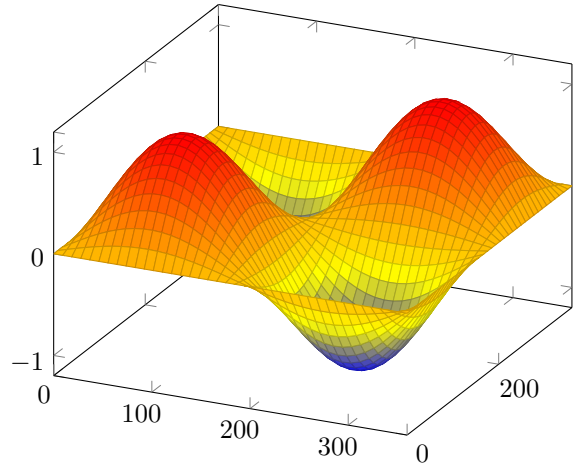# TikZ Tutorial

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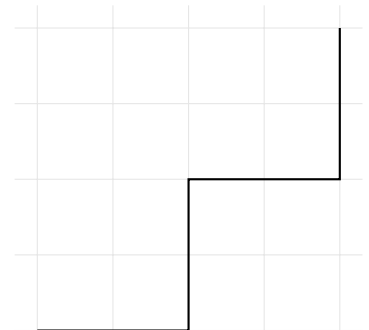
1 TikZ Evvironment in LaTeX

General Setup

```latex
\documentclass{...}
\usepackage{tikz}

\begin{document}

\begin{tikzpicture}
  % TikZ commands for cool visualization
\end{tikzpicture}

\end{document}
```
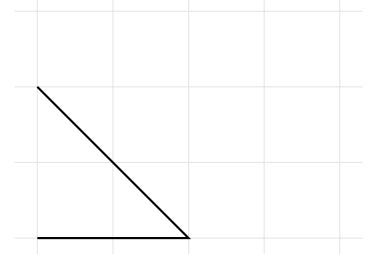
2 Relative and calculated coordinates

