

The `liftarm` package

Draw liftarms with TikZ

Matthias Floré

2022-03-08

Abstract

This package is based on the package `tikz` (see [5]) and can be used to draw liftarms with TikZ. It provides several options for the appearance of the liftarms, a command which connects two liftarms and an environment to describe a construction. This is the manual for version 1.0.

Contents

1	Usage	1
2	Drawing liftarms	1
3	Connecting liftarms	5
4	Describing a construction	6
5	Additional examples	8
	Index	12

1 Usage

The package `liftarm` can be used by putting

```
\usepackage{liftarm}
```

in the preamble.

The package `liftarm` loads the packages `etoolbox`, `xcolor` with the option `dvipsnames`, `tikz` and the TikZ library `calc`. Since `xcolor` is loaded with the option `dvipsnames`, packages such as `pgfplots` and `tcolorbox` must be loaded *after* `liftarm`.

2 Drawing liftarms

`\liftarm[<options>]{<point>}{<length>}{<angle>}`

This command can be placed inside a `tikzpicture` environment. It draws a liftarm of *<length>* starting at *<point>*. The angle between the liftarm and the *x*-axis can be specified by *<angle>* in degrees. The distance between the holes is 1.



```
\begin{tikzpicture}
\liftarm{1,2}{3}{20}
\end{tikzpicture}
```

Note that the number of holes is $\langle length \rangle + 1$. The *<options>* can be given with the following keys.



`/liftarm/axle holes={⟨values⟩}` (no default)

This key defines the holes in the liftarm where axle holes will be drawn.



```
\begin{tikzpicture}
\liftarm[axle holes={0,4}]{0,1}{4}{0}
\end{tikzpicture}
```

`/liftarm/brick={boolean}` (default true, initially false)

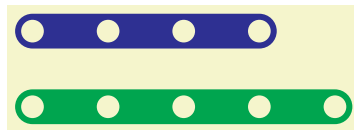
If true, a brick will be drawn instead of a liftarm.



```
\begin{tikzpicture}
\liftarm[brick]{0,1}{2}{0}
\end{tikzpicture}
```

`/liftarm/color={⟨name⟩}` (no default)

This key defines the color of the liftarm. The color can also be specified without key.



```
\begin{tikzpicture}
\liftarm[color=green]{0,1}{4}{0}
\liftarm[Blue]{0,2}{3}{0}
\end{tikzpicture}
```

`/liftarm/color 0={⟨name⟩}` (no default, initially Gray)

`/liftarm/color 1={⟨name⟩}` (no default, initially darkgray)

`/liftarm/color 2={⟨name⟩}` (no default, initially Yellow)

`/liftarm/color 3={⟨name⟩}` (no default, initially Orange)

`/liftarm/color 4={⟨name⟩}` (no default, initially Red)

`/liftarm/color 5={⟨name⟩}` (no default, initially Green)

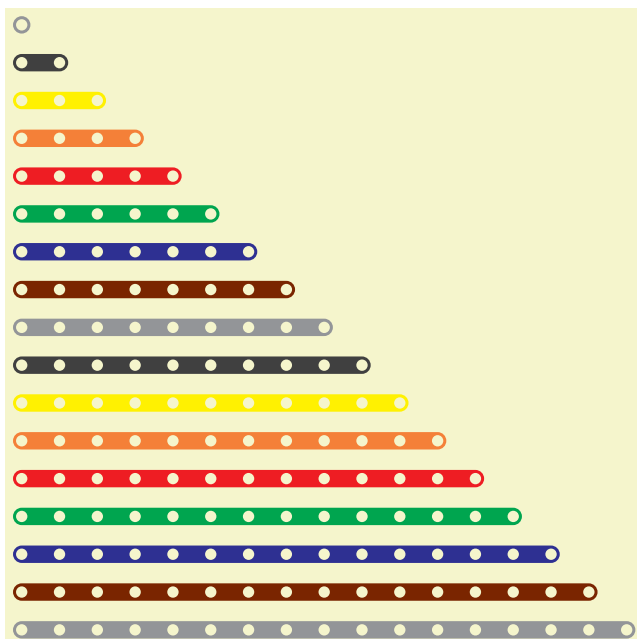
`/liftarm/color 6={⟨name⟩}` (no default, initially Blue)

`/liftarm/color 7={⟨name⟩}` (no default, initially Brown)

These keys define the colors of the liftarms which have as their length the number following color.

