

Freedom and Constraint Topology: Design Chart

Legend:

Translation
Rotation
Screw

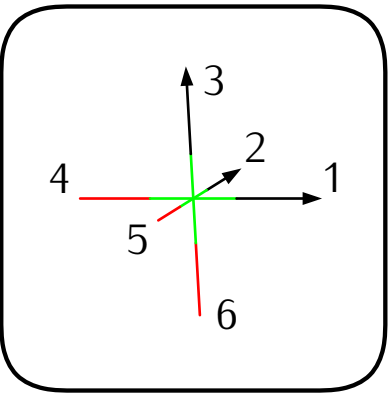
Constraint line

Flexure elastic deformation limit (approx):

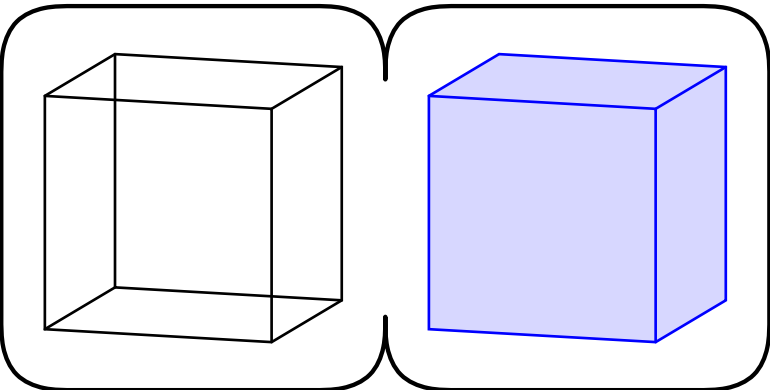
Input values are thickness of the flexure wire/blade and flexure height. Angular deformation was optimized for X blade flexure and parallel for ½ height travel.

$$\frac{\text{elongation at yield}}{\text{safety factor}} = \begin{cases} \frac{\text{thickness}}{\text{height}} \left(0.5 \frac{\text{arc travel}}{\text{height}} + 0.025 \frac{\text{arc travel}^3}{\text{height}^3} \right), & \text{if angular} \\ \frac{\text{thickness}}{\text{height}} \left(2.76 \frac{\text{travel}}{\text{height}} + 0.2 \frac{\text{travel}^2}{\text{height}^2} + 2.3 \frac{\text{travel}^4}{\text{height}^4} \right), & \text{if parallel} \\ 0.5 \frac{\text{thickness}}{\text{minimal deformation radius}}, & \text{if other} \end{cases}$$

Degrees of freedom legend:

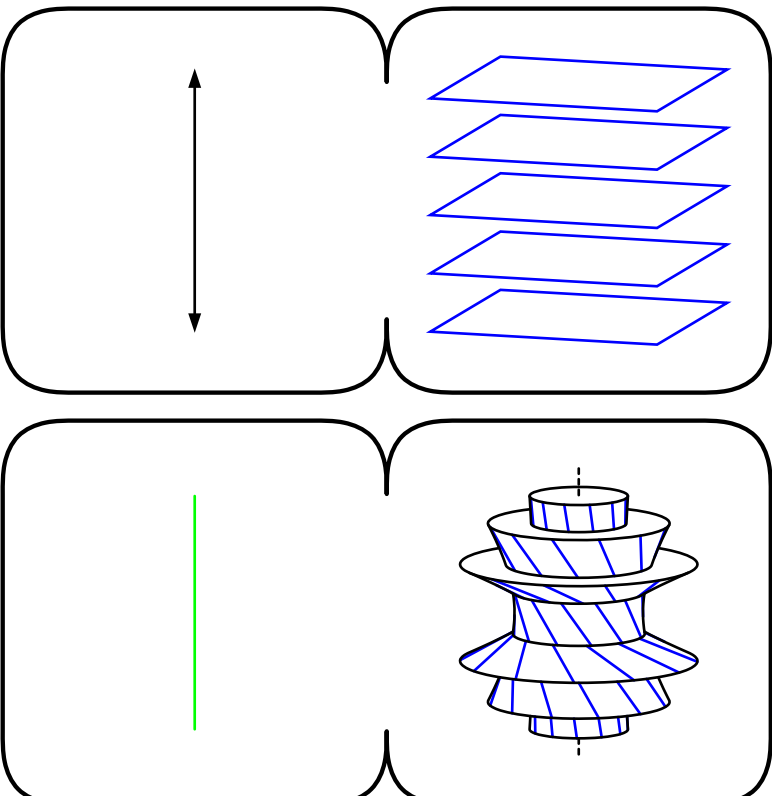


0° of freedom:

