HOMEWORK 1 SOLUTION

Prepared by : Mümin Özsipahi (C-206)
Assignment Date : October 16, 2014
Due Date : October 30, 2014 (submit your homework to room C-206 until 16:00. Late submissions will not be accepted!)

Name, Surname : …………………………………
Student ID : …………………………………

IMPORTANT NOTE: Please solve the questions in the spaces provided after the questions on this sheet and do not attach any other paper. Also check your list number from the web site and write it on the top left corner of this page. Each question will be graded equally.

Question
For the following 10 systems:
a) Label the links and the joint types on the sketches, fill in the following tables and determine the DOF of the system using the equation (DOF).
b) Is the actual DOF equal to the one provided by the equation (DOF)? If not, explain why and find the actual DOF. Explain your reasoning clearly.

Sample Solution (Slider-Crank Mechanism)

\[ F = \lambda(l - j - 1) + \sum_{i=j}^i f_i \]
\[ = 3(4 - 4 - 1) + 4 = 1 \]

<table>
<thead>
<tr>
<th>( \lambda )</th>
<th>( l )</th>
<th>( j ) (specify joint types)</th>
<th>( \sum f_i )</th>
<th>DOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>4</td>
<td>3R+1P</td>
<td>(3x1)+(1x1)=4</td>
<td>1</td>
</tr>
</tbody>
</table>
1) 

Hint: Check the animation from [http://www.youtube.com/watch?v=r92k9A3sgrg&feature=youtu.be](http://www.youtube.com/watch?v=r92k9A3sgrg&feature=youtu.be)

\[
F = \lambda(l - j - 1) + \sum_{i=1}^{i=j} f_i \\
= 3(8 - 10 - 1) + 10 = 1
\]

<table>
<thead>
<tr>
<th>( \lambda )</th>
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</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>8</td>
<td>8R+2P</td>
<td>(8x1)+(2x1)=10</td>
<td>1</td>
</tr>
</tbody>
</table>

2) Alternating Reciprocal Motion

Hint: Check the animation from [http://www.youtube.com/watch?v=rGYGcQtggk](http://www.youtube.com/watch?v=rGYGcQtggk)

\[
F = \lambda(l - j - 1) + \sum_{i=1}^{i=j} f_i \\
= 3(7 - 9 - 1) + 10 = 1
\]

<table>
<thead>
<tr>
<th>( \lambda )</th>
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<th>( \sum f_i )</th>
<th>DOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>7</td>
<td>7R+1P+1G</td>
<td>(7x1)+(1x1)+(1x2)=10</td>
<td>1</td>
</tr>
</tbody>
</table>
3) Ball Lifter

Hint: Check the animation from http://www.youtube.com/watch?v=6HJwBHx-93Q

\[ F = \lambda(l - j - 1) + \sum_{i=1}^{i=j} f_i \]
\[ = 3(10 - 14 - 1) + 16 = 1 \]

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<th>DOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>10</td>
<td>12R+2G</td>
<td>(12x1)+(2x2)=16</td>
<td>1</td>
</tr>
</tbody>
</table>

4)

Hint: Check the animation from http://www.youtube.com/watch?v=qGHpenVs6wg

\[ F = \lambda(l - j - 1) + \sum_{i=1}^{i=j} f_i \]
\[ = 3(7 - 8 - 1) + 9 = 3 \]

However, the rotation of link (6) around its own axis is insignificant. Therefore, significant DOF is, \( 3 - 1 = 2 \)

<table>
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<th>( \sum f_i )</th>
<th>DOF</th>
</tr>
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<tbody>
<tr>
<td>3</td>
<td>7</td>
<td>7R+1Cp</td>
<td>(7x1)+(1x2)=9</td>
<td>3</td>
</tr>
</tbody>
</table>
Hint: Check the animation from [http://www.youtube.com/watch?v=w2sHE327EXk&feature=youtu.be](http://www.youtube.com/watch?v=w2sHE327EXk&feature=youtu.be)

\[
F = \lambda(l - j - 1) + \sum_{i=1}^{i=j} f_i
= 3(8 - 11 - 1) + 13 = 1
\]

### Problem 5)

<table>
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<tr>
<th>( \lambda )</th>
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<th>( j ) (specify joint types)</th>
<th>( \sum f_i )</th>
<th>DOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>8</td>
<td>8R+1P+2G</td>
<td>(8x1)+(1x1)+(2x2)=13</td>
<td>1</td>
</tr>
</tbody>
</table>