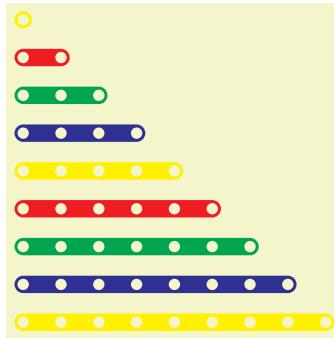
`/liftarm/color modulo={⟨number⟩}` (no default, initially 8)

The default colors of the liftarms are determined by computing the length of the liftarm modulo the value of this key and selecting the color from the previous keys.



```
\begin{tikzpicture}[scale=0.5]
\foreach \n in {0,...,16}{
\liftarm{0,-\n}{\n}{0}
}
\end{tikzpicture}
```



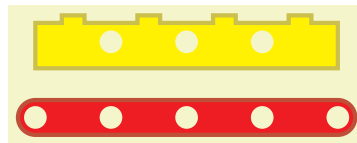


```
\begin{tikzpicture}[scale=0.5]
\pgfkeys{
  /liftarm,
  color 0=Yellow,
  color 1=Red,
  color 2=Green,
  color 3=Blue,
  color modulo=4
}
\foreach\i in {0,...,8}{
  \liftarm{0,-\i}{\i}{0}
}
\end{tikzpicture}
```

/liftarm/contour=*(boolean)*

(default true, initially false)

If true, a contour will be drawn around the liftarm.

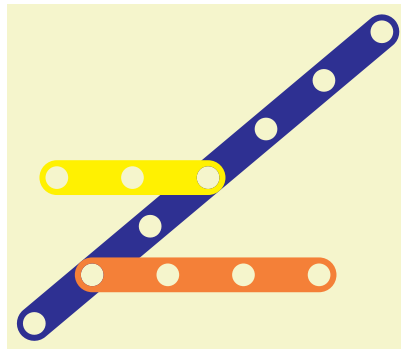


```
\begin{tikzpicture}
\liftarm[contour]{0,1}{4}{0}
\liftarm[brick,contour]{1,2}{2}{0}
\end{tikzpicture}
```

/liftarm/coordinate=*{(number 1/name 1)}...*

(no default)

This key defines coordinates with name *(name i)* at hole *(number i)* of the liftarm.



```
\begin{tikzpicture}
\liftarm[
  coordinate={1/A,3/B}
]{0,1}{6}{40}
\liftarm{A}{3}{0}
\liftarm{B}{2}{180}
\end{tikzpicture}
```

/liftarm/hole radius=*{(value)}*

(no default, initially 0.3)

The *(value)* of this key, multiplied with the *(value)* of the key **scalefactor** defines the radius of the holes.

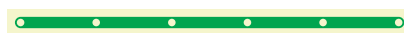


```
\begin{tikzpicture}
\liftarm[hole radius=0.1]{0,0}{5}{0}
\end{tikzpicture}
```

/liftarm/liftarm thickness=*{(value)}*

(no default, initially 0.92)

The *(value)* of this key, multiplied with the *(value)* of the key **scalefactor** defines the thickness of the liftarm.



```
\begin{tikzpicture}
\liftarm[
  hole radius=0.1,
  liftarm thickness=0.3
]{0,0}{5}{0}
\end{tikzpicture}
```

/liftarm/mark color=*{(name)}*

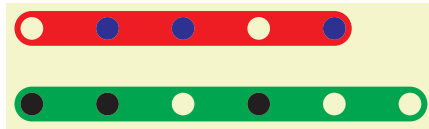
(no default, initially Black)

/liftarm/mark holes=*{(values)}*

(no default)

The key **mark holes** defines the holes in the liftarm which will be marked. The key **mark color** defines the color of these marks.



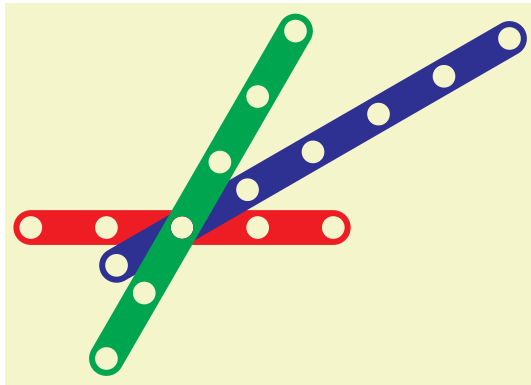


```
\begin{tikzpicture}
\liftarm[
  mark holes={0,1,3}
]{0,0}{5}{0}
\liftarm[
  mark holes={1,2,4},
  mark color=Blue
]{0,1}{4}{0}
\end{tikzpicture}
```

`/liftarm/origin={⟨number⟩}`

(no default, initially 0)

This key defines the number of the hole which will be placed at the coordinate given as argument to the liftarm.