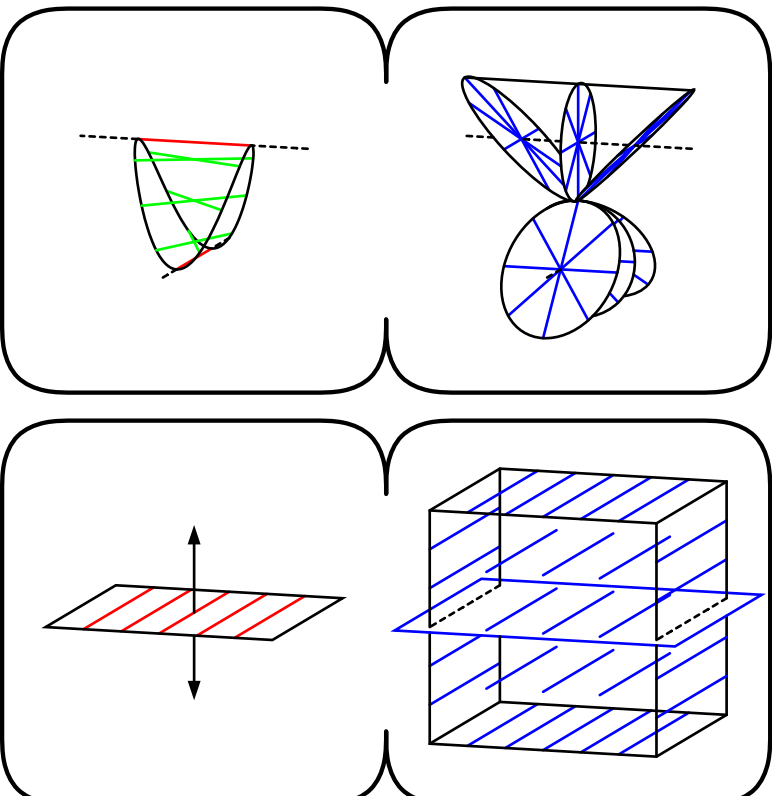


Freedom space Constraint space

1° of freedom:

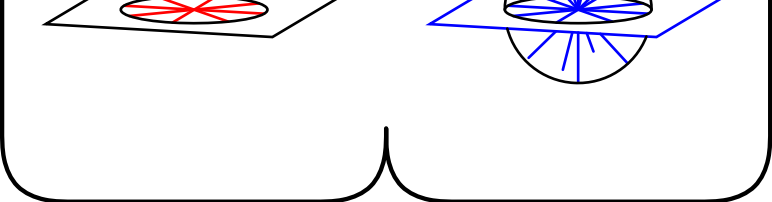
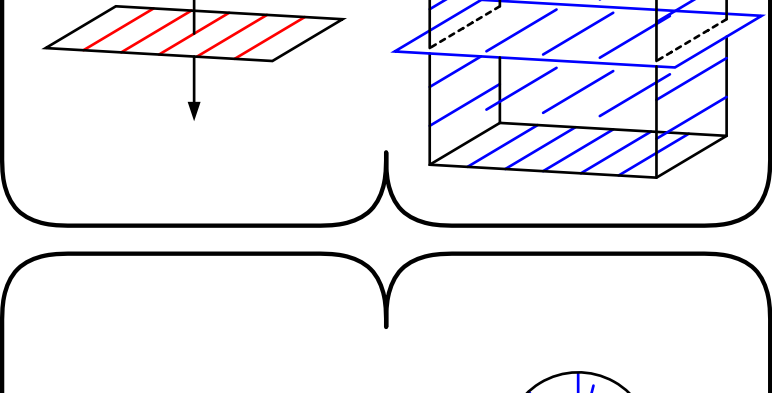
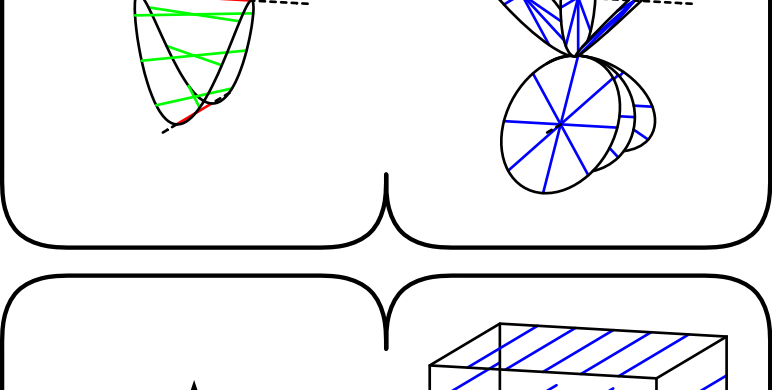
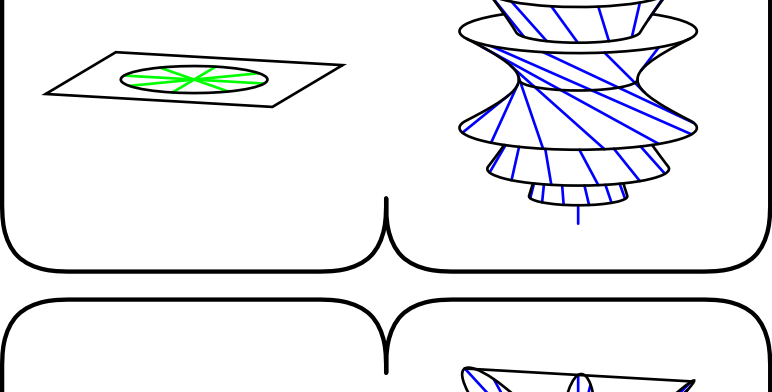
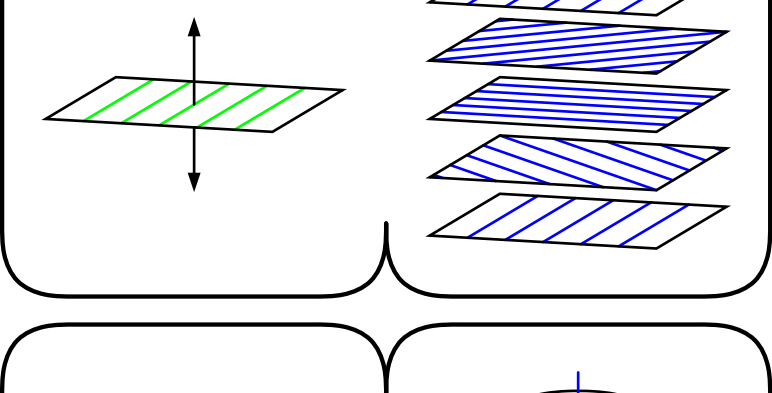