Relative Coordinates (Vector Addition)

```latex
\begin{tikzpicture}
  ...
  % ++ Remembers last coordinate
  \draw (0,0) -- ++(2,0) -- ++(0,2) -- ++(2,0) -- ++(0,2);
  ...
\end{tikzpicture}
```

```latex
\begin{tikzpicture}
  ...
  % + Remembers only first coordinate
  \draw (0,0) -- +(2,0) -- +(0,2);
  ...
\end{tikzpicture}
```
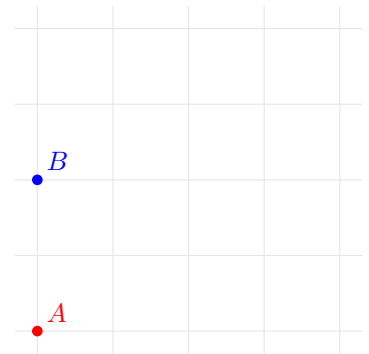
Defining Coordinates

```
\begin{tikzpicture}
  ...
  \coordinate (A) at (0,0);
  \coordinate (B) at (0,2);

  \fill[red] (A) circle (2pt);
  \fill[blue] (B) circle (2pt);

  % Shorthand
  % \fill[red]  (A) at (0,0) circle (2pt);
  % \fill[blue] (B) at (0,2) circle (2pt);
  ...
\end{tikzpicture}
```
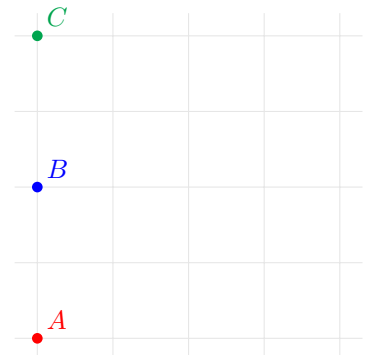
Arithmetic with coordinates

```
\usetikzlibrary{calc} % Import necessary

\begin{tikzpicture}
  ...
  \coordinate (A) at (0,0);
  \coordinate (B) at (0,2);
  \coordinate (C) at ($(A) + 2*(B)$);

  \fill[red] (A) circle (2pt);
  \fill[blue] (B) circle (2pt);
  \fill[Green] (C) circle (2pt);
  ...
\end{tikzpicture}
```
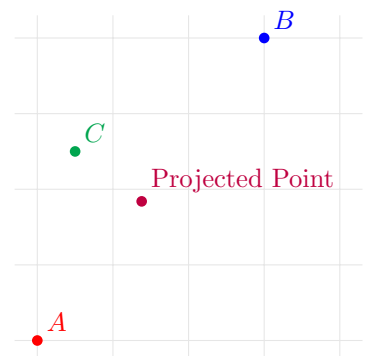
Projected Points

```
\begin{tikzpicture}
  ...
  \coordinate (A) at (0,0);
  \coordinate (B) at (3,4);
  \coordinate (C) at (0.5,2.5);

  \fill[red] (A) circle (2pt);
  \fill[blue] (B) circle (2pt);
  \fill[green] (C) circle (2pt);
  \fill[purple] ($(A)!(C)!(B)$) circle (2pt);
  ...
\end{tikzpicture}
```
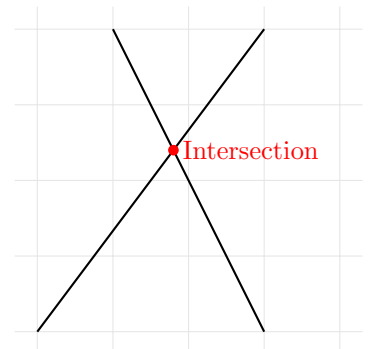
Intersections

```
\usetikzlibrary{intersections} % Import necessary

\begin{tikzpicture}
  ...
  \draw[name path=vector1, thick] (0,0) -- (3,4);
  \draw[name path=vector2, thick] (3,0) -- (1,4);
  \fill[name intersections={of=vector1 and vector2,
      by=intersectionPoint}, red] (intersectionPoint) circle
      (2pt);
  ...
\end{tikzpicture}
```
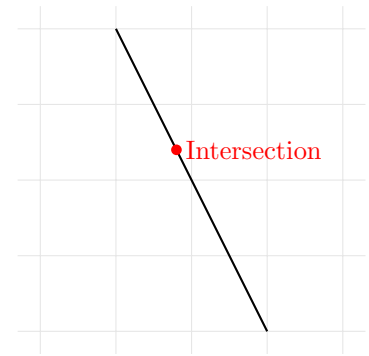
Paths

```
1  \usetikzlibrary{intersections} % Import necessary
2
3  \begin{tikzpicture}
4    ...
5    % Not drawn but still exists
6    \path[name path=vector1, thick] (0,0) -- (3,4);
7    \draw[name path=vector2, thick] (3,0) -- (1,4);
8    \fill[name intersections={of=vector1 and vector2,
         by=intersectionPoint}, red] (intersectionPoint) circle
         (2pt);
9    ...
10 \end{tikzpicture}
```
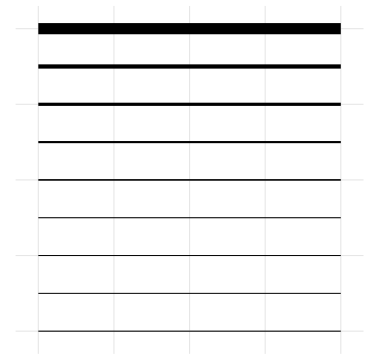
3   Options and Keys

Common Options (Line thickness)

```
1  \begin{tikzpicture}
2    ...
3    \draw                   (0,0) -- (4,0);          % 0.4pt
4    \draw[ultra thin]       (0.0,0.5) -- (4.0,0.5); % 0.1pt
5    \draw[very thin]        (0.0,1.0) -- (4.0,1.0); % 0.2pt
6    \draw[thin]             (0.0,1.5) -- (4.0,1.5); % 0.4pt
7    \draw[semithick]        (0.0,2.0) -- (4.0,2.0); % 0.6pt
8    \draw[thick]            (0.0,2.5) -- (4.0,2.5); % 0.8pt
9    \draw[very thick]       (0.0,3.0) -- (4.0,3.0); % 1.2pt
10   \draw[ultra thick]      (0.0,3.5) -- (4.0,3.5); % 1.6pt
11   \draw[line width=4.2pt] (0.0,4.0) -- (4.0,4.0); % 4.2pt
12   ...
13 \end{tikzpicture}
```