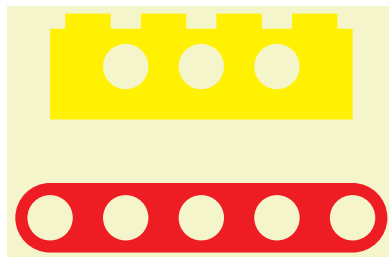


```
\begin{tikzpicture}
\liftarm{-2,0}{4}{0}
\liftarm[origin=1]{0,0}{6}{30}
\liftarm[origin=2]{0,0}{5}{60}
\end{tikzpicture}
```

`/liftarm/scalefactor={⟨value⟩}`

(no default, initially 0.5)

The `⟨value⟩` of this key defines the factor which scales the thickness of the liftarm and the radius of the holes.



```
\begin{tikzpicture}
\liftarm[scalefactor=1]{0,0}{4}{0}
\liftarm[brick,scalefactor=1]{1,2}{2}{0}
\end{tikzpicture}
```

`/liftarm/screw color={⟨name⟩}`

(no default, initially Black)

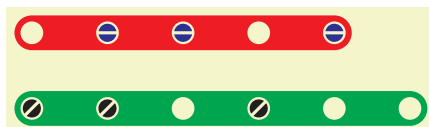
`/liftarm/screw holes={⟨values⟩}`

(no default)

`/liftarm/screw holes angle={⟨angle⟩}`

(no default, initially 45)

The key `screw holes` defines the holes in the liftarm where a screw will be drawn. The key `screw color` defines the color of these screws. The key `screw holes angle` defines the angle in degrees around which the screws are drawn.



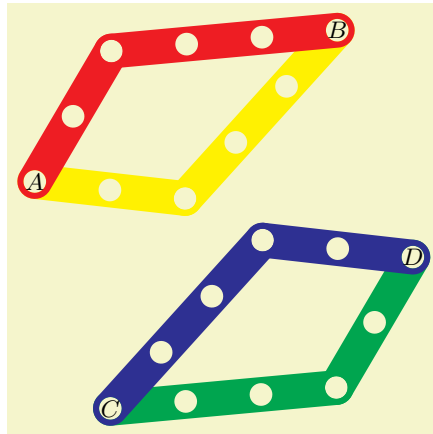
```
\begin{tikzpicture}
\liftarm[
  screw holes={0,1,3}
]{0,0}{5}{0}
\liftarm[
  screw holes={1,2,4},
  screw color=Blue,
  screw holes angle=0
]{0,1}{4}{0}
\end{tikzpicture}
```



3 Connecting liftarms

`\liftarmconnect`[*options*]{*point1*}{*length1*}{*point2*}{*length2*}

This command can be placed inside a `tikzpicture` environment. It draws a liftarm of *length1* starting at *point1* and a liftarm of *length2* starting at *point2* in such a way that their last holes have the same coordinate in case that such a point exists. If such a point does not exist then nothing is drawn. In case that there exist 2 such points then this point is chosen counterclockwise. In that case, the other configuration of the 2 liftarms can be obtained by simply swapping {*point1*}{*length1*} and {*point2*}{*length2*}. The keys for the command `\liftarm` can be given to the *options*. In this case these keys will be passed to both liftarms.

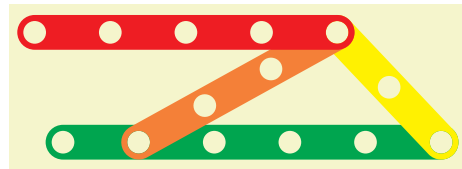


```
\begin{tikzpicture}
\coordinate (A) at (0,0);
\coordinate (B) at (4,2);
\coordinate (C) at (1,-3);
\coordinate (D) at (5,-1);
\liftarmconnect[Yellow]{A}{2}{B}{3}
\liftarmconnect[Red]{B}{3}{A}{2}
\liftarmconnect[Green]{C}{3}{D}{2}
\liftarmconnect[Blue]{D}{2}{C}{3}
\foreach\coord in {A,B,C,D}{
  \node at (\coord) {\small $\coord$};
}
\end{tikzpicture}
```

Additionally, the *options* can be given with the following keys.

