Graphics with TikZ

Math 351

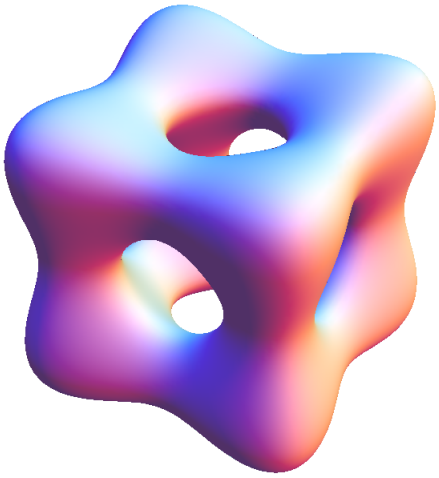
There is no substitute for high quality graphics. If a technical topic is visual in nature, much time and attention should be paid to creating powerful images. A good image communicates information more easily than the printed word.

1 Including outside images

Images can be included using the `graphicx` package (loaded in the preamble). Include an image using `\includegraphics[options]{file}` where `file` can be a file in `.pdf`, `.jpg`, or `.png` format. Available `options` are

`width = X`	to specify a width `X`
`height = X`	to specify height `X`
`scale = X`	to scale by multiplier `X`
`angle = X`	to rotate counter-clockwise by `X` degrees

For example, the image



was created in Mathematica by plotting the set of x, y, z coordinates in $\mathbb{R}^3$ which satisfy $x^4 + y^4 + z^4 + 3/8 = x^2 + y^2 + z^2$. It was saved as `HolyCube.pdf` and then shown here using `\includegraphics[scale = 1.25]{HolyCube}`.

2 TikZ

TikZ can produce graphics of excellent quality. It can do lots of things, but there is an initial time investment necessary to understand TikZ code.

This document does not attempt to give a good description—or even a coherent introduction—to creating graphics with TikZ. For those purposes, refer to the short "Minimal introduction to TikZ" and the long (1161 page, 10MB) "PGF manual" found at https://www.ctan.org/pkg/pgf. Instead, this document will display some of TikZ's abilities with a few well chosen examples. Many more interesting examples are available at http://www.texample.net/tikz/examples/.

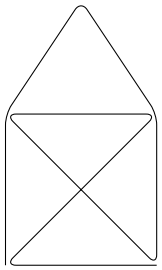
To use TikZ, load the package `tikz` in the preamble and then place TikZ code in the `tikzpicture` environment.

Think about TikZ code as doing two things:

1. identifying some (x, y) coordinates, and
2. describing how to connect those points.

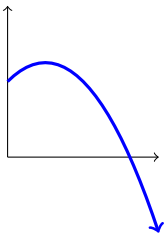
The `\draw` command draws lines connecting a list of (x, y) coordinates separated by the `--` delimiter. The `\draw` command and all other TikZ commands must end with a semicolon. Optional commands to `\draw` are called using brackets. One of the many such options is `rounded corners`, which gives rounded corners.

```
\begin{tikzpicture}
\draw [rounded corners]
  (0,0) -- (0,2) -- (1,3.5) -- (2,2) --
  (2,0) -- (0,2) -- (2,2)   -- (0,0) -- (2,0);
\end{tikzpicture}
```



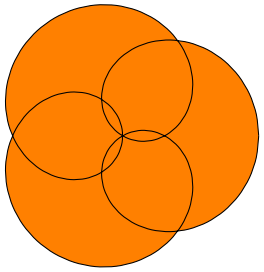
Simple functions like polynomials and trigonometric functions can be plotted using "plot" within `\draw` command; below is the graph of $-x^2+x+1$ on $[0, 2]$:

```
\begin{tikzpicture}
   \draw [->] (0,0) -- (2,0);
   \draw [->] (0,0) -- (0,2);
   \draw [blue, very thick, domain=0:2, ->]
       plot (\x, {-1*pow(\x, 2) + \x + 1});
\end{tikzpicture}
```



Parametric equations can also be graphed; for instance, to graph the parametric equations $(\cos(4t) + \cos t, \sin(4t) + \sin t)$ for $t \in [0, 2\pi]$, do this:

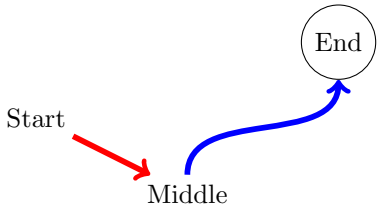
```
\begin{tikzpicture}[scale = .9]
   \draw [domain=0:2*pi, samples = 100, smooth, fill = orange]
      plot ({cos(4*\x r) + cos(\x r)}, {sin(4*\x r) + sin(\x r}};
\end{tikzpicture}
```



The `r` in `cos(4*\x r)` indicates that `\x` is in radians, not degrees. For complicated curves without a simple formula it is best to use outside software to generate a lots of (x, y) coordinates which can then be called with `\draw`.