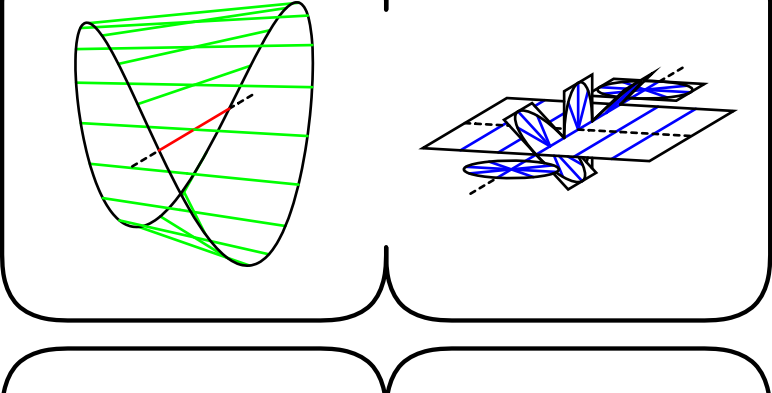
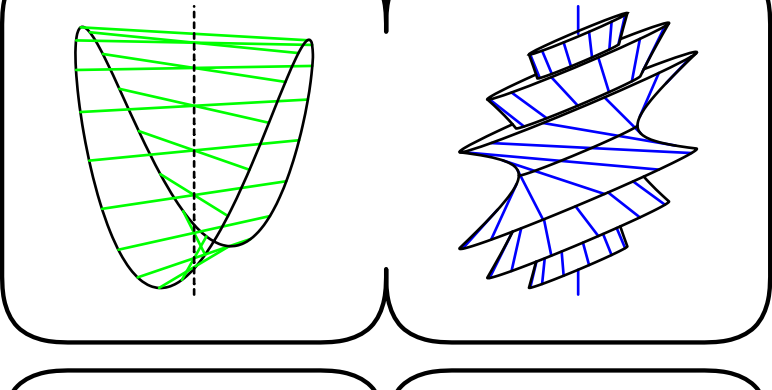
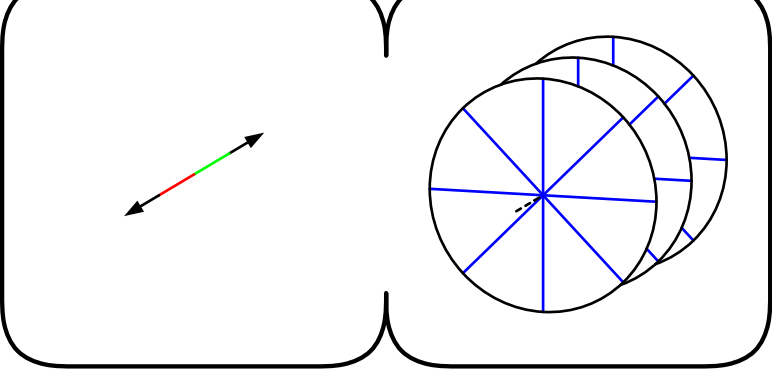
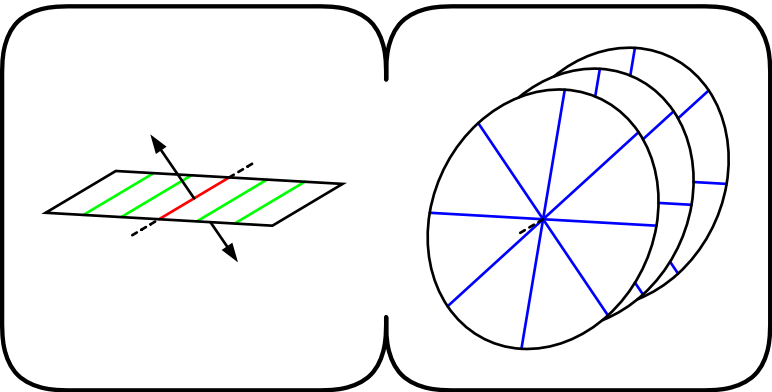


