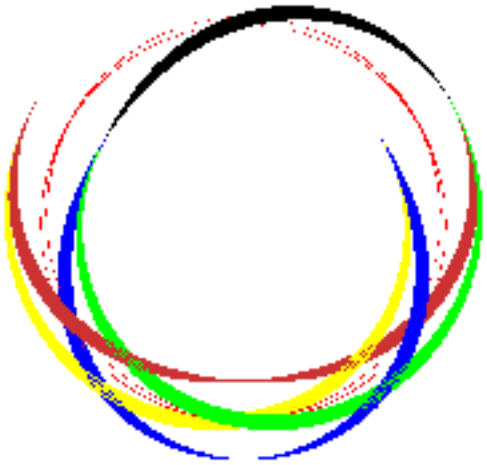
$tord2o := plot3d\left(NB(u,v), u = \frac{2\cdot\pi}{3} .. \frac{4\cdot\pi}{3}, v = -0.2 .. 0.2, color = orange, style = patchnogrid, grid = [100, 4]\right):$

$tord2b := plot3d\left(P(2\cdot\pi - 4\cdot u, 3\cdot u + v), u = \frac{\pi}{3} .. \frac{2\cdot\pi}{3}, v = -0.2 .. 0.2, color = yellow, style = patchnogrid, grid = [100, 4]\right):$

$tord2cfin := plot3d\left(P(2\cdot\pi - 4\cdot u, 3\cdot u + v), u = \frac{4\cdot\pi}{3} .. \frac{5\cdot\pi}{3}, v = -0.2 .. 0.2, color = green, style = patchnogrid, grid = [100, 4]\right):$

> $tord2cdebut := plot3d\left(NB(u,v), u = \frac{4\cdot\pi}{3} .. \frac{5\cdot\pi}{3}, v = -0.2 .. 0.2, color = black, style = patchnogrid, grid = [100, 4]\right):$

> $display(bandeRrho(0.9), tord2a, tord2o, tord2b, tord2cfin, tord2cdebut, view = [-R-r-2 .. R+r+1, -R-r-2 .. R+r+1, -R-r-1 .. R+r+1], scaling = constrained, orientation = [0, 0]);$



> $tordbouge2 := t \rightarrow plot3d\left(NB(u,v)\cdot(1-t) + P(2\cdot\pi - 4\cdot u, 3\cdot u + v)\cdot t, u = \frac{4\cdot\pi}{3} .. \frac{5\cdot\pi}{3}, v = -0.2..0.2, color = brown, style = patchnogrid, grid = [100,4] \right):$

> $\#animate(tordbouge2, [t], t = 0..1, background = display(bandeRrho(0.9), tord2a, tord2o, tord2b, view = [-R-r-2..R+r+1, -R-r-2..R+r+1, -R-r-1..R+r+1], scaling = constrained, orientation = [0,0]));$

> Tout est réécrit en pur bleu

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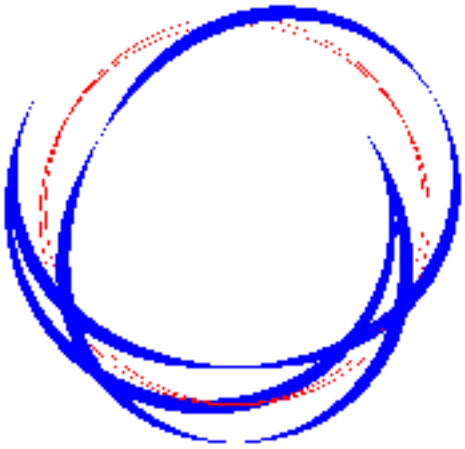
> $tord2a := plot3d\left(NB(u,v), u = -\frac{\pi}{3} .. \frac{\pi}{3}, v = -0.2..0.2, color = blue, style = patchnogrid, grid = [100,4] \right):$

$tord2o := plot3d\left(NB(u,v), u = \frac{2\cdot\pi}{3} .. \frac{4\cdot\pi}{3}, v = -0.2..0.2, color = blue, style = patchnogrid, grid = [100,4] \right):$

```
tord2b := plot3d( P(2·π − 4·u, 3·u + v), u = π/3 .. 2·π/3, v = −0.2 .. 0.2, color = blue, style
    = patchnogrid, grid = [100, 4] ) :
tord2cfin := plot3d( P(2·π − 4·u, 3·u + v), u = 4·π/3 .. 5·π/3, v = −0.2 .. 0.2, color = blue,
    style = patchnogrid, grid = [100, 4] ) :
> tord2cdebut := plot3d( NB(u, v), u = 4·π/3 .. 5·π/3, v = −0.2 .. 0.2, color = blue, style
    = patchnogrid, grid = [100, 4] ) :
>
> tordbouge2 := t → plot3d( NB(u, v)·(1 − t) + P(2·π − 4·u, 3·u + v)·t, u = 4·π/3
    .. 5·π/3, v = −0.2 .. 0.2, color = blue, style = patchnogrid, grid = [100, 4] ) :
> animate(tordbouge2, [t], t = 0 .. 1, background = display(bandeRrho(0.9), tord2a, tord2o,
    tord2b, view = [−R−r−2 .. R + r + 1, −R−r−2 .. R + r + 1, −R−r−1 .. R + r + 1],
    orientation = [0, 0]), scaling = constrained);
```

