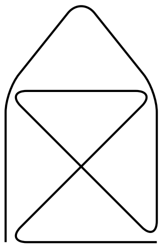
Part I
教程和指导

by Till Tantau

为了帮你入门 Ti*k*Z，本手册没有立刻给出长长的安装和配置过程，而是直接从教程开始。这些教程解释了该系统所有基本特性和部分高级特性，并不深入所有细节。这部分还指导你在用 Ti*k*Z 绘图时，如何继续前进。



```
\tikz \draw[thick,rounded corners=8pt]
  (0,0) -- (0,2) -- (1,3.25) -- (2,2) -- (2,0) -- (0,2) -- (2,2) -- (0,0) -- (2,0);
```

1 Tutorial: Euclid's Amber Version of the *Elements*

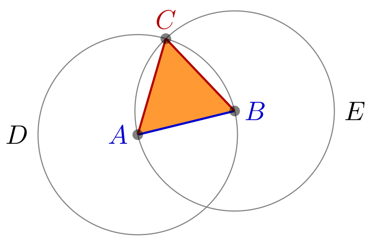
In this third tutorial we have a look at how Ti*k*Z can be used to draw geometric constructions.

Euclid is currently quite busy writing his new book series, whose working title is "Elements" (Euclid is not quite sure whether this title will convey the message of the series to future generations correctly, but he intends to change the title before it goes to the publisher). Up to know, he wrote down his text and graphics on papyrus, but his publisher suddenly insists that he must submit in electronic form. Euclid tries to argue with the publisher that electronics will only be discovered thousands of years later, but the publisher informs him that the use of papyrus is no longer cutting edge technology and Euclid will just have to keep up with modern tools.

Slightly disgruntled, Euclid starts converting his papyrus entitled "Book I, Proposition I" to an amber version.

1.1 Book I, Proposition I

The drawing on his papyrus looks like this:[1]



Proposition I
To construct an equilateral triangle on a given finite straight line.

Let AB be the given finite straight line. It is required to construct an equilateral triangle on the straight line AB.
Describe the circle BCD with center A and radius AB. Again describe the circle ACE with center B and radius BA. Join the straight lines CA and CB from the point C at which the circles cut one another to the points A and B.
Now, since the point A is the center of the circle CDB, therefore AC equals AB. Again, since the point B is the center of the circle CAE, therefore BC equals BA. But AC was proved equal to AB, therefore each of the straight lines AC and BC equals AB. And things which equal the same thing also equal one another, therefore AC also equals BC. Therefore the three straight lines AC, AB, and BC equal one another. Therefore the triangle ABC is equilateral, and it has been constructed on the given finite straight line AB.

Let us have a look at how Euclid can turn this into Ti*k*Z code.

1.1.1 Setting up the Environment

As in the previous tutorials, Euclid needs to load Ti*k*Z, together with some libraries. These libraries are `calc`, `intersections`, `through`, and `backgrounds`. Depending on which format he uses, Euclid would use one of the following in the preamble:

```
% For LaTeX:
\usepackage{tikz}
\usetikzlibrary{calc,intersections,through,backgrounds}
```

```
% For plain TeX:
\input tikz.tex
\usetikzlibrary{calc,intersections,through,backgrounds}
```

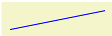
```
% For ConTeXt:
\usemodule[tikz]
\usetikzlibrary[calc,intersections,through,backgrounds]
```

[1]The text is taken from the wonderful interactive version of Euclid's Elements by David E. Joyce, to be found on his website at Clark University.

1.1.2 The Line *AB*

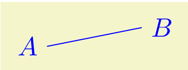
The first part of the picture that Euclid wishes to draw is the line AB. That is easy enough, something like `\draw (0,0) --(2,1);` might do. However, Euclid does not wish to reference the two points A and B as $(0,0)$ and $(2,1)$ subsequently. Rather, he wishes to just write `A` and `B`. Indeed, the whole point of his book is that the points A and B can be arbitrary and all other points (like C) are constructed in terms of their positions. It would not do if Euclid were to write down the coordinates of C explicitly.