Freedom space Constraint space



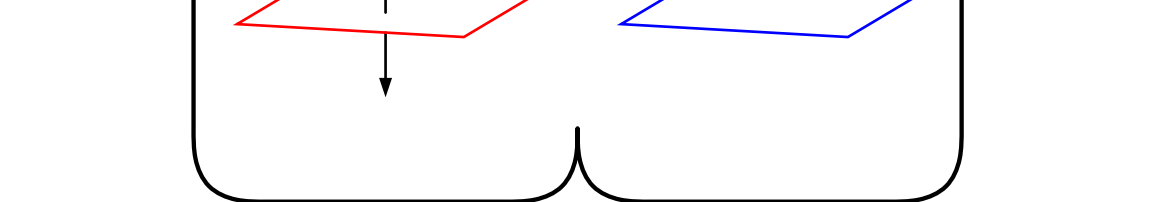
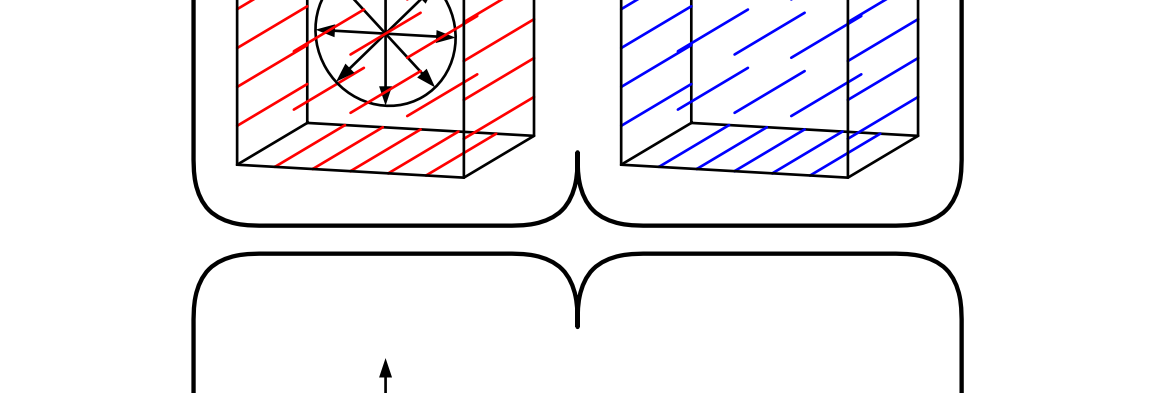
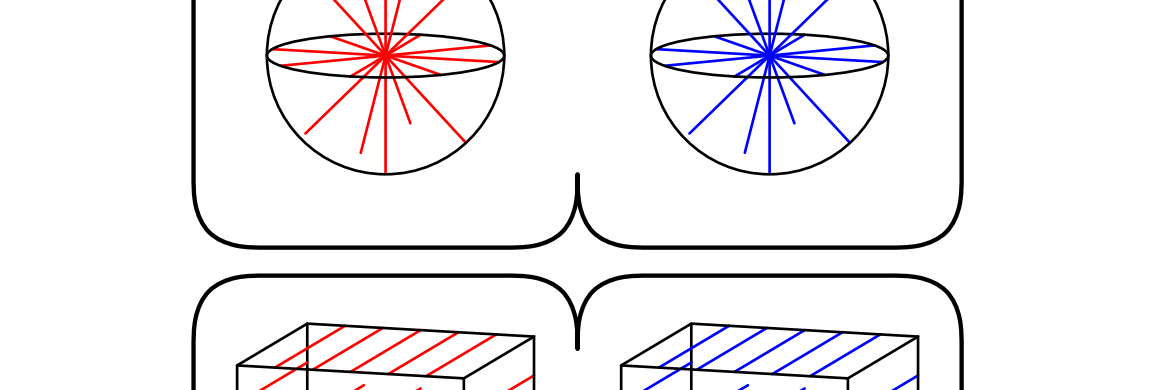