$t = 0.$



>

les bleus se tassent

> (avec les notations du document texte)

> La bande bleue est maintenant constituée des :

FAB qui est = P(2*u,3*u+v) pour u entre - et + Pi/3 : on va tasser u vers 0

CDE qui est = P(2*u,3*u+v) pour u entre 2 et 4 Pi/3 : on va tasser u vers Pi

le premier nouveau : $P\left(2\cdot\pi-4\cdot u, 3\cdot u+v\right), u=\frac{\pi}{3}..\frac{2\cdot\pi}{3}$: on va tasser u vers Pi/2

le second nouveau : $P\left(2\cdot\pi-4\cdot u, 3\cdot u+v\right), u=\frac{4\cdot\pi}{3}..\frac{5\cdot\pi}{3}$: on va tasser u vers 3*Pi/2

$$[(5+\cos(3u+v))\cos(4u), -(5+\cos(3u+v))\sin(4u), \sin(3u+v)], u=\frac{1}{3}\pi..\frac{2}{3}\pi$$

$$[(5+\cos(3u+v))\cos(4u), -(5+\cos(3u+v))\sin(4u), \sin(3u+v)], u=\frac{4}{3}\pi..\frac{5}{3}\pi \quad \textbf{(5.1)}$$

> On commence par tout ré-écrire avec u entre - et + Pi/3 :

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```
> tasseP := (m, θ, α) → [(R + r*cos(α))*cos(m·θ), (R + r*cos(α))*sin(m·θ), r
      *sin(α)];
```

$$tasseP := (m, \theta, \alpha) \rightarrow [(R + r\cos(\alpha))\cos(m\,\theta), (R + r\cos(\alpha))\sin(m\,\theta), r\sin(\alpha)] \quad \textbf{(5.2)}$$

```
> tasseNB := (m, u, v) → tasseP(m, 2*u, 3*u + v);
```

$$tasseNB := (m, u, v) \rightarrow tasseP(m, 2\,u, 3\,u + v) \quad \textbf{(5.3)}$$

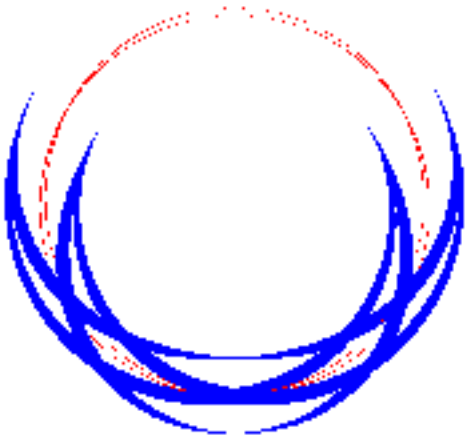
```
> FAB := t→plot3d(tasseNB((1 − t), u, v), u=-π/3..π/3, v=-0.2..0.2, color=blue, style
      =patchnogrid, grid=[100, 4]):
> CDE := t→plot3d(tasseNB((1 − t), (u + π), v), u=-π/3..π/3, v=-0.2..0.2, color
      =blue, style=patchnogrid, grid=[100, 4]):
> new1 := t→plot3d(tasseP((1 − t), (2·π − 4·((u + π)/2)), 3·((u + π)/2) + v), u
      =-π/3..π/3, v=-0.2..0.2, color=blue, style=patchnogrid, grid=[100, 4]):
> new2 := t→plot3d(tasseP((1 − t), 2·π − 4·((-π + (u + 3·π))/2), 3·((-π + (u + 3·π))/2)
      + v), u=-π/3..π/3, v=-0.2..0.2, color=blue, style=patchnogrid, grid=[100, 4]):
> display(FAB(0), CDE(0), new1(0), new2(0), scaling=constrained, orientation=[0, 0]);
```

```
>
> toutbouge := t→display(FAB(t), CDE(t), new1(t), new2(t), scaling = constrained);
```

$$toutbouge := t \rightarrow plots:\text{-}display(FAB(t), CDE(t), new1(t), new2(t), scaling = constrained) \quad \textbf{(5.4)}$$

```
> animate(toutbouge, [t], t = 0..0.8, background = display(bandeRrho(0.9), view = [-R-r-2
      ..R + r + 1, -R-r-2..R + r + 1, -R-r-1..R + r + 1], scaling = constrained, orientation
      = [0, 0]));
```

$t = 0.$



En fait ça ne marche pas ...

> Car la première variable des P ou NB ou tasse P ... n'est pas simplement "u", donc la multiplication par m n'a pas l'effet voulu, il faut donc ré-écrire les formules utilisées sous la forme NB(u,truc)

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> la formule pour FAB :

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```
> NB(u, v);
```

$$[(5+\cos(3u+v))\cos(2u), (5+\cos(3u+v))\sin(2u), \sin(3u+v)] \quad \textbf{(5.5)}$$

```
> NB(u, v);
```

$$[(5+\cos(3u+v))\cos(2u), (5+\cos(3u+v))\sin(2u), \sin(3u+v)] \quad \textbf{(5.6)}$$

> la formule pour CDE :