### Airplane Wheel Retracting Mechanism

\[
F = \lambda(l - j - 1) + \sum_{i=1}^{i=j} f_i
= 6(4 - 4 - 1) + 8 = 2
\]

However, the rotation of link (3) around its own axis is insignificant. Therefore, significant DOF is, \(2 - 1 = 1\)

Hint: Check the animation from [http://www.youtube.com/watch?v=Te8Ul7GmcQQ](http://www.youtube.com/watch?v=Te8Ul7GmcQQ)

<table>
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<th>( \sum f_i )</th>
<th>DOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>4</td>
<td>1R+1P+2S</td>
<td>(1x1)+(1x1)+(2x3)=8</td>
<td>2</td>
</tr>
</tbody>
</table>

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5)

[Diagram of Airplane Wheel Retracting Mechanism]

6) Airplane Wheel Retracting Mechanism

[Diagram of Airplane Wheel Retracting Mechanism]
F = λ(l − j − 1) + ∑_{i=1}^{i=j} f_i

= 3(6 − 7 − 1) + 7 = 1

<table>
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<th>λ</th>
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<th>∑ f_i</th>
<th>DOF</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>6</td>
<td>7R</td>
<td>(7x1)= 7</td>
<td>1</td>
</tr>
</tbody>
</table>

F = λ(l − j − 1) + ∑_{i=1}^{i=j} f_i

= 6(7 − 6 − 1) + 6 = 6

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</thead>
<tbody>
<tr>
<td>6</td>
<td>7</td>
<td>6R</td>
<td>(6x1)= 6</td>
<td>6</td>
</tr>
</tbody>
</table>
For this mechanism, $\lambda$ is varying. So, divide this mechanism to 2 sub-mechanisms to find the DOF.

**Mechanism #1:** (1) - (2) - (3) - (4) - Irrotational Planar Mechanism, $\lambda = 2$, $l=4$, $j=5$ (5P)

$$F_1 = \lambda(n - j - 1) + \sum f_i \quad \rightarrow \quad F_1 = 2(4 - 5 - 1) + 5 = 1$$

Hence, once 1 variable parameters are known, the positions of all links (including link 4) will be known. So, now consider the following mechanism (with the position of link 4, hence the position of $R_{46}$, being known),

**Mechanism #2:** (1) - (5) - (6) - (7) - (8) - Planar Mechanism, $\lambda = 3$, $l=5$, $j=6$ (6R)

$$F_2 = \lambda(n - j - 1) + \sum f_i \quad \rightarrow \quad F_2 = 3(5 - 6 - 1) + 6 = 0$$

Mechanism 2 is a structure (i.e., we don’t need to specify any variable parameters to determine the positions of links.

So, $F_{\text{actual}} = F_1 + F_2 = 0 + 1 = 1$. (Number of variable parameters to be specified to determine the positions of all links in the mechanism when the dimensions are given is 1)
Degree of freedom of the original mechanism, \( F = 3(12 - 16 - 1) + 16 = 1 \) but actual DOF is different. Because we have a mechanism which is in permanently critical form due to special dimensions used in the mechanism.

Considering the figure on the left,

\[ x_G = b \cos \theta \quad \text{and} \quad y_G = b \sin \theta \]

Distance \( OG \) can be written as,

\[ |OG| = \sqrt{x_G^2 + y_G^2} = \sqrt{(b \cos \theta)^2 + (b \sin \theta)^2} = b = \text{constant} \]

So, distance \( OG \) does not depend on the orientation of link (3). Link (4) has no effect on the motion of links (2), (3) and (5), hence it can be neglected in the mechanism.

Also, link (9) and (10) do not interfere with the motion of the parallelogram mechanism consisting of links (1), (8), (11) and (12). Therefore, original mechanism (on the top) is equivalent to the following mechanism (where links (4), (9), (10) which exist in the original mechanism are also shown in color in dashed lines),

Degree of freedom of the equivalent mechanism, \( F_{\text{actual}} = 3(9 - 11 - 1) + 11 = 2 \).

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>12</td>
<td>14R+2P</td>
<td>(14x1)+(2x1)=16</td>
<td>( \lambda )</td>
</tr>
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</table>

Excluding links (4), (9) and (12) shown in dashed lines.