`/liftarm/connect coordinate={name}` (no default)

This key defines a coordinate with name *name* at the connection point of both liftarms.



```
\begin{tikzpicture}
\liftarm{-3,0}{5}{0}
\liftarmconnect[
  connect coordinate=A
]{2,0}{2}{-2,0}{3}
\liftarm{A}{4}{180}
\end{tikzpicture}
```

`/liftarm/connect reverse={boolean}` (default true, initially false)

If true, the first liftarm of `\liftarmconnect` will be drawn second and the second liftarm will be drawn first. This option can be used to change the appearance at the connection point of both liftarms.



```
\begin{tikzpicture}
\liftarmconnect{2,0}{1}{0,0}{2}
\liftarmconnect[
  connect reverse
]{5,0}{1}{3,0}{2}
\end{tikzpicture}
```

`/liftarm/liftarm 1={options}` (style, no default, initially empty)

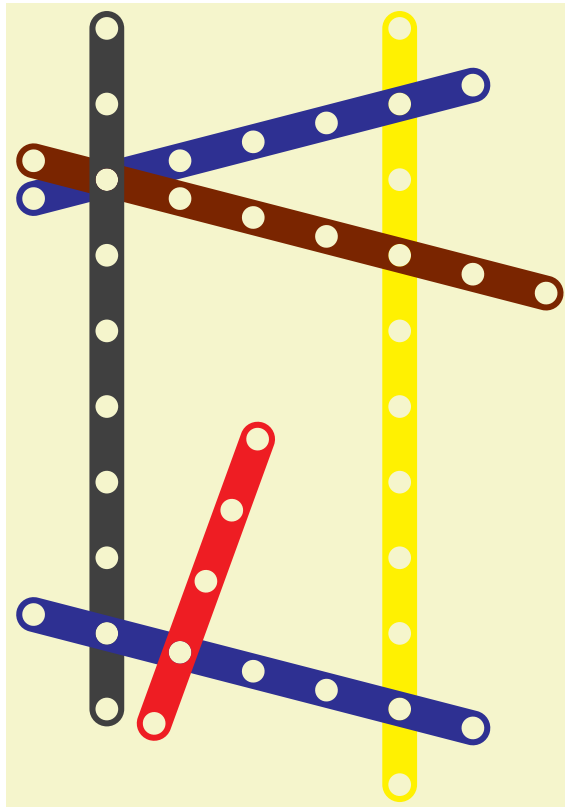
`/liftarm/liftarm 2={options}` (style, no default, initially empty)

These keys accept a list of keys which will be applied to the first respectively second liftarm. These lists of keys accept the same options as the command `\liftarm`. Additionally, the key `connect` below can be given.

`/liftarm/connect={number}` (no default)

This key defines the number of the hole which will be connected to the matching liftarm. If this key is not given then the last hole of the liftarm is taken as the connecting point.





```
\begin{tikzpicture}
\liftarm{0,-7}{10}{90}
\liftarmconnect[
  connect coordinate=A,
  liftarm 1={
    origin=1,
    connect=5
  },
  liftarm 2={
    origin=2,
    connect=6
  }
]{0,2}{6}{0,0}{7}
\liftarmconnect[
  liftarm 1={
    origin=2,
    connect=8
  },
  liftarm 2={
    origin=1,
    connect=5,
    coordinate=4/B
  }
]{A}{9}{0,-6}{6}
\liftarm[origin=1]{B}{4}{70}
\end{tikzpicture}
```

4 Describing a construction

If a construction involves many liftarms then it is convenient to describe this construction in separate steps and `tikzpicture`s. Then the content of previous `tikzpicture`s would need to be copied in each new `tikzpicture`. This process can be automated by using the `liftarmconstruction` environment and the command `\liftarmconstruct` below.

```
\begin{liftarmconstruction}[\langle options \rangle]
  \langle environment contents \rangle
\end{liftarmconstruction}
```

This environment is in fact an `enumerate` environment with the addition that it resets the content of the `tikzpicture` which is displayed by the command `\liftarmconstruct` below. Thus in particular, `\item` can be used inside the `liftarmconstruction` environment. The `\langle options \rangle` will be passed to each `tikzpicture` drawn by the command `\liftarmconstruct` inside this environment. The following command can be used inside this environment.

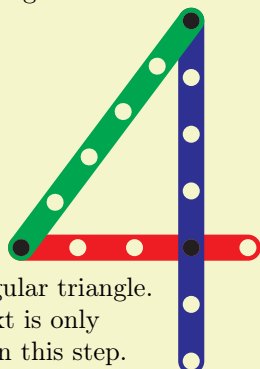
```
\liftarmconstruct[\langle options \rangle]{\langle text \rangle}{\langle commands \rangle}
```

This command starts an `\item` and shows `\langle text \rangle`. Then it displays a `tikzpicture` containing `\langle commands \rangle` and also the `\langle commands \rangle` of previous `\liftarmconstruct` commands inside the same `liftarmconstruction` environment. The `\langle options \rangle` will be added to this `tikzpicture` but *only* in the current step.