Common Options (Dash Patterns)

```
1  \begin{tikzpicture}
2    ...
3    % Dash Patterns
4    \draw                      (0,0.0) -- (4,0.0);
5    \draw[solid]               (0,0.3) -- (4,0.3);
6    \draw[dashed]              (0,0.6) -- (4,0.6);
7    \draw[densely dashed]      (0,0.9) -- (4,0.9);
8    \draw[loosely dashed]      (0,1.2) -- (4,1.2);
9    \draw[dotted]              (0,1.5) -- (4,1.5);
10   \draw[densely dotted]      (0,1.8) -- (4,1.8);
11   \draw[loosely dotted]      (0,2.1) -- (4,2.1);
12   \draw[dash dot]            (0,2.4) -- (4,2.4);
13   \draw[densely dash dot]    (0,2.7) -- (4,2.7);
14   \draw[loosely dash dot]    (0,3.0) -- (4,3.0);
15   \draw[dash dot dot]        (0,3.3) -- (4,3.3);
16   \draw[densely dash dot dot] (0,3.6) -- (4,3.6);
17   \draw[loosely dash dot dot] (0,3.9) -- (4,3.9);
18   ...
19 \end{tikzpicture}
```
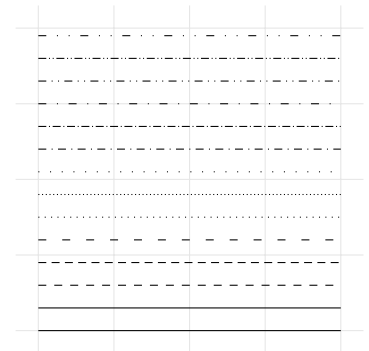
Common Options (Colors and Opacity)

```
\begin{tikzpicture}
  ...
  % Fill opacities
  \draw[fill=red, fill opacity=0.2]  (0,0) circle (8pt);
  \draw[fill=red, fill opacity=0.4]  (0,1) circle (8pt);
  \draw[fill=red, fill opacity=0.6]  (0,2) circle (8pt);
  \draw[fill=red, fill opacity=0.8]  (0,3) circle (8pt);
  \draw[fill=red, fill opacity=1]    (0,4) circle (8pt);

  % Stroke opacities
  \draw[draw=red, draw opacity=0.2]  (2,0) circle (8pt);
  \draw[draw=red, draw opacity=0.4]  (2,1) circle (8pt);
  \draw[draw=red, draw opacity=0.6]  (2,2) circle (8pt);
  \draw[draw=red, draw opacity=0.8]  (2,3) circle (8pt);
  \draw[draw=red, draw opacity=1]    (2,4) circle (8pt);

  % Reducing color intensity (color mixing with white)
  \draw[fill=red!20]                 (4,0) circle (8pt);
  \draw[fill=red!40]                 (4,1) circle (8pt);
  \draw[fill=red!60]                 (4,2) circle (8pt);
  \draw[fill=red!80]                 (4,3) circle (8pt);
  \draw[fill=red]                    (4,4) circle (8pt);
  ...
\end{tikzpicture}
```
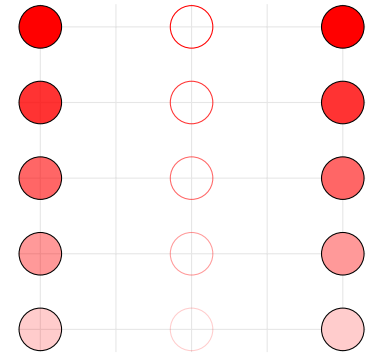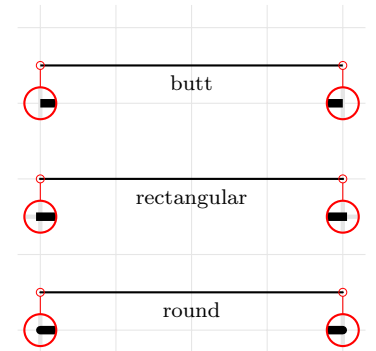