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```
> NB(u + π, v);
```

$$[(5-\cos(3u+v))\cos(2u), (5-\cos(3u+v))\sin(2u), -\sin(3u+v)] \quad \textbf{(5.7)}$$

> $NB(u, v+\pi);$

$$[(5-\cos(3u+v))\cos(2u),\ (5-\cos(3u+v))\sin(2u),\ -\sin(3u+v)] \quad (5.8)$$

> la formule pour new1 :

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> $P\left(2\cdot\pi-4\cdot\left(\frac{(u+\pi)}{2}\right), 3\cdot\left(\frac{(u+\pi)}{2}\right)+v\right)$

$$\left[\left(5+\sin\left(\frac{3}{2}u+v\right)\right)\cos(2u),\ -\left(5+\sin\left(\frac{3}{2}u+v\right)\right)\sin(2u),\ -\cos\left(\frac{3}{2}u+v\right)\right] \quad (5.9)$$

> $NB(x, y);$

$$[(5+\cos(3x+y))\cos(2x),\ (5+\cos(3x+y))\sin(2x),\ \sin(3x+y)] \quad (5.10)$$

> $NB\left(-u, v+\frac{9\cdot u}{2}-\frac{\pi}{2}\right);$

$$\left[\left(5+\sin\left(\frac{3}{2}u+v\right)\right)\cos(2u),\ -\left(5+\sin\left(\frac{3}{2}u+v\right)\right)\sin(2u),\ -\cos\left(\frac{3}{2}u+v\right)\right] \quad (5.11)$$

> la formule pour new2 :

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> $P\left(2\cdot\pi-4\cdot\left(\left(\frac{(u+3\cdot\pi)}{2}\right)\right), 3\cdot\left(\left(\frac{(u+3\cdot\pi)}{2}\right)\right)+v\right);$

$$\left[\left(5-\sin\left(\frac{3}{2}u+v\right)\right)\cos(2u),\ -\left(5-\sin\left(\frac{3}{2}u+v\right)\right)\sin(2u),\ \cos\left(\frac{3}{2}u+v\right)\right] \quad (5.12)$$

> $P(x, y);$

$$[(5+\cos(y))\cos(x),\ (5+\cos(y))\sin(x),\ \sin(y)] \quad (5.13)$$

> $P\left(-2\cdot u, 2\cdot\pi-4\cdot\left(\left(\frac{(u+3\cdot\pi)}{2}\right)\right), 3\cdot\left(\left(\frac{(u+3\cdot\pi)}{2}\right)\right)+v\right);$

$$[(5+\cos(2u))\cos(2u),\ -(5+\cos(2u))\sin(2u),\ -\sin(2u)] \quad (5.14)$$

> $reFAB := t\rightarrow plot3d\left(tasseNB((1-t), u, v), u=-\frac{\pi}{3}..\frac{\pi}{3}, v=-0.2..0.2, color=blue, style=patchnogrid, grid=[100, 4]\right):$

> $reCDE := t\rightarrow plot3d\left(tasseNB((1-t), u, v+\pi), u=\frac{-\pi}{3}..\frac{\pi}{3}, v=-0.2..0.2, color=blue, style=patchnogrid, grid=[100, 4]\right):$

> $renew1 := t\rightarrow plot3d\left(tasseNB\left((1-t), -u, v+\frac{9\cdot u}{2}-\frac{\pi}{2}\right), u=\frac{-\pi}{3}..\frac{\pi}{3}, v=-0.2..0.2, color=blue, style=patchnogrid, grid=[100, 4]\right):$

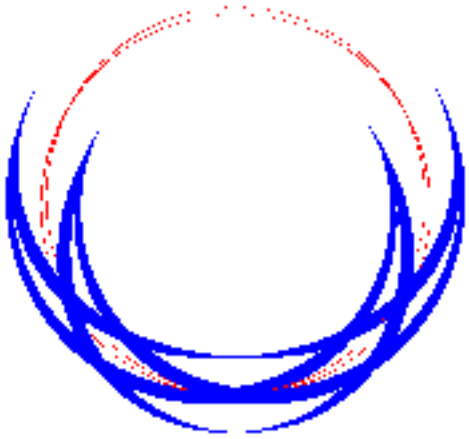
> $renew2 := t\rightarrow plot3d\left(tasseNB\left((1-t), -u, v+\frac{9\cdot u}{2}-\frac{3\cdot\pi}{2}\right), u=\frac{-\pi}{3}..\frac{\pi}{3}, v=-0.2..0.2, color=blue, style=patchnogrid, grid=[100, 4]\right):$

```
> retoutbouge := t→display(reFAB(t), reCDE(t), renew1(t), renew2(t), scaling
      =constrained);
```

```
retoutbouge := t→plots:-display(reFAB(t), reCDE(t), renew1(t), renew2(t), scaling      (5.15)
    =constrained)
```