As an example, we describe below the construction of a regular pentagon from [1].

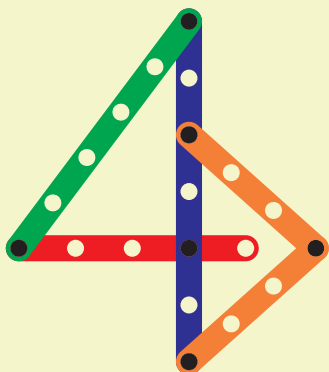


1. We start with 3 liftarms to form a rectangular triangle.

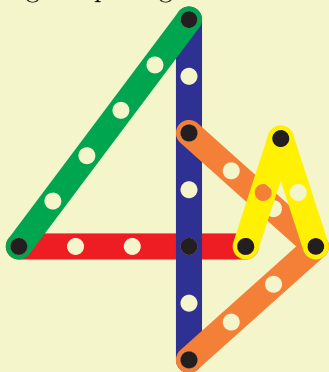


Rectangular triangle.
This text is only
visible in this step.

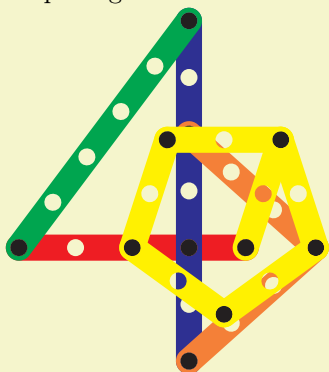
2. An `\item` can be added since this is an `enumerate` environment.
3. Now we add 2 liftarms of length 3.



4. In this step we construct the first side of the regular pentagon.



5. Now we finish the construction of the regular pentagon.

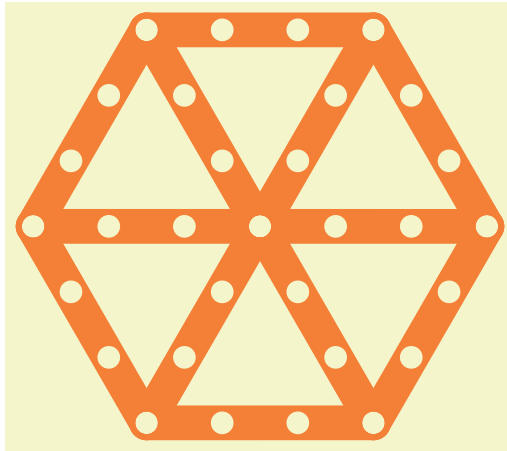


```
\begin{minipage}{0.5\linewidth}%only for
%usage in this manual%\linewidth-6pt
%\begin{multicols}{2}%only for
%usage in this manual
\begin{liftarmconstruction}[scale=0.75]
\liftarmconstruct[
  {\node[left,align=left]
    at (-0.5,-1.3)
    {Rectangular triangle.\%
    This text is only\%
    visible in this step.};}
]{
  We start with 3 liftarms to form
  a rectangular triangle.
}{
  \liftarm{-3,0}{4}{0}
  \liftarmconnect[
    liftarm 1={
      origin=2,
      mark holes={2,6}
    },
    liftarm 2={
      mark holes=0
    }
  ]{0,0}{6}{-3,0}{5}}
  \item An \item can be added since this
  is an enumerate environment.
  \liftarmconstruct{
    Now we add 2 liftarms of length 3$.
  }{\liftarmconnect[
    connect coordinate=A,
    liftarm 1={
      mark holes={0,3}
    },
    liftarm 2={
      mark holes=0
    }
  ]{0,-2}{3}{0,2}{3}}
  \liftarmconstruct{
    In this step we construct the first
    side of the regular pentagon.
  }{\liftarmconnect[
    connect coordinate=B,
    liftarm 2={
      mark holes={0,2}
    }
  ]{A}{2}{1,0}{2}}
  \liftarmconstruct{
    Now we finish the construction
    of the regular pentagon.
  }{\liftarmconnect[
    liftarm 2={
      mark holes={0,2}
    }
  ]{B}{2}{-1,0}{2}}
  \liftarmconnect[
    liftarm 1={
      mark holes=2
    }
  ]{-1,0}{2}{A}{2}}
  \end{liftarmconstruction}
%\end{multicols}
\end{minipage}
```



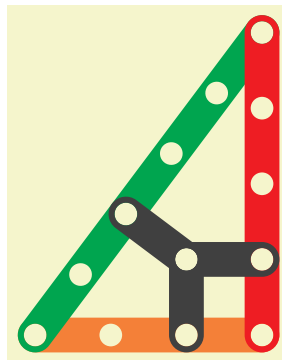
5 Additional examples

The following example shows a regular hexagon.