Common Options (Line Caps)

```
\begin{tikzpicture}
  ...
  \draw[line cap=round] (0,0.5) -- (4,0.5);
  \draw[line cap=rect]  (0,2)   -- (4,2);
  \draw[line cap=butt]  (0,3.5) -- (4,3.5);
  ...
\end{tikzpicture}
```
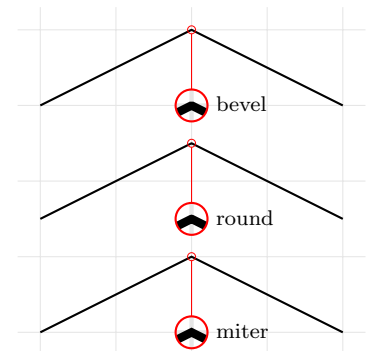

Common Options (Line Joins)

```
\begin{tikzpicture}
  ...
  \draw[line join=miter] (0,0)   -- (2,1)   -- (4,0);
  \draw[line join=round] (0,1.5) -- (2,2.5) -- (4,1.5);
  \draw[line join=bevel] (0,3)   -- (2,4)   -- (4,3);
  ...
\end{tikzpicture}
```
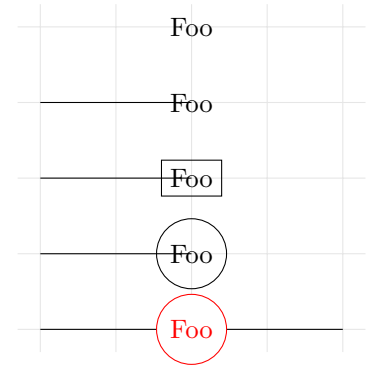

4

4 Nodes

Node structure

```
1  \begin{tikzpicture}
2    ...
3    % node[Optionen] (A) {};
4    \draw (2,4) node {Foo};
5    \draw (0,3) -- (2,3) node {Foo};
6    \draw (0,2) -- (2,2) node[draw] {Foo};
7    \draw (0,1) -- (2,1) node[draw, circle] {Foo};
8    \draw (0,0) -- (2,0) node[draw, circle, red, fill=white]
         {Foo} -- (4,0);
9    ...
10 \end{tikzpicture}
```
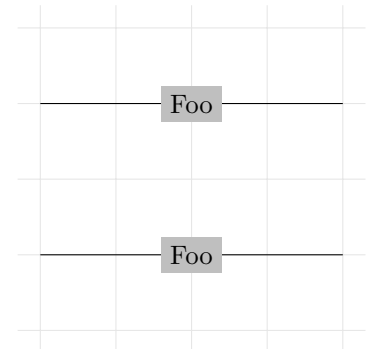
\node operator

```
1  \begin{tikzpicture}
2    ...
3    % node[Optionen] (A) {};
4    \draw (2,4) node {Foo};
5    \draw (0,3) -- (2,3) node {Foo};
6    \draw (0,2) -- (2,2) node[draw] {Foo};
7    \draw (0,1) -- (2,1) node[draw, circle] {Foo};
8    \draw (0,0) -- (2,0) node[draw, circle, red, fill=white]
         {Foo} -- (4,0);
9    ...
10 \end{tikzpicture}
```