```
> animate(retoutbouge, [t], t=0..0.9, background=display(bandeRrho(0.9), view=[-R-r
      -2..R+r+1,-R-r-2..R+r+1,-R-r-1..R+r+1], orientation=[0, 0]), scaling
      =constrained);
```

$$t = 0.$$



On enchaîne du départ au "3B & 2R"

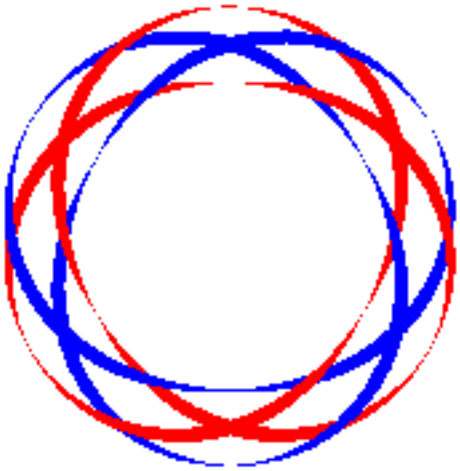
```
> Da3B2R :=proc(t) if t < 0.8
            then display(bandeB, bandeRrho(t))
            else if t < 1.8 then display(bandeRrho(0.8), tord1a, tord1b, tordbouge1(t
      −0.8))
            else if t < 2.8 then display(bandeRrho(0.8), tord2a, tord2b, tord2o,
      tordbouge2(t − 1.8))
            else if t < 3.7 then display(bandeRrho(0.8), retoutbouge(t − 2.8))
             else display(pneu) fi fi fi fi end:
```

```
>
```

```
> animate(Da3B2R, [t], t=0..3.69, view=[-R-r-2..R+r+1,-R-r-2..R+r+1,-R-r-1
```

$..R + r + 1], scaling = constrained, orientation = [0, 0]);$

$t = 0.$



La moitié "symétrique"

La bande bleue se contracte

```
> NBrho:=(u,v,t)->Prho(2*u,3*u+v,t):;
> bandeBrho:=t->plot3d(NBrho(u,v,1-t),u=0..2*Pi,v=-0.2..0.2,
  color=blue,style=patchnogrid,grid=[100,4]):
> #display(pneu,bandeR,bandeBrho(0.5),scaling=constrained,
  view=[-R-r..R+r,-R-r..R+r,-R-r..R+r]):
```

$> animate(bandeBrho, [t], t = 0..0.8, background = display(pneu, bandeR), scaling = constrained):$

```
>
```

La bande rouge traverse le trou : première moitié

> " Il suffit de tourner de Pi/3 pour que la situation soit la même " en fait la mise au point des 'détails' est juste aussi dure que la première fois

Error, missing operator or `;`

> $tord1Ra := plot3d\left(NR(u,v), u = \frac{-\pi}{3}..0, v = -0.2..0.2, color = blue, style = patchnogrid, grid = [100,4]\right):$

$tord1Rb := plot3d\left(NR(u,v), u = \frac{\pi}{3}..\frac{5\cdot\pi}{3}, v = -0.2..0.2, color = yellow, style = patchnogrid, grid = [100,4]\right):$

$tord1Rcfin := plot3d\left(P\left(\frac{\pi}{3} - 4\cdot u, 3\cdot u + v\right), u = 0..\frac{\pi}{3}, v = -0.2..0.2, color = green, style = patchnogrid, grid = [100,4]\right):$

>

> $tord1Rcdebut := plot3d\left(NR(u,v), u = 0..\frac{\pi}{3}, v = -0.2..0.2, color = black, style = patchnogrid, grid = [100,4]\right):$

> $display(bandeBrho(0.9), tord1Ra, tord1Rb, tord1Rcfin, tord1Rcdebut, view = [-R-r-2..R+r+1, -R-r-2..R+r+1, -R-r-1..R+r+1], scaling = constrained, orientation = [0,0]):$

> $tordbougeR := t \to plot3d\left(NR(u,v)\cdot(1-t) + P\left(\frac{\pi}{3} - 4\cdot u, 3\cdot u + v\right)\cdot t, u = 0..\frac{\pi}{3}, v = -0.2..0.2, color = brown, style = patchnogrid, grid = [100,4]\right):$

> $animate(tordbougeR, [t], t = 0..1, background = display(bandeBrho(0.9), tord1Ra, tord1Rb, view = [-R-r-2..R+r+1, -R-r-2..R+r+1, -R-r-1..R+r+1], scaling = constrained, orientation = [0,0])):$

> Tout est réécrit en pur rouge

Error, missing operator or `;`

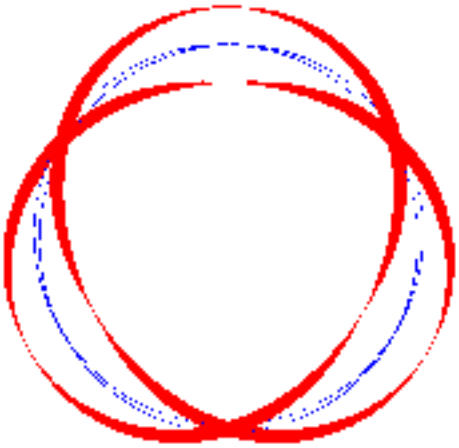
> $tord1Ra := plot3d\left(NR(u,v), u = \frac{-\pi}{3}..0, v = -0.2..0.2, color = red, style = patchnogrid, grid = [100,4]\right):$

$tord1Rb := plot3d\left(NR(u,v), u = \frac{\pi}{3}..\frac{5\cdot\pi}{3}, v = -0.2..0.2, color = red, style = patchnogrid, grid = [100,4]\right):$

$tord1Rcfin := plot3d\left(P\left(\frac{\pi}{3} - 4\cdot u, 3\cdot u + v\right), u = 0..\frac{\pi}{3}, v = -0.2..0.2, color = red, style = patchnogrid, grid = [100,4]\right):$