So, Euclid starts with defining two coordinates using the `\coordinate` command:



```
\begin{tikzpicture}
  \coordinate (A) at (0,0);
  \coordinate (B) at (1.25,0.25);

  \draw[blue] (A) -- (B);
\end{tikzpicture}
```

That was easy enough. What is missing at this point are the labels for the coordinates. Euclid does not want them *on* the points, but next to them. He decides to use the `label` option:




```
\begin{tikzpicture}
  \coordinate [label=left:\textcolor{blue}{$A$}]  (A) at (0,0);
  \coordinate [label=right:\textcolor{blue}{$B$}] (B) at (1.25,0.25);

  \draw[blue] (A) -- (B);
\end{tikzpicture}
```

At this point, Euclid decides that it would be even nicer if the points A and B were in some sense "random." Then, neither Euclid nor the reader can make the mistake of taking "anything for granted" concerning these position of these points. Euclid is pleased to learn that there is a `rand` function in Ti*k*Z that does exactly what he needs: It produces a number between -1 and 1. Since Ti*k*Z can do a bit of math, Euclid can change the coordinates of the points as follows:

```
\coordinate [...] (A) at (0+0.1*rand,0+0.1*rand);
\coordinate [...] (B) at (1.25+0.1*rand,0.25+0.1*rand);
```

This works fine. However, Euclid is not quite satisfied since he would prefer that the "main coordinates" $(0,0)$ and $(1.25,0.25)$ are "kept separate" from the perturbation $0.1(rand, rand)$. This means, he would like to specify that coordinate A as "The point that is at $(0,0)$ plus one tenth of the vector $(rand, rand)$."

It turns out that the `calc` library allows him to do exactly this kind of computation. When this library is loaded, you can use special coordinates that start with `($` and end with `$)` rather than just `(` and `)`. Inside these special coordinates you can give a linear combination of coordinates. (Note that the dollar signs are only intended to signal that a "computation" is going on; no mathematical typesetting is done.)

The new code for the coordinates is the following:

```
\coordinate [...] (A) at ($ (0,0) + .1*(rand,rand) $);
\coordinate [...] (B) at ($ (1.25,0.25) + .1*(rand,rand) $);
```

Note that if a coordinate in such a computation has a factor (like `.1`), you must place a `*` directly before the opening parenthesis of the coordinate. You can nest such computations.

1.1.3 The Circle Around *A*

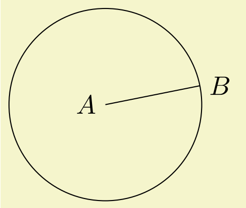
The first tricky construction is the circle around A. We will see later how to do this in a very simple manner, but first let us do it the "hard" way.

The idea is the following: We draw a circle around the point A whose radius is given by the length of the line AB. The difficulty lies in computing the length of this line.

Two ideas "nearly" solve this problem: First, we can write `($ (A) - (B) $)` for the vector that is the difference between A and B. All we need is the length of this vector. Second, given two numbers x and y, one can write `veclen(`x`,`y`)` inside a mathematical expression. This gives the value $\sqrt{x^2 + y^2}$, which is exactly the desired length.

The only remaining problem is to access the x- and y-coordinate of the vector AB. For this, we need a new concept: the *let operation*. A let operation can be given anywhere on a path where a normal path operation like a line-to or a move-to is expected. The effect of a let operation is to evaluate some coordinates and to assign the results to special macros. These macros make it easy to access the x- and y-coordinates of the coordinates.