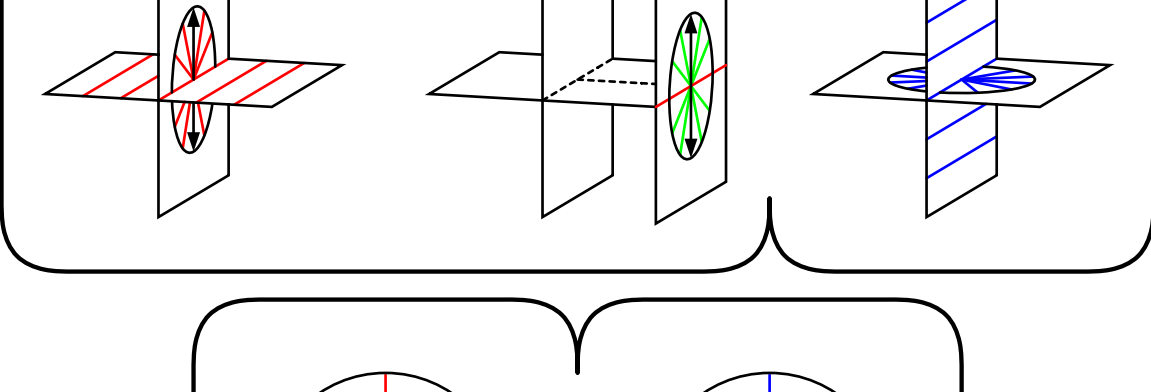
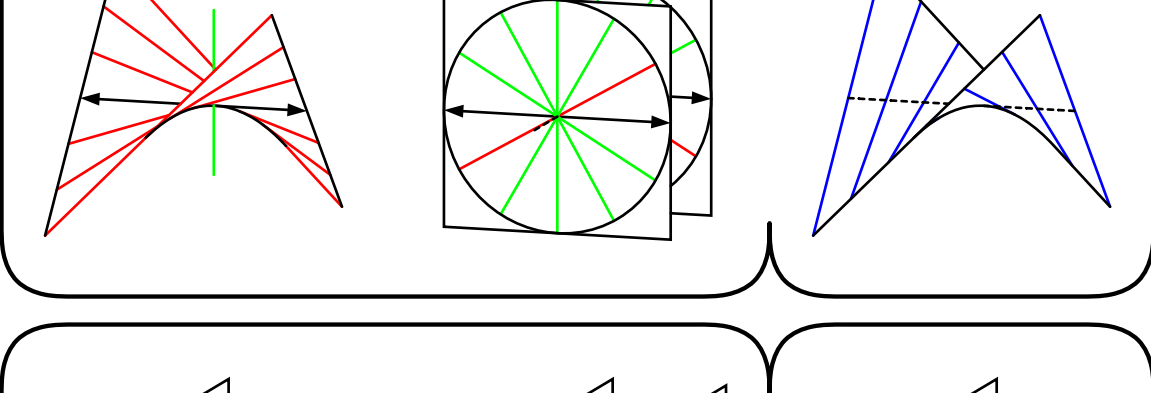
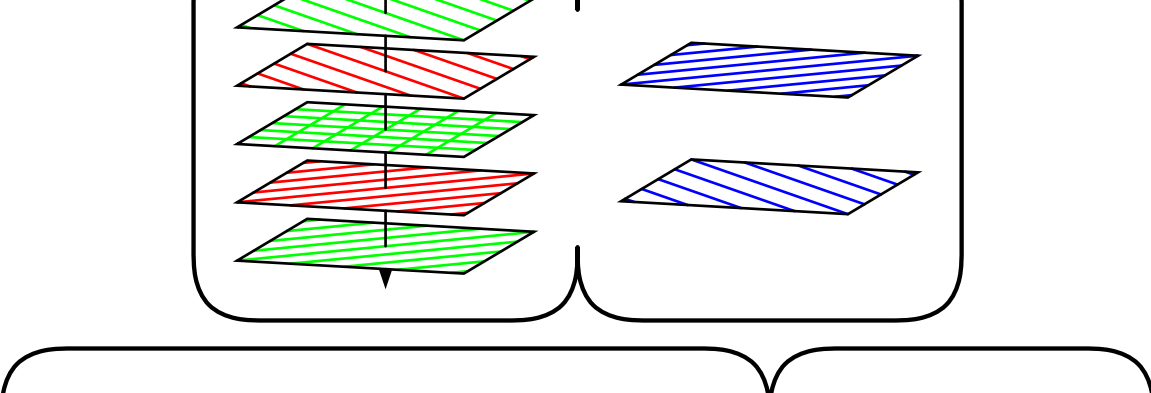