Common Node Shapes

```
1  \usetikzlibrary{shapes.geometric} % Import necessary
2  \usetikzlibrary{shapes.symbols}   % Import necessary
3
4  \begin{tikzpicture}
5    ...
6    % defaults shapes
7    \node[draw, rectangle]      at (0,3) {};
8    \node[draw, circle]         at  (1,3) {};
9
10   % requires shapes.geometric
11   \node[draw, ellipse]        at (0,1.5) {};
12   \node[draw, diamond]        at (1,1.5) {};
13   \node[draw, regular polygon] at (2,1.5) {};
14   \node[draw, star]           at (3,1.5) {};
15   \node[draw, semicircle]     at (4,1.5) {};
16
17   % requires shapes.symbols
18   \node[cloud, draw]          at (0,0) {};
19   \node[starburst, draw]      at (1,0) {};
20   \node[signal, draw]         at (2,0) {};
21   \node[tape, draw]           at (3,0) {};
22   \node[magnetic tape, draw]  at (4,0) {};
23   ...
24 \end{tikzpicture}
```
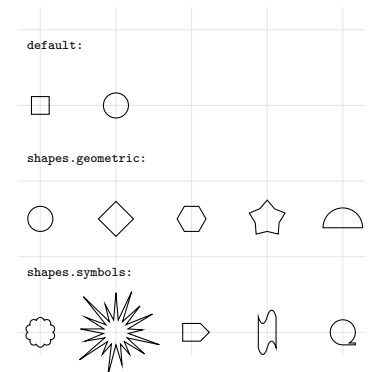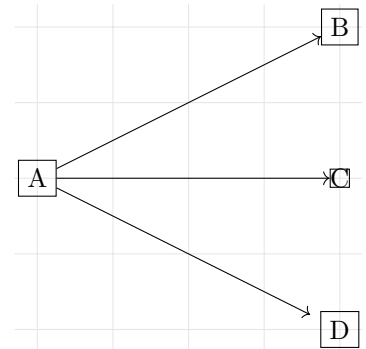
Margin and padding

```
\begin{tikzpicture}
  ...
  \node[draw] (a) at (0,2) {A};
  \node[draw] (b) at (4,4) {B};
  \node[draw, inner sep=0] (c) at (4,2) {C}; % Padding
  \node[draw, outer sep=4] (d) at (4,0) {D}; % Margin

  \draw[->] (a) -- (b);
  \draw[->] (a) -- (c);
  \draw[->] (a) -- (d);
  ...
\end{tikzpicture}
```

Positions

```
\begin{tikzpicture}
  ...
  \draw (1,0) -- (1,4)
  node[pos=0,        draw, fill=white]{pos=0.00}
  node[pos=0.25,     draw, fill=white]{pos=0.25}
  node[pos=0.5,      draw, fill=white]{pos=0.50}
  node[pos=0.75,     draw, fill=white]{pos=0.75}
  node[pos=1,        draw, fill=white]{pos=1.00}
  ;

  \draw (3,0) -- (3,4)
  node[pos=0,        draw, fill=white]{pos=0.00}
  node[near start,   draw, fill=white]{near start}
  node[midway,       draw, fill=white]{midway}
  node[near end,     draw, fill=white]{near end}
  node[pos=1,        draw, fill=white]{pos=1.00}
  ;
  ...
\end{tikzpicture}
```
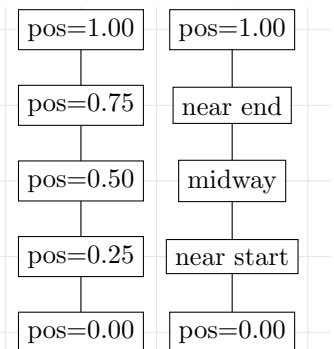
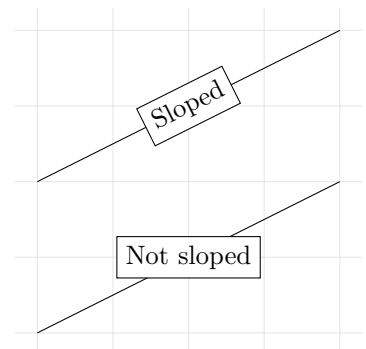## Sloping

```
\begin{tikzpicture}
  ...
  \draw (0,0) -- (4,2) node[draw, midway] {Not sloped};
  \draw (0,2) -- (4,4) node[draw, midway, sloped] {Sloped};
  ...
\end{tikzpicture}
```
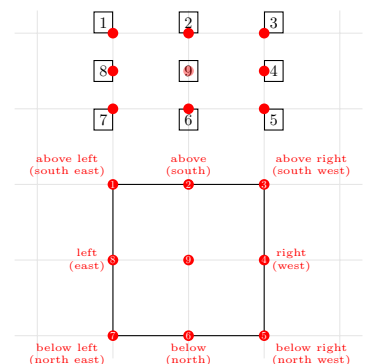
Anchors

```
\begin{tikzpicture}
  ...
  \node[draw, above left]  at (1,4)   {1};
  \node[draw, above]       at (2,4)   {2};
  \node[draw, above right] at (3,4)   {3};
  \node[draw, right]       at (3,3.5) {4};
  \node[draw, below right] at (3,3)   {5};
  \node[draw, below]       at (2,3)   {6};
  \node[draw, below left]  at (1,3)   {7};
  \node[draw, left]        at (1,3.5) {8};
  \node[draw]              at (2,3.5) {9};
  ...
\end{tikzpicture}
```
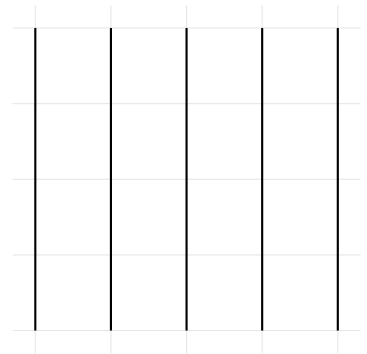
5 `foreach` Loops