```
>
> tord1Rcdebut := plot3d(NR(u, v), u = 0 .. π/3, v = -0.2 ..0.2, color = red, style
      = patchnogrid, grid = [100, 4]) :
>
> tordbougeR := t→ plot3d(NR(u, v)·(1 - t) + P(π/3 - 4·u, 3·u + v)·t, u = 0 .. π/3, v =
      -0.2 ..0.2, color = red, style = patchnogrid, grid = [100, 4]) :
> animate(tordbougeR, [t], t = 0 ..1, background = display(bandeBrho(0.9), tord1Ra,
      tord1Rb, view = [-R-r-2 ..R + r + 1, -R-r-2 ..R + r + 1, -R-r-1 ..R + r + 1],
      scaling = constrained, orientation = [0, 0]));
```

$t = 0.$



```
>
```

La bande rouge traverse le trou : seconde moitié

> La bande rouge est divisée en : (analogues)
FAB (bleu) qui ne bougera pas

CDE (orange) qui ne bougera pas
un jaune qui ne bougera pas (c'est le final du mouvement précédent)

un morceau noir qui va se déplacer pour donner le vert. Quand on regarde sous les angles -95,88 on "voit" pourquoi ce mouvement ne va pas rencontrer bandeRrho(0.8)

Error, missing operator or `;`

> $tord2Ra := plot3d\left(NR(u,v), u = -\frac{2\cdot\pi}{3}..0, v = -0.2..0.2, color = blue, style = patchnogrid, grid = [100,4]\right):$

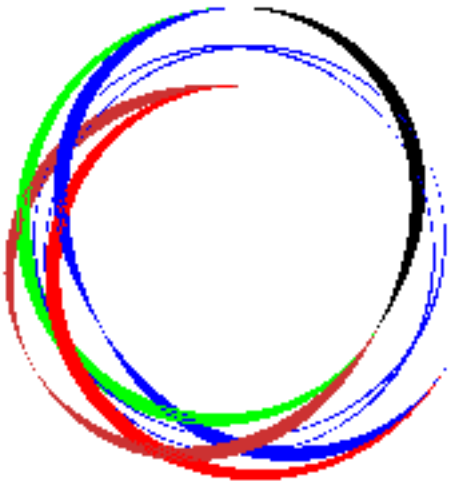
$tord2Ro := plot3d\left(NR(u,v), u = \frac{\pi}{3}..\frac{3\cdot\pi}{3}, v = -0.2..0.2, color = orange, style = patchnogrid, grid = [100,4]\right):$

$tord2Rb := plot3d\left(P\left(\frac{\pi}{3} - 4\cdot u, 3\cdot u + v\right), u = 0..\frac{\pi}{3}, v = -0.2..0.2, color = red, style = patchnogrid, grid = [100,4]\right):$

$tord2Rcfin := plot3d\left(P\left(\frac{\pi}{3} - 4\cdot u, 3\cdot u + v\right), u = \frac{3\cdot\pi}{3}..\frac{4\cdot\pi}{3}, v = -0.2..0.2, color = green, style = patchnogrid, grid = [100,4]\right):$

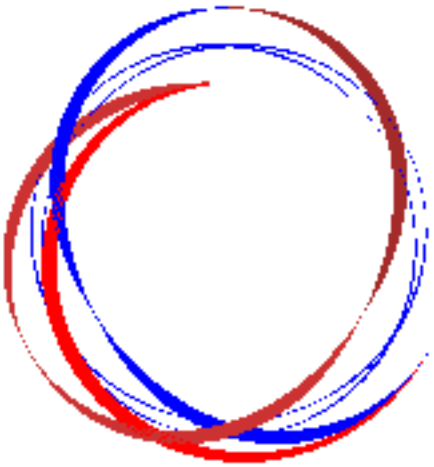
> $tord2Rcdebut := plot3d\left(NR(u,v), u = \frac{3\cdot\pi}{3}..\frac{4\cdot\pi}{3}, v = -0.2..0.2, color = black, style = patchnogrid, grid = [100,4]\right):$

> $display(bandeBrho(0.8), tord2Ra, tord2Ro, tord2Rb, tord2Rcfin, tord2Rcdebut, view = [-R-r-2..R+r+1, -R-r-2..R+r+1, -R-r-1..R+r+1], scaling = constrained, orientation = [0,0]);$



```
> tordbouge2R := t→ plot3d(NR(u, v)·(1 − t) + P(π/3 − 4·u, 3·u + v)·t, u = 3·π/3
    ..4·π/3, v = −0.2..0.2, color = brown, style = patchnogrid, grid = [100, 4]) :
> animate(tordbouge2R, [t], t = 0..1, background = display(bandeBrho(0.8), tord2Ra,
    tord2Ro, tord2Rb, view = [−R − r − 2..R + r + 1, −R − r − 2..R + r + 1, −R − r − 1..R + r
    + 1], scaling = constrained, orientation = [0, 0]));
```

$t = 0.$



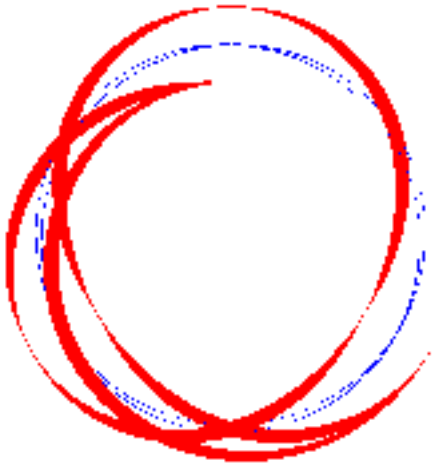
> Tout est réécrit en pur rouge

Error, missing operator or `;`