Euclid would write the following:




```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (1.25,0.25);
  \draw (A) -- (B);

  \draw (A) let
              \p1 = ($ (B) - (A) $)
            in
              circle ({veclen(\x1,\y1)});
\end{tikzpicture}
```

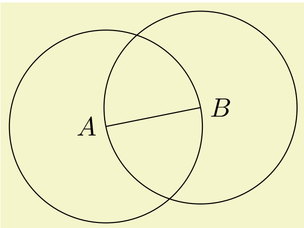
Each assignment in a let operation starts with `\p`, usually followed by a ⟨*digit*⟩. Then comes an equal sign and a coordinate. The coordinate is evaluated and the result is stored internally. From then on you can use the following expressions:

1. `\x`⟨*digit*⟩ yields the x-coordinate of the resulting point.
2. `\y`⟨*digit*⟩ yields the y-coordinate of the resulting point.
3. `\p`⟨*digit*⟩ yields the same as `\x`⟨*digit*⟩`,\y`⟨*digit*⟩.

You can have multiple assignments in a let operation, just separate them with commas. In later assignments you can already use the results of earlier assignments.

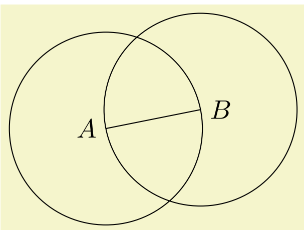
Note that `\p1` is not a coordinate in the usual sense. Rather, it just expands to a string like `10pt,20pt`. So, you cannot write, for instance, `(\p1.center)` since this would just expand to `(10pt,20pt.center)`, which makes no sense.

Next, we want to draw both circles at the same time. Each time the radius is `veclen(\x1,\y1)`. It seems natural to compute this radius only once. For this, we can also use a let operation: Instead of writing `\p1 = ...`, we write `\n2 = ...`. Here, "n" stands for "number" (while "p" stands for "point"). The assignment of a number should be followed by a number in curly braces.




```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (1.25,0.25);
  \draw (A) -- (B);

  \draw let \p1 = ($ (B) - (A) $),
            \n2 = {veclen(\x1,\y1)}
        in
          (A) circle (\n2)
          (B) circle (\n2);
\end{tikzpicture}
```

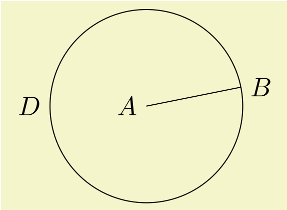
In the above example, you may wonder, what `\n1` would yield? The answer is that it would be undefined – the `\p`, `\x`, and `\y` macros refer to the same logical point, while the `\n` macro has "its own namespace." We could even have replaced `\n2` in the example by `\n1` and it would still work. Indeed, the digits following these macros are just normal TeX parameters. We could also use a longer name, but then we have to use curly braces:




```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (1.25,0.25);
  \draw (A) -- (B);

  \draw let \p1        = ($ (B) - (A) $),
            \n{radius} = {veclen(\x1,\y1)}
        in
          (A) circle (\n{radius})
          (B) circle (\n{radius});
\end{tikzpicture}
```

At the beginning of this section it was promised that there is an easier way to create the desired circle. The trick is to use the `through` library. As the name suggests, it contains code for creating shapes that go through a given point.

The option that we are looking for is `circle through`. This option is given to a *node* and has the following effects: First, it causes the node's inner and outer separations to be set to zero. Then it sets the shape of the node to `circle`. Finally, it sets the radius of the node such that it goes through the parameter given to `circle through`. This radius is computed in essentially the same way as above.