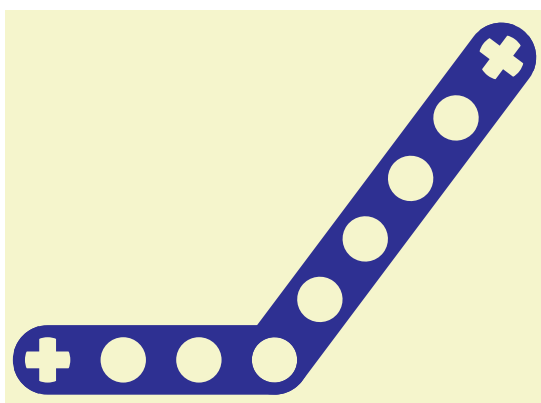
```
\begin{tikzpicture}
\def\r{3}
\foreach\m in {1,...,6}{
  \liftarmconnect{0,0}{\r}{\m*60:\r}{\r}
}
\end{tikzpicture}
```

The following example illustrates that $2 \operatorname{atan}(\frac{1}{2}) = \operatorname{atan}(\frac{4}{3})$.



```
\begin{tikzpicture}
\liftarm{0,0}{3}{0}
\liftarm{0,0}{5}{atan(4/3)}
\liftarm{3,0}{4}{90}
\liftarm{2,0}{1}{90}
\liftarm{2,1}{1}{0}
\liftarm{2,1}{1}{90+atan(4/3)}
\end{tikzpicture}
```

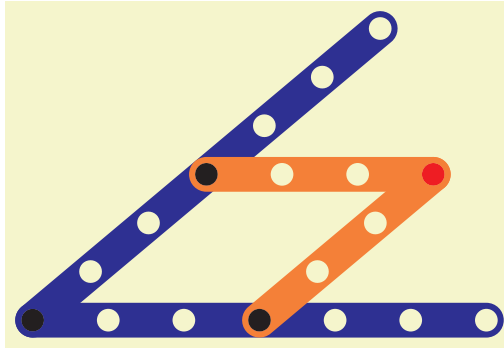
Below is an example of an angled liftarm.



```
\begin{tikzpicture}
\pgfkeys{
  /liftarm,
  scalefactor=1,
  Blue
}
\liftarm[axle holes=0]{0,0}{3}{0}
\liftarm[axle holes=5]{3,0}{5}{atan(4/3)}
\end{tikzpicture}
```

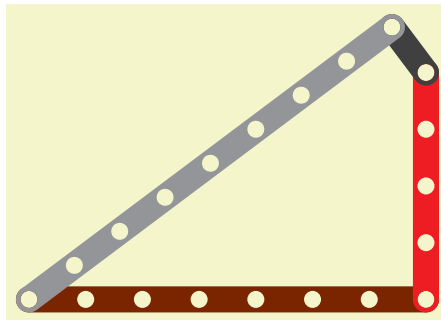
The following example illustrates an angle bisection.





```
\begin{tikzpicture}
\def\ang{40}
\def\r{3}
\liftarm[mark holes={0,\r}]{0,0}{2*\r}{0}
\liftarm[mark holes=\r]{0,0}{2*\r}{\ang}
\liftarm[
mark holes=\r,
mark color=Red
]{\r,0}{\r}{\ang}
\liftarm{\ang:\r}{\r}{0}
\end{tikzpicture}
```

The following example illustrates that $7^2 + 4^2 = 8^2 + 1^2$.



```
\begin{tikzpicture}[scale=0.75]
\def\a{4}
\def\b{7}
\def\c{1}
\def\d{8}
%\liftarm{0,0}{\b}{0}
%\liftarm{\b,0}{\a}{90}
\liftarmconnect{0,0}{\b}{\b,\a}{\a}
%\liftarm{\b,\a}{1}{atan(\a/\b)+atan(\c/\d)+90}
%\liftarm{0,0}{\d}{atan(\a/\b)+atan(\c/\d)}
\liftarmconnect{\b,\a}{\c}{0,0}{\d}
\end{tikzpicture}
```