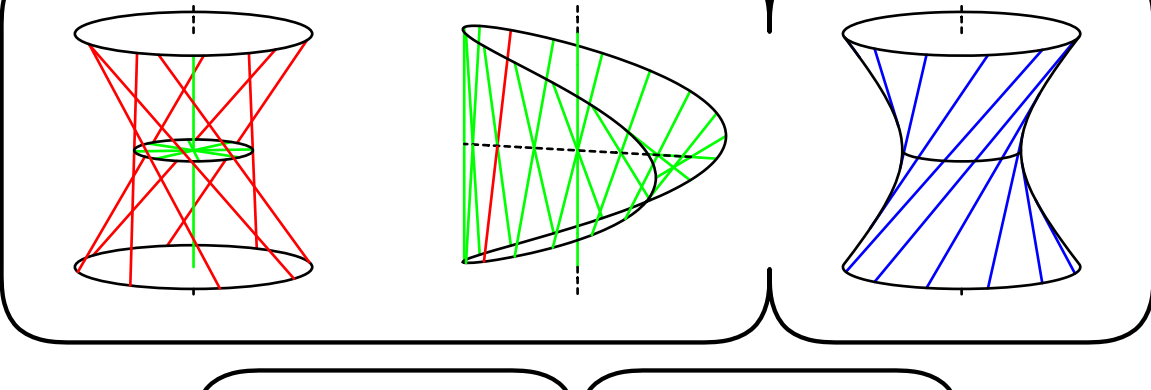
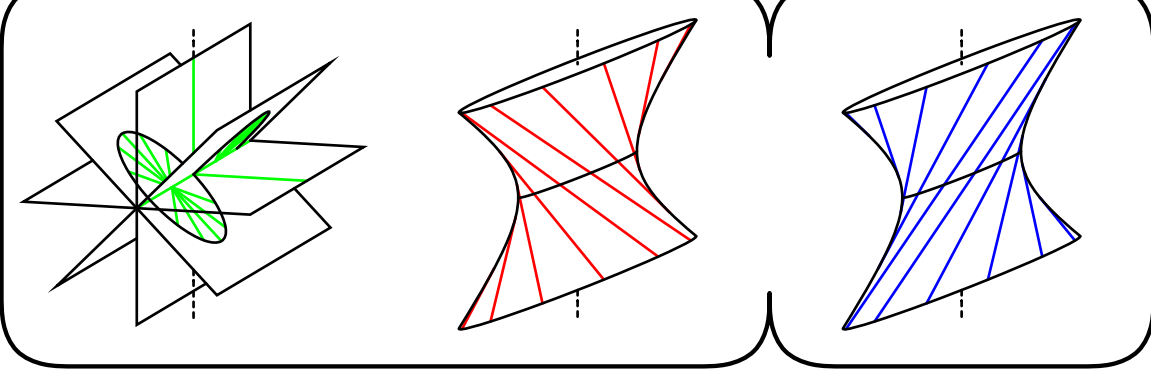
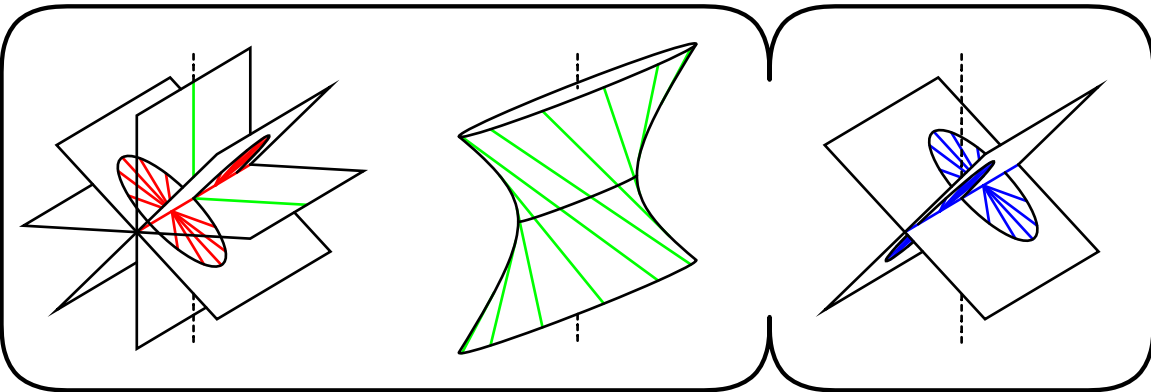
Freedom space Constraint space

