DOF Truss

\[ M = 3(L-1) - 2J_1 - J_2 \]

\[ L = 6 \]
\[ J_1 = 8 \]
\[ J_2 = 0 \]

\[ M = 3(6-1) - 2 \cdot 8 = 15 - 16 \]

\[ M = -1 \]

Redundant system
Desk Lamp

L = 5
J_1 = 5
J_2 = 0

M = 3(L-1) - 2J_1 =
3(5-1) - 2*5 = 12 - 10 = 2

Rotation of arm 2
Rotation of head 5
Arm of earth moving equipment

\[ M = 3(L-1) - 2J_s = 3 \cdot 5 - 2 \cdot 6 = 3 \text{ DOF} \]
Cam follower

L = 3  \( J_1 = 2 \)  \( J_2 = 1 \)

\[ M = 3 \times 2 - 2 \times 2 - 1 = 6 - 4 - 1 = 1 \]
Mechanisms and structures

# DOF > 0: mechanism

# DOF = 0 structure

# DOF < 0

preloaded structure

Paradoxes: Kutzbach eq. ⇒ counterintuitive results in some extreme cases

\[ M = 3(5-1) - 2.6 = 0 \text{ O.K.} \]
Kinematic inversion

Inversion: create different mechanisms by grounding a different link.
Grashof condition
Predicts rational behavior of 4-bar linkage

S can rotate 360° if

\[ \mathbf{S} + \mathbf{L} \leq \mathbf{P} + \mathbf{Q} \]

Shortest Longest

Intermediate links

If Grashof condition satisfied at least one mechanism exists so that crank can rotate 360°.
Example non-Grashof mechanism

\[ P = Q = S \]

\[ S + L > P + Q \]

non Grashof linkage

Example

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>P</th>
<th>( Q )</th>
<th>L</th>
<th>( S + L ) ( P + Q )</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>2</td>
<td>4.5</td>
<td>7</td>
<td>9</td>
<td>11 \leq 11.5 OK</td>
</tr>
<tr>
<td>b</td>
<td>2</td>
<td>3.5</td>
<td>7</td>
<td>9</td>
<td>11 \leq 10.5 No</td>
</tr>
<tr>
<td>c</td>
<td>2</td>
<td>4.1</td>
<td>6</td>
<td>8</td>
<td>10 = 10 Special Grashof</td>
</tr>
</tbody>
</table>