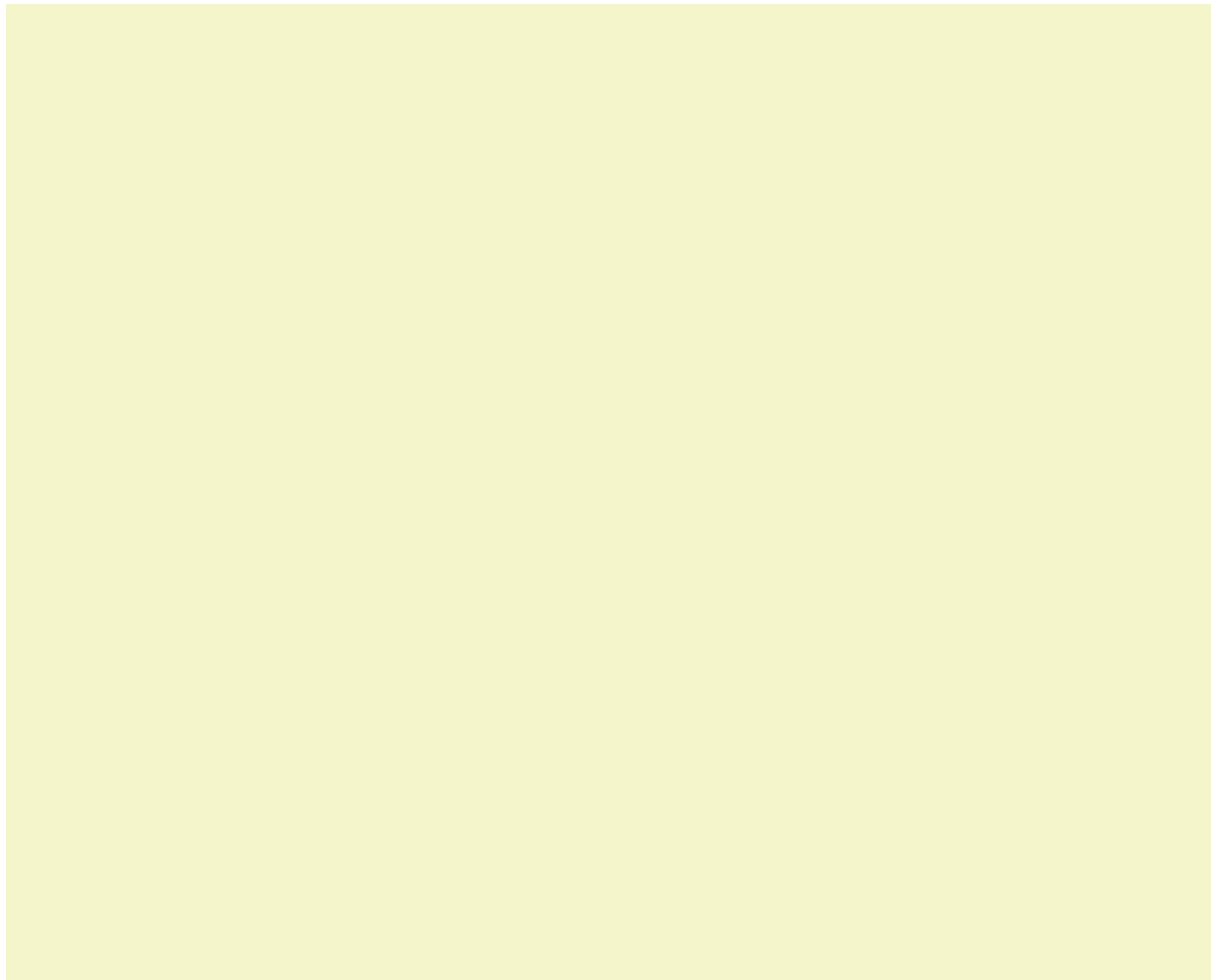
Below is an animation of the Peaucellier-Lipkin linkage, see e.g. [4].



```
\newcommand{\PLlinkage}[1]{
\begin{tikzpicture}[scale=0.75]
\def\a{3}
\def\b{4}
\def\c{9}
\pgfmathsetmacro{\x}{
2*\a+((\c^2-\b^2-(2*\a)^2)/(2*\a))
}
\useasboundingbox (-0.23,-6) rectangle
(\x+0.23,6);
\draw (\x,-5)--(\x,5);
\liftarm{0,0}{\a}{0}
\liftarm[coordinate=\a/\d]{\a,0}{\a}{#1}
\liftarmconnect[
connect coordinate=B,
connect reverse
]{A}{\b}{0,0}{\c}
\liftarmconnect[
connect coordinate=C
]{0,0}{\c}{A}{\b}
\liftarmconnect{C}{\b}{B}{\b}
\end{tikzpicture}
}
\begin{animateinline}[
autoplay,
controls,
loop
]{30}
\multiframe{80}{rXmax=-40+1}{
\PLlinkage{\rXmax}
}
\newframe
\multiframe{80}{rXmax=-40+1}{
\PLlinkage{-\rXmax}
}
\end{animateinline}
```