2° of freedom:



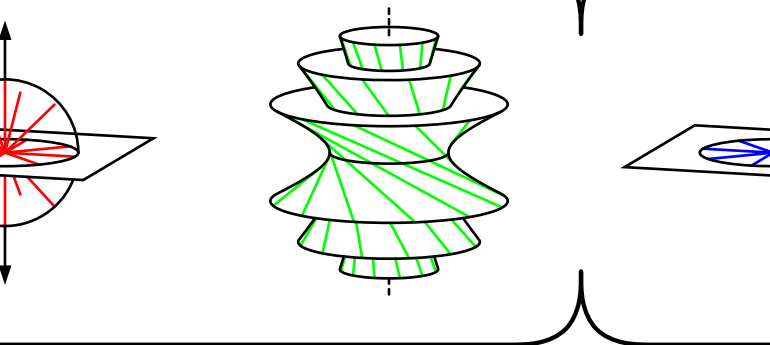
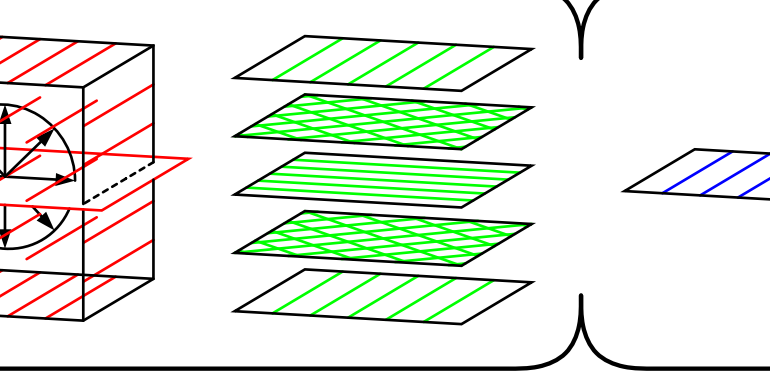
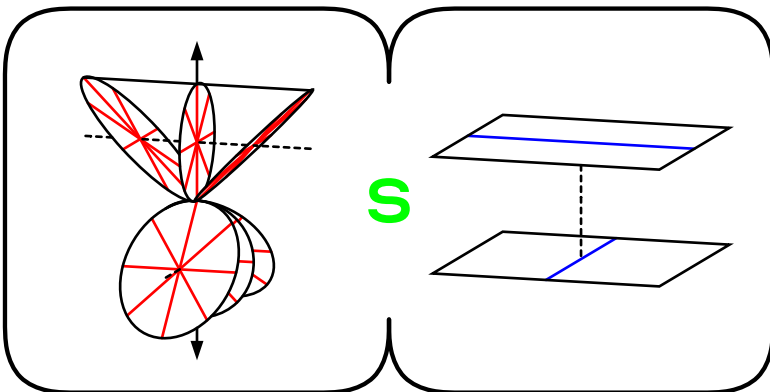
Freedom space Constraint space

3° of freedom:



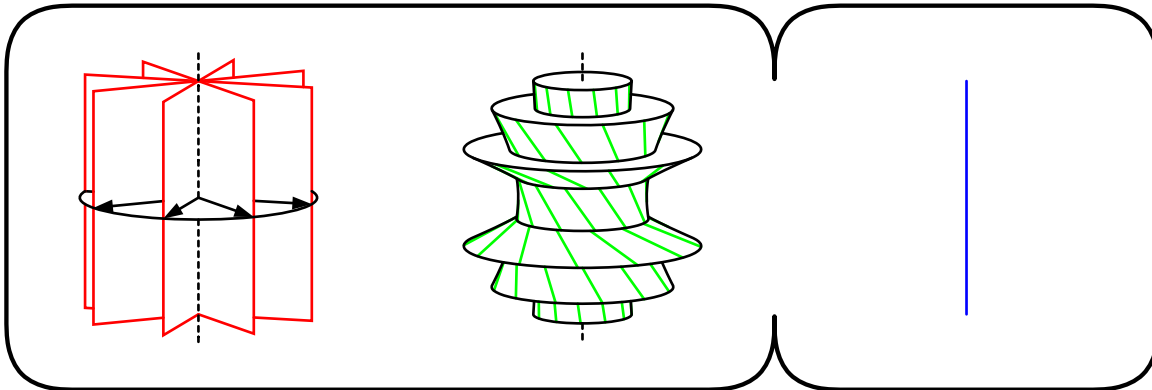
Freedom space Constraint space

4° of freedom:



Freedom space Constraint space

5° of freedom:



Freedom space Constraint space

Degrees of freedom:

One wire constrains one degree of freedom in an exactly constrained flexure. Redundant wires result in an over-constrained flexure. Only serial flexures are under-constrained.

Screws:

For a screw motion, pitch is defined as a ratio of translation over rotation.

$$\text{pitch} = \frac{\text{travel}}{\tan(\text{angle at wires})}$$

Serial / Parallel:

For a serial flexure, the final freedom space is the sum of intermediate freedom spaces.

For a parallel flexure, intersection defines the new freedom space.