```
> tord2Ra := plot3d(NR(u, v), u = -2·π/3 ..0, v = -0.2 ..0.2, color = red, style
      = patchnogrid, grid = [100, 4]) :
  tord2Ro := plot3d(NR(u, v), u = π/3 .. 3·π/3, v = -0.2 ..0.2, color = red, style
      = patchnogrid, grid = [100, 4]) :
  tord2Rb := plot3d(P(π/3 - 4·u, 3·u + v), u = 0 .. π/3, v = -0.2 ..0.2, color = red , style
      = patchnogrid, grid = [100, 4]) :
  tord2Rcfin := plot3d(P(π/3 - 4· u, 3·u + v), u = 3·π/3 .. 4·π/3, v = -0.2 ..0.2, color
      = red, style = patchnogrid, grid = [100, 4]) :
```

```
> tord2Rcdebut := plot3d(NR(u, v), u = 3·π/3 .. 4·π/3, v = -0.2 .. 0.2, color = red, style
      = patchnogrid, grid = [100, 4]) :
> tordbouge2R := t → plot3d(NR(u, v)·(1 - t) + P(π/3 - 4·u, 3·u + v)·t, u = 3·π/3
      .. 4·π/3, v = -0.2 .. 0.2, color = red, style = patchnogrid, grid = [100, 4]) :
> animate(tordbouge2R, [t], t = 0 .. 1, background = display(bandeBrho(0.9), tord2Ra,
      tord2Ro, tord2Rb, view = [-R - r - 2 .. R + r + 1, -R - r - 2 .. R + r + 1, -R - r - 1 .. R + r
      + 1], orientation = [0, 0]), scaling = constrained);
```

$$t = 0.$$



```
>
```

les rouges se tassent

> La bande rouge est maintenant :
les $P\left(\frac{\pi}{3} + 2\cdot u, 3\cdot u + v\right)$ pour u entre -2 Pi/3 et 0

les $P\left(\frac{\pi}{3}+2\cdot u, 3\cdot u+v\right), u=\frac{\pi}{3}..\frac{3\cdot\pi}{3}$

les $P\left(\frac{\pi}{3}-4\cdot u, 3\cdot u+v\right), u=0..\frac{\pi}{3}$

les $P\left(\frac{\pi}{3}-4\cdot u, 3\cdot u+v\right), u=\frac{3\cdot\pi}{3}..\frac{4\cdot\pi}{3}$

$$\left[(5+\cos(3u+v))\cos\left(\frac{1}{3}\pi+2u\right), (5+\cos(3u+v))\sin\left(\frac{1}{3}\pi+2u\right), \sin(3u+v)\right]$$

$$\left[(5+\cos(3u+v))\cos\left(\frac{1}{3}\pi+2u\right), (5+\cos(3u+v))\sin\left(\frac{1}{3}\pi+2u\right), \sin(3u+v)\right], u=\frac{1}{3}\pi..\pi$$

$$\left[(5+\cos(3u+v))\sin\left(\frac{1}{6}\pi+4u\right), (5+\cos(3u+v))\cos\left(\frac{1}{6}\pi+4u\right), \sin(3u+v)\right], u=0..\frac{1}{3}\pi$$

$$\left[(5+\cos(3u+v))\sin\left(\frac{1}{6}\pi+4u\right), (5+\cos(3u+v))\cos\left(\frac{1}{6}\pi+4u\right), \sin(3u+v)\right], u=\pi..\frac{4}{3}\pi \quad \textbf{(7.4.1)}$$

> $NR(u, v)$

$$\left[(5+\cos(3u+v))\cos\left(\frac{1}{3}\pi+2u\right), (5+\cos(3u+v))\sin\left(\frac{1}{3}\pi+2u\right), \sin(3u+v)\right] \quad \textbf{(7.4.2)}$$

> $P(x, y);$

$$[(5+\cos(y))\cos(x), (5+\cos(y))\sin(x), \sin(y)] \quad \textbf{(7.4.3)}$$

> $P\left(\frac{\pi}{3}+2\cdot u, 3\cdot u+v\right);$

$$\left[(5+\cos(3u+v))\cos\left(\frac{1}{3}\pi+2u\right), (5+\cos(3u+v))\sin\left(\frac{1}{3}\pi+2u\right), \sin(3u+v)\right] \quad \textbf{(7.4.4)}$$

> $arc1 := plot3d\left(P\left(2\cdot x, 3\cdot x-\frac{\pi}{2}+y\right), x=-\frac{\pi}{2}..\frac{\pi}{6}, y=-0.2..0.2, color=green, style=patchnogrid, grid=[100, 4]\right):$

> $arc2 := plot3d\left(P\left(2\cdot x, 3\cdot x+\frac{\pi}{2}+y\right), x=\frac{-\pi}{2}..\frac{\pi}{6}, y=-0.2..0.2, color=blue, style$

$$= \text{patchnogrid}, \text{grid} = [100, 4]\Big) :$$

$$> \ arc3 := plot3d\left(P\left(2 \cdot x, \frac{3 \cdot x}{2} - \frac{\pi}{4} + y\right), x = -\frac{\pi}{2} .. \frac{\pi}{6}, y = -0.2 .. 0.2, \text{color} = \text{red}, \text{style}\right.$$

$$= \text{patchnogrid}, \text{grid} = [100, 4]\Big) :$$

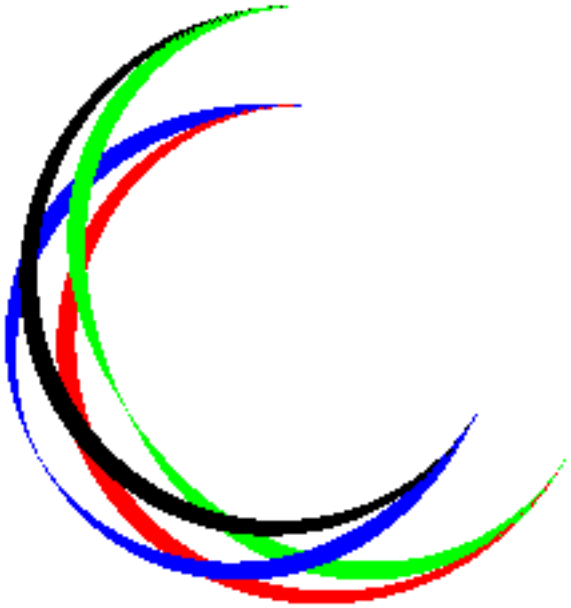
$$> \ arc4 := plot3d\left(P\left(2 \cdot x, \frac{3 \cdot x}{2} - \frac{13 \cdot \pi}{4} + y\right), x = \frac{-\pi}{2} .. \frac{\pi}{6}, y = -0.2 .. 0.2, \text{color}\right.$$

$$= \text{black}, \text{style} = \text{patchnogrid}, \text{grid} = [100, 4]\Big) :$$

>

>