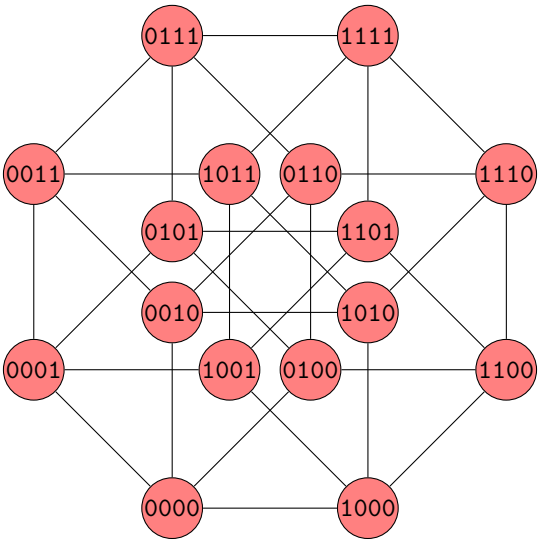
The (x, y) coordinates can be given names and labels using the `\node` command, in this way:

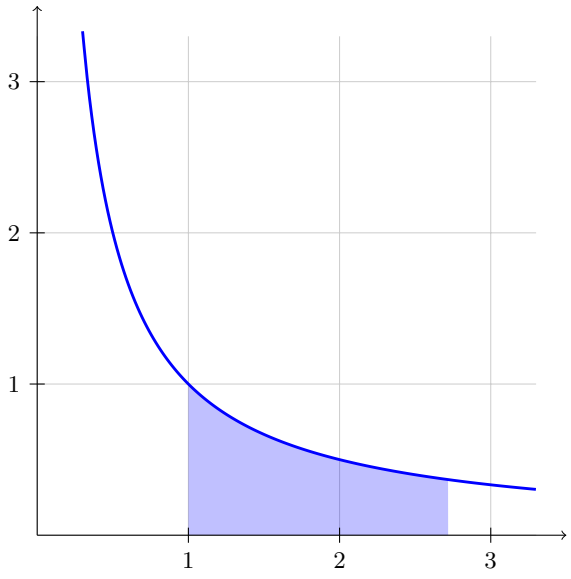
```
\begin{tikzpicture}
  \node (A) at (0,0) {Start};
  \node (B) at (2,-1) {Middle};
  \node [draw, circle] (C) at (4,1) {End};
  \draw [line width=.5ex, ->, red] (A) -- (B);
  \draw [line width=.5ex, ->, blue] (B) to [out=90, in=270] (C);
\end{tikzpicture}
```

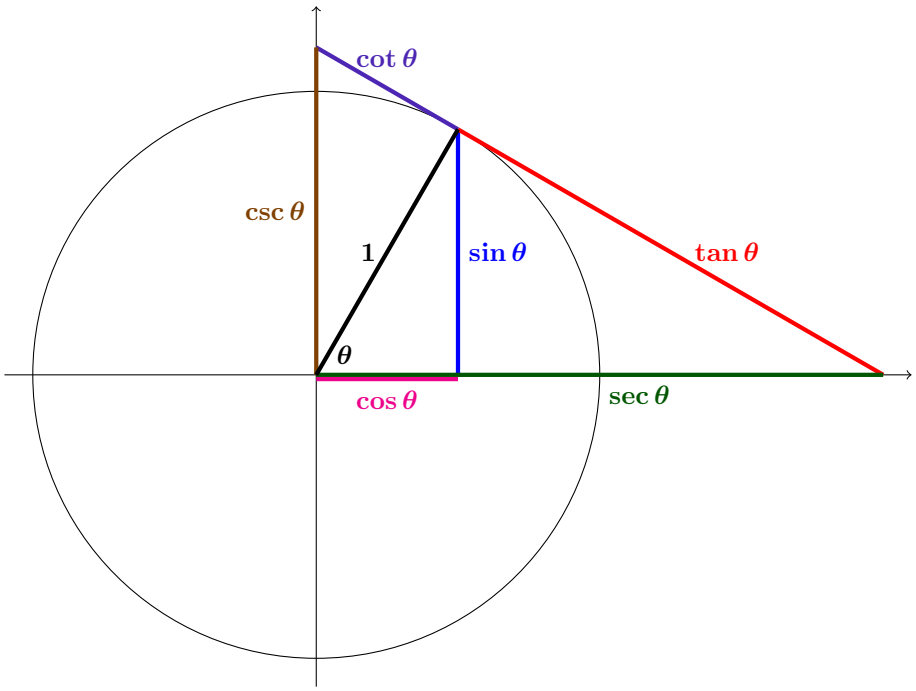


This last example used a slightly different syntax in the `\draw` command; instead of using a `--` delimiter, the command `to` was used, which contains the option of specifying the outgoing and incoming angles in degrees.

The remainder of this document displays good examples of TikZ figures. The generating code can be found in the LaTeX `.tex` file.







To access three dimensional coordinates, the `tikz-3dplot` package must be loaded in the preamble.