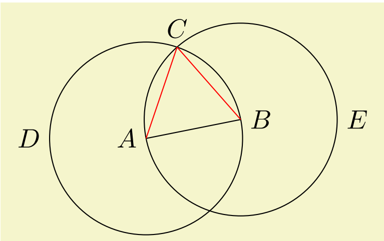



```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (1.25,0.25);
  \draw (A) -- (B);

  \node [draw,circle through=(B),label=left:$D$] at (A) {};
\end{tikzpicture}
```

1.1.4 The Intersection of the Circles

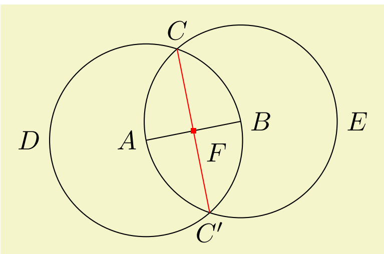
Euclid can now draw the line and the circles. The final problem is to compute the intersection of the two circles. This computation is a bit involved if you want to do it "by hand." Fortunately, the intersection library allows us to compute the intersection of arbitrary paths.

The idea is simple: First, you "name" two paths using the `name path` option. Then, at some later point, you can use the option `name intersections`, which creates coordinates called `intersection-1`, `intersection-2`, and so on at all intersections of the paths. Euclid assigns the names `D` and `E` to the paths of the two circles (which happen to be the same names as the nodes themselves, but nodes and their paths live in different "namespaces").




```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (1.25,0.25);
  \draw (A) -- (B);

  \node (D) [name path=D,draw,circle through=(B),label=left:$D$]  at (A) {};
  \node (E) [name path=E,draw,circle through=(A),label=right:$E$] at (B) {};

  % Name the coordinates, but do not draw anything:
  \path [name intersections={of=D and E}];

  \coordinate [label=above:$C$] (C) at (intersection-1);

  \draw [red] (A) -- (C);
  \draw [red] (B) -- (C);
\end{tikzpicture}
```

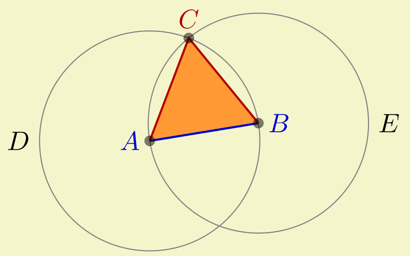
It turns out that this can be further shortened: The `name intersections` takes an optional argument `by`, which lets you specify names for the coordinates and options for them. This creates more compact code. Although Euclid does not need it for the current picture, it is just a small step to computing the bisection of the line AB:



```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (1.25,0.25);
  \draw [name path=A--B] (A) -- (B);

  \node (D) [name path=D,draw,circle through=(B),label=left:$D$]  at (A) {};
  \node (E) [name path=E,draw,circle through=(A),label=right:$E$] at (B) {};

  \path [name intersections={of=D and E, by={[label=above:$C$]C, [label=below:$C'$]C'}}];

  \draw [name path=C--C',red] (C) -- (C');

  \path [name intersections={of=A--B and C--C',by=F}];
  \node [fill=red,inner sep=1pt,label=-45:$F$] at (F) {};
\end{tikzpicture}
```

1.1.5 The Complete Code

Back to Euclid's code. He introduces a few macros to make life simpler, like a `\A` macro for typesetting a blue A. He also uses the `background` layer for drawing the triangle behind everything at the end.



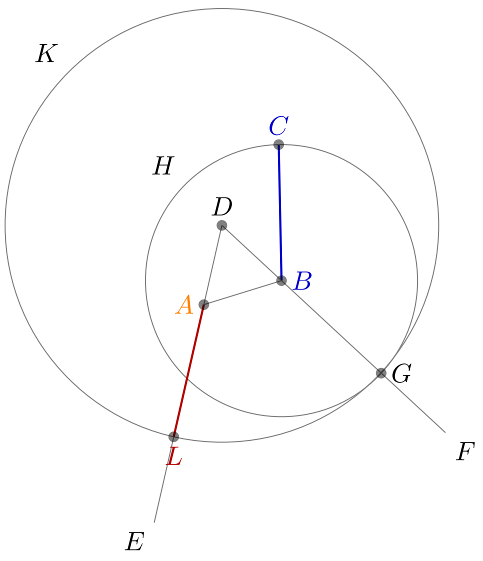
Proposition I
To construct an equilateral triangle on a given finite straight line.