```
> display(arc1,arc2,arc3,arc4,scaling=constrained,orientation = [0, 0]);
```



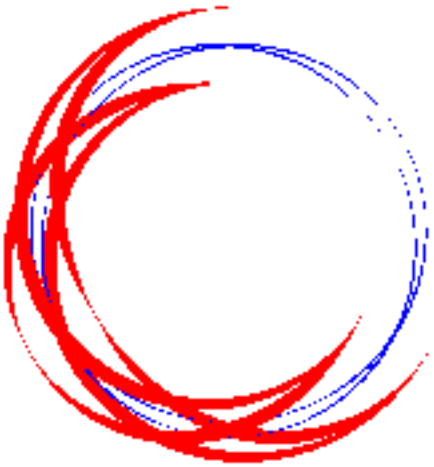
$$> \ rearc1 := plot3d\left(P\left(2 \cdot x, 3 \cdot x - \frac{\pi}{2} + y\right), x = -\frac{\pi}{2} .. \frac{\pi}{6}, y = -0.2 .. 0.2, \text{color} = \text{green}, \text{style}\right.$$

$$= \text{patchnogrid}, \text{grid} = [100, 4]\Big) :$$

```
> rearc2 := plot3d(P(2·x, 3·x + π/2 + y), x = -π/2 .. π/6, y = -0.2 ..0.2, color = blue,
      style = patchnogrid, grid = [100, 4]) :
> rearc3 := plot3d(P(2·x, 3·x/2 - π/4 + y), x = -π/2 .. π/6, y = -0.2 ..0.2, color = red, style
      = patchnogrid, grid = [100, 4]) :
> rearc4 := plot3d(P(2·x, 3·x/2 - 13·π/4 + y), x = -π/2 .. π/6, y = -0.2 ..0.2, color
      = black, style = patchnogrid, grid = [100, 4]) :
> #display(rearc1, rearc2, rearc3, rearc4, scaling = constrained, orientation = [0, 0]);
>
> On prend un paramètre symétrique % -π/6 :
Error, invalid fraction
                On prend un paramètre symétrique % -π/6 :
> rearc1S := plot3d(P(-π/3 + 2·a, 3·a - π + b), a = -π/3 .. π/3, b = -0.2 ..0.2, color
      = green, style = patchnogrid, grid = [100, 4]) :
> rearc2S := plot3d(P(-π/3 + 2·a, 3·a + b), a = -π/3 .. π/3, b = -0.2 ..0.2, color = blue,
      style = patchnogrid, grid = [100, 4]) :
> rearc3S := plot3d(P(-π/3 + 2·a, 3·a/2 - π/2 + b), a = -π/3 .. π/3, b = -0.2 ..0.2, color
      = red, style = patchnogrid, grid = [100, 4]) :
> rearc4S := plot3d(P(-π/3 + 2·a, 3·a/2 - 14·π/4 + b), a = -π/3 .. π/3, b = -0.2 ..0.2,
      color = black, style = patchnogrid, grid = [100, 4]) :
> #display(rearc1S, rearc2S, rearc3S, rearc4S, scaling = constrained, orientation = [0,
      0]);
> On refait avec un paramètre qui tasse (et en rouge)
                On refait avec un paramètre qui tasse et en rouge                (7.4.5)
> rearc1ST := t→ plot3d(P(-π/3 + 2·a·(1 - t), 3·a - π + b), a = -π/3 .. π/3, b = -0.2
```