Below is an animation of Kempe's trisector, as shown in [3].



```
\newcommand{\trisector}[1]{
\begin{tikzpicture}[scale=0.33]
\useasboundingbox (-27.3,-0.5) rectangle (21.2,37);
\liftarm[coordinate=8/A]{0,0}{27}{180}
\liftarm[coordinate=12/B]{0,0}{27}{180-(#1)}
\liftarm[coordinate=18/C]{0,0}{27}{180-2*(#1)}
\liftarm[coordinate=27/D]{0,0}{27}{180-3*(#1)}
\liftarmconnect{C}{27}{D}{18}
\liftarmconnect[liftarm 2={connect=8}]{A}{12}{B}{18}
\end{tikzpicture}
}
\begin{animateinline}[autoplay,controls,loop]{5}
\multiframe{20}{rXmax=0+1}{
\trisector{15+\rXmax}
}
\newframe
\multiframe{20}{rXmax=0+1}{
\trisector{35-\rXmax}
}
\end{animateinline}
```

Below is an animation of Chebyshev's Lambda Mechanism.



```

\newcommand{\CL}[1]{
\begin{tikzpicture}[scale=0.8]
\def\r{1}
\useasboundingbox (-2*\r-0.5,-2*\r-0.5)
rectangle (10*\r-0.5,10*\r+0.5);
\liftarm{0,0}{4*\r}{0}
\liftarm[
mark holes={0,2*\r}
]{0,0}{2*\r}{#1}
\liftarmconnect[
liftarm 1={mark holes={0,5*\r}},
liftarm 2={
connect=5*\r,
mark holes=10*\r,
mark color=Red
}
]{4*\r,0}{5*\r}{#1:2*\r}{10*\r}
\end{tikzpicture}
}
\begin{animateinline}[
autoplay,
controls,
loop
]{60}
\multiframe{360}{rXmax=0+1}{
\CL{\rXmax}
}
\end{animateinline}

```

References

- [1] Gerard 't Hooft, *Meccano Math I*,
<https://webpace.science.uu.nl/~hooft101/lectures/meccano.pdf>, 2006.
- [2] Gerard 't Hooft, *Meccano Math II*,
<https://webpace.science.uu.nl/~hooft101/lectures/meccano2.pdf>, 2008.
- [3] Gerard 't Hooft, *Meccano Math III*,
<https://webpace.science.uu.nl/~hooft101/lectures/meccano3.pdf>, 2014.
- [4] Alfred Bray Kempe, *On a general method of producing exact rectilinear motion by linkwork*, 1875.
- [5] Till Tantau, *The TikZ and PGF Packages*, Manual for version 3.1.9a, <https://www.ctan.org/pkg/pgf>, 2021.



Index

axle holes key, 2

brick key, 2

color key, 2

color 0 key, 2

color 1 key, 2

color 2 key, 2

color 3 key, 2

color 4 key, 2

color 5 key, 2

color 6 key, 2

color 7 key, 2

color modulo key, 2

connect key, 5

connect coordinate key, 5

connect reverse key, 5

contour key, 3

coordinate key, 3

Environments

 liftarmconstruction, 6

hole radius key, 3

\liftarm, 1

/liftarm/

 axle holes, 2

 brick, 2

 color, 2

 color 0, 2

 color 1, 2

 color 2, 2

 color 3, 2

 color 4, 2

 color 5, 2

color 6, 2

color 7, 2

color modulo, 2

connect, 5

connect coordinate, 5

connect reverse, 5

contour, 3

coordinate, 3

hole radius, 3

liftarm 1, 5

liftarm 2, 5

liftarm thickness, 3

mark color, 3

mark holes, 3

origin, 4

scalefactor, 4

screw color, 4

screw holes, 4

screw holes angle, 4

liftarm 1 key, 5

liftarm 2 key, 5

liftarm thickness key, 3

\liftarmconnect, 5

\liftarmconstruct, 6

liftarmconstruction environment, 6

mark color key, 3

mark holes key, 3

origin key, 4

scalefactor key, 4

screw color key, 4

screw holes key, 4

screw holes angle key, 4