Let AB be the given finite straight line. ...

```
\begin{tikzpicture}[thick,help lines/.style={thin,draw=black!50}]
  \def\A{\textcolor{input}{$A$}}     \def\B{\textcolor{input}{$B$}}
  \def\C{\textcolor{output}{$C$}}    \def\D{$D$}
  \def\E{$E$}

  \colorlet{input}{blue!80!black}    \colorlet{output}{red!70!black}
  \colorlet{triangle}{orange}

  \coordinate [label=left:\A]  (A) at ($ (0,0) + .1*(rand,rand) $);
  \coordinate [label=right:\B] (B) at ($ (1.25,0.25) + .1*(rand,rand) $);

  \draw [input] (A) -- (B);

  \node [name path=D,help lines,draw,label=left:\D]   (D) at (A) [circle through=(B)] {};
  \node [name path=E,help lines,draw,label=right:\E]  (E) at (B) [circle through=(A)] {};

  \path [name intersections={of=D and E,by={[label=above:\C]C}}];

  \draw [output] (A) -- (C) -- (B);

  \foreach \point in {A,B,C}
    \fill [black,opacity=.5] (\point) circle (2pt);

  \begin{pgfonlayer}{background}
    \fill[triangle!80] (A) -- (C) -- (B) -- cycle;
  \end{pgfonlayer}

  \node [below right, text width=10cm,align=justify] at (4,3) {
    \small\textbf{Proposition I}\par
    \emph{To construct an \textcolor{triangle}{equilateral triangle}
      on a given \textcolor{input}{finite straight line}.}
    \par\vskip1em
    Let \A\B\ be the given \textcolor{input}{finite straight line}.  \dots
  };
\end{tikzpicture}
```

1.2 Book I, Proposition II

The second proposition in the Elements is the following:



Proposition II
To place a straight line equal to a given straight line with one end at a given point.

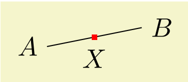
Let A be the given point, and BC the given straight line. It is required to place a straight line equal to the given straight line BC with one end at the point A.
Join the straight line AB from the point A to the point B, and construct the equilateral triangle DAB on it.
Produce the straight lines AE and BF in a straight line with DA and DB. Describe the circle CGH with center B and radius BC, and again, describe the circle GKL with center D and radius DG.
Since the point B is the center of the circle CGH, therefore BC equals BG. Again, since the point D is the center of the circle GKL, therefore DL equals DG. And in these DA equals DB, therefore the remainder AL equals the remainder BG. But BC was also proved equal to BG, therefore each of the straight lines AL and BC equals BG. And things which equal the same thing also equal one another, therefore AL also equals BC.
Therefore the straight line AL equal to the given straight line BC has been placed with one end at the given point A.

1.2.1 Using Partway Calculations for the Construction of D

Euclid's construction starts with "referencing" Proposition I for the construction of the point D. Now, while we could simply repeat the construction, it seems a bit bothersome that one has to draw all these circles and do all these complicated constructions.

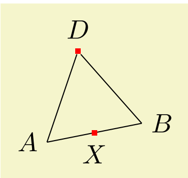
For this reason, Ti*k*Z supports some simplifications. First, there is a simple syntax for computing a point that is "partway" on a line from p to q: You place these two points in a coordinate calculation – remember, they start with `($` and end with `$)` – and then combine them using `!`⟨*part*⟩`!`. A ⟨*part*⟩ of `0` refers to the *first* coordinate, a ⟨*part*⟩ of `1` refers to the second coordinate, and a value in between refers to a point on the line from p to q. Thus, the syntax is similar to the `xcolor` syntax for mixing colors.