```
..0.2, color = red , style = patchnogrid, grid = [100, 4] ) :
> rearc2ST := t→plot3d( P( -π/3 + 2·a·(1 − t), 3·a + b ), a = -π/3 ..π/3, b = -0.2 ..0.2,
color = red , style = patchnogrid, grid = [100, 4] ) :
> rearc3ST := t→ plot3d( P( -π/3 + 2·a·(1 − t), 3·a/2 − π/2 + b ), a = -π/3 ..π/3, b =
-0.2 ..0.2, color = red , style = patchnogrid, grid = [100, 4] ) :
> rearc4ST := t→plot3d( P( -π/3 + 2·a·(1 − t), 3·a/2 − 14·π/4 + b ), a = -π/3 ..π/3, b =
-0.2 ..0.2, color = red , style = patchnogrid, grid = [100, 4] ) :
> #display(rearc1ST(0), rearc2ST(0), rearc3ST(0), rearc4ST(0), scaling
= constrained, orientation = [0, 0]);
> final := t→display(rearc1ST(t), rearc2ST(t), rearc3ST(t), rearc4ST(t), scaling
= constrained, orientation = [0, 0]) :
> animate(final, [t], t = 0 ..0.9, background = display(bandeBrho(0.8), view = [ -R-r-2
..R + r + 1, -R-r-2 ..R + r + 1, -R-r-1 ..R + r + 1], orientation = [0, 0]), scaling
= constrained);
```

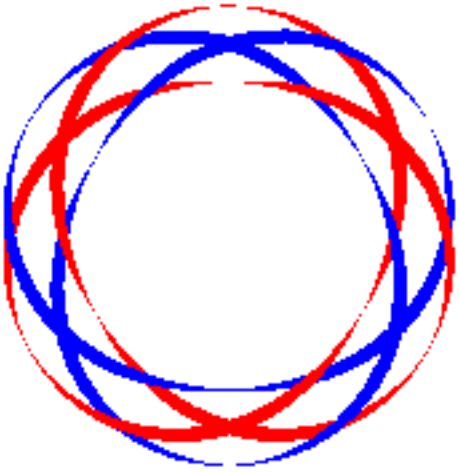
$t = 0.$



On enchaîne du Début à 3R+2B

```
> Da3R2B := proc(t) if t < 0.8
                then display(bandeR, bandeBrho(t))
                else if t < 1.8 then display(bandeBrho(0.8), tord1Ra, tord1Rb,
    tordbougeR(t - 0.8))
                else if t < 2.8 then display(bandeBrho(0.8), tord2Ra, tord2Rb, tord2Ro,
    tordbouge2R(t - 1.8))
                else if t < 3.7 then display(bandeBrho(0.8), final(t - 2.8))
                 else display(pneu) fi fi fi fi end:
> animate(Da3R2B, [t], t = 0..3.69, view = [-R-r-2..R + r + 1, -R-r-2..R + r + 1, -R
    -r-1..R + r + 1], scaling = constrained, orientation = [0, 0]);
```

$t = 0.$

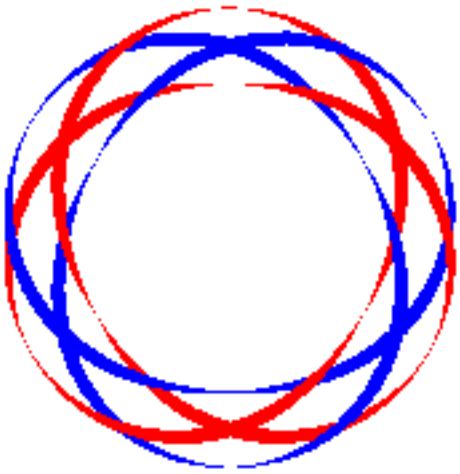


>

Tout ... regroupe tout

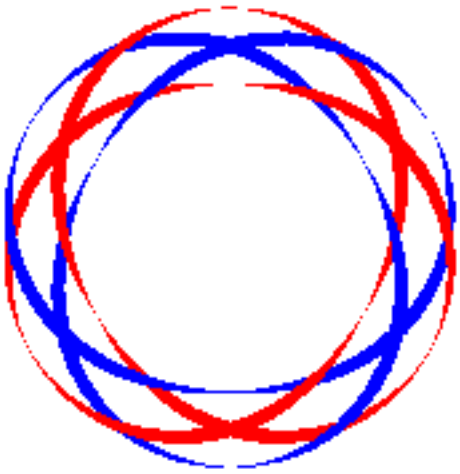
```
> animate(Da3B2R, [t], t=0..3.69, view=[-R-r-2..R+r+1,-R-r-2..R+r+1,-R-r-1
      ..R+r+1], scaling=constrained, orientation=[0, 0]);
```

$t = 0.$



```
> animate(Da3R2B, [t], t=0..3.69, view=[-R-r-2..R+r+1,-R-r-2..R+r+1,-R-r-1
  ..R+r+1], scaling=constrained, orientation=[0,0]);
```

$t = 0.$



```
> MontreTout := proc(t) if t < 0 then Da3R2B(-t) else Da3B2R(t) fi end:
> animate(MontreTout, [t], t=-3.69..3.69, view=[-R-r-2..R+r+1,-R-r-2..R+r+1,
      -R-r-1..R+r+1], scaling=constrained, orientation=[-25, 0], frames=100);
```

$t = -3.69$