Basic Looping

```
1 \begin{tikzpicture}
2   ...
3     \foreach \c in {0,1,2,3,4} {
4       \draw (\c, 0) -- (\c, 2);
5     }
6   ...
7 \end{tikzpicture}
```
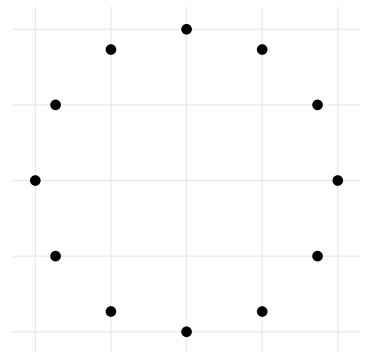
Automatic Ranges and Steps

```
1 \begin{tikzpicture}
2   ...
3   \foreach \angle in {0,20,...,340} {
4     \fill ($(2,2) + (\angle:2)$) circle (2pt);
5   }
6   ...
7 \end{tikzpicture}
```
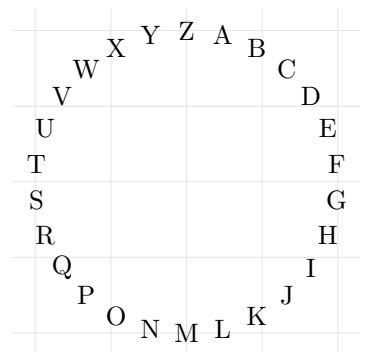
Loop Indexing

```
1 \begin{tikzpicture}
2   ...
3   \foreach[count=\x] \c in {A, ..., Z} {
4     \node at ($(2,2) + (90 - \x * 360/26:2)$) {\c};
5   }
6   ...
7 \end{tikzpicture}
```
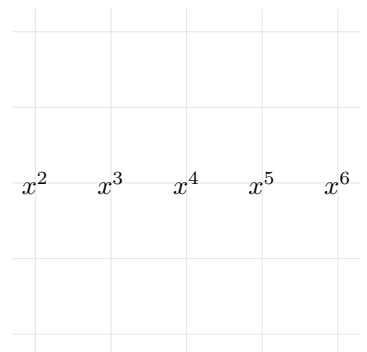
Specifying Automatic Ranges

```
1 \begin{tikzpicture}
2   ...
3   \foreach[count=\x from 0] \c in {x^2, x^..., x^6} {
4     \node at (\x, 2) {$\c$};
5   }
6   ...
7 \end{tikzpicture}
```
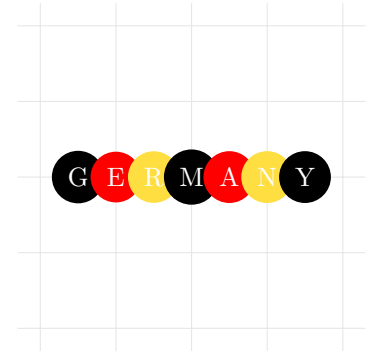
Unpacking variables

```
\begin{tikzpicture}
  ...
  \foreach[count=\i from 0] \ch/\col in
  {G/black, E/red, R/yellow, M/black, A/red, N/yellow, Y/black}
  {
    \node[circle, fill=\col] at ({\i/2 + 0.5} , 2) {\ch};
  }
  ...
\end{tikzpicture}
```

6 Plotten
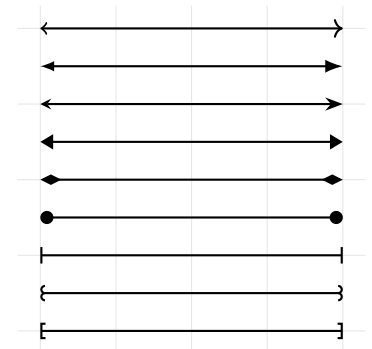
7 Arrows

Most common arrow types

```
\usetikzlibrary{arrows.meta} % Import necessary

\begin{tikzpicture}
  ...
  \draw[{to}-{To}]               (0,4.0)  -- (4,4.0);
  \draw[{latex}-{Latex}]         (0,3.5)  -- (4,3.5);
  \draw[{stealth}-{Stealth}]     (0,3.0)  -- (4,3.0);
  \draw[{Triangle}-{Triangle}]   (0,2.5)  -- (4,2.5);
  \draw[{Diamond}-{Diamond}]     (0,2.0)  -- (4,2.0);
  \draw[{Circle}-{Circle}]       (0,1.5)  -- (4,1.5);
  \draw[{Bar}-{Bar}]             (0,1.0)  -- (4,1.0);
  \draw[{Hooks}-{Hooks}]         (0,0.5)  -- (4,0.5);
  \draw[{Bracket}-{Bracket}]     (0,0.0)  -- (4,0.0);
  ...
\end{tikzpicture}
```
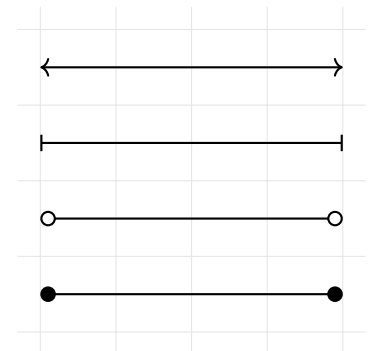
Shorthands

```
\usetikzlibrary{arrows} % Import necessary

\begin{tikzpicture}
  ...
    \draw[<->] (0,3.5) -- (4,3.5);
    \draw[|-|] (0,2.5) -- (4,2.5);
    \draw[o-o] (0,1.5) -- (4,1.5);
    \draw[*-*] (0,0.5) -- (4,0.5);
  ...
\end{tikzpicture}
```
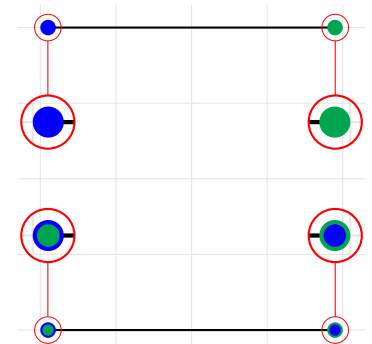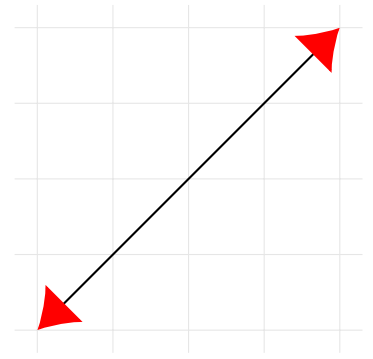
Colors

```
\begin{tikzpicture}
  ...
  \draw[{*[color=blue]}-{*[color=Green]}]
    (0,4) -- (4,4);
  \draw[{*[color=blue, fill=Green]}-{*[color=Green, fill=blue]}]
    (0,2) -- (4,2);
  ...
\end{tikzpicture}
```
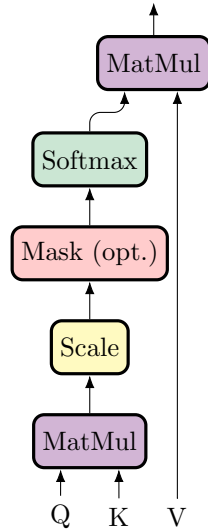
Shortcut for custom arrows

```
1  \begin{tikzpicture}
2    ...
3    \draw [{*[color=blue]}-{*[color=Green]}]
4      (0,4) -- (4,4);
5    \draw [{*[color=blue, fill=Green]}-{*[color=Green, fill=blue]}]
6      (0,2) -- (4,2);
7    ...
8  \end{tikzpicture}
```

8 Positioning (a full on example)

In research papers, especially related to computer science, you often see diagrams as such

This requires placing nodes relative to another and is usually done as follows:

Defining node styles

First some styles are defined that can be reused for multiple nodes

```
...
\begin{tikzpicture}[
  % Styles
  MATMUL/.style   = {rectangle, draw=black, fill=Plum!30,   very thick, rounded corners},
  SOFTMAX/.style  = {rectangle, draw=black, fill=Green!20,  very thick, rounded corners},
  MASK/.style     = {rectangle, draw=black, fill=red!20,    very thick, rounded corners},
  SCALE/.style    = {rectangle, draw=black, fill=yellow!30, very thick, rounded corners},
  ]
\end{tikzpicture}
...
```

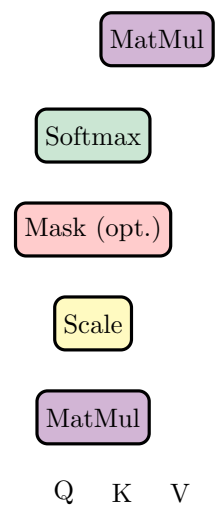### Positioning nodes

You then go on positioning nodes relative to other nodes

```
\begin{tikzpicture}
  [
  % Styles
  ...
  ]
  % Nodes
  \node (Q) {Q};
  \node (K) [right=of Q] {K};
  \node (V) [right=of K] {V};
  \node[MATMUL] (MatMulFirst) at ($(Q)!0.5!(K) + (0,1cm)$) {MatMul};
  \node[SCALE] (Scale) [above=0.5cm of MatMulFirst] {Scale};
  \node[MASK] (Mask) [above=0.5cm of Scale] {Mask (opt.)};
  \node[SOFTMAX] (Softmax) [above=0.5cm of Mask] {Softmax};
  \node[MATMUL] (MatMulSecond) at ($(K)!0.6!(V) + (0,6cm)$) {MatMul};
  ...
\end{tikzpicture}
```

Connecting nodes

Lastly you connect the nodes

```
1  \begin{tikzpicture}
2    [
3    % Styles
4    ...
5    ]
6    % Nodes
7    ...
8    % Connections
9    \draw[-{Latex}] (Q.north) -- ($(MatMulFirst.south) + (-0.385cm, 0)$);
10   \draw[-{Latex}] (K.north) -- ($(MatMulFirst.south) + (0.385cm, 0)$);
11   \draw[-{Latex}] (MatMulFirst.north) -- (Scale.south);
12   \draw[-{Latex}] (Scale.north) -- (Mask.south);
13   \draw[-{Latex}] (Mask.north) -- (Softmax.south);
14   \draw[-{Latex}] (V.north) -| ($(MatMulSecond.south) + (0.3126cm, 0)$);
15   \draw[-{Latex}, rounded corners] (Softmax.north) -- ++(0,0.25cm) -|
        ($(MatMulSecond.south) + (-0.385cm, 0)$);
16   \draw[-{Latex}] (MatMulSecond.north) -- ($(MatMulSecond) + (0,0.8cm)$);
17   ...
18 \end{tikzpicture}
```