Here is the computation of the point in the middle of the line AB:



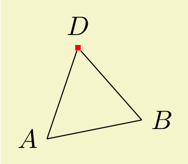

```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (1.25,0.25);
  \draw (A) -- (B);
  \node [fill=red,inner sep=1pt,label=below:$X$] (X) at ($ (A)!.5!(B) $) {};
\end{tikzpicture}
```

The computation of the point D in Euclid's second proposition is a bit more complicated. It can be expressed as follows: Consider the line from X to B. Suppose we rotate this line around X for 90° and then stretch it by a factor of $\sin(60°) \cdot 2$. This yields the desired point D. We can do the stretching using the partway modifier above, for the rotation we need a new modifier: the rotation modifier. The idea is that the second coordinate in a partway computation can be prefixed by an angle. Then the partway point is computed normally (as if no angle were given), but the resulting point is rotated by this angle around the first point.




```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (1.25,0.25);
  \draw (A) -- (B);
  \node [fill=red,inner sep=1pt,label=below:$X$] (X) at ($ (A)!.5!(B) $) {};
  \node [fill=red,inner sep=1pt,label=above:$D$] (D) at
    ($ (X) ! {sin(60)*2} ! 90:(B) $) {};
  \draw (A) -- (D) -- (B);
\end{tikzpicture}
```

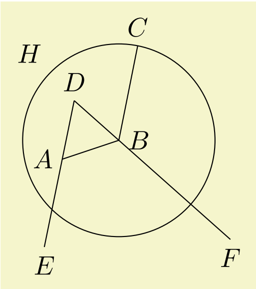
Finally, it is not necessary to explicitly name the point X. Rather, again like in the `xcolor` package, it is possible to chain partway modifiers:




```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (1.25,0.25);
  \draw (A) -- (B);
  \node [fill=red,inner sep=1pt,label=above:$D$] (D) at
    ($ (A) ! .5 ! (B) ! {sin(60)*2} ! 90:(B) $) {};
  \draw (A) -- (D) -- (B);
\end{tikzpicture}
```

1.2.2 Intersecting a Line and a Circle

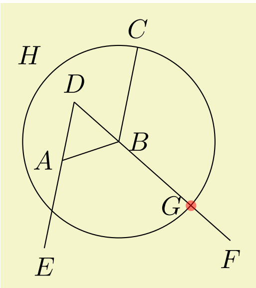
The next step in the construction is to draw a circle around B through C, which is easy enough to do using the `circle through` option. Extending the lines DA and DB can be done using partway calculations, but this time with a part value outside the range $[0, 1]$:




```
\begin{tikzpicture}
  \coordinate [label=left:$A$]  (A) at (0,0);
  \coordinate [label=right:$B$] (B) at (0.75,0.25);
  \coordinate [label=above:$C$] (C) at (1,1.5);
  \draw (A) -- (B) -- (C);
  \coordinate [label=above:$D$] (D) at
    ($ (A) ! .5 ! (B) ! {sin(60)*2} ! 90:(B) $) {};
  \node (H) [label=135:$H$,draw,circle through=(C)] at (B) {};
  \draw (D) -- ($ (D) ! 3.5 ! (B) $) coordinate [label=below:$F$] (F);
  \draw (D) -- ($ (D) ! 2.5 ! (A) $) coordinate [label=below:$E$] (E);
\end{tikzpicture}
```

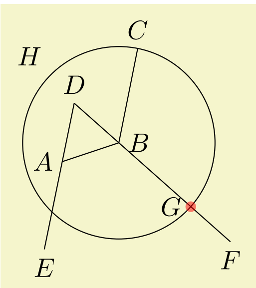
We now face the problem of finding the point G, which is the intersection of the line BF and the circle H. One way is to use yet another variant of the partway computation: Normally, a partway computation has the form $\langle p\rangle!\langle factor\rangle!\langle q\rangle$, resulting in the point $(1-\langle factor\rangle)\langle p\rangle+\langle factor\rangle\langle q\rangle$. Alternatively, instead of $\langle factor\rangle$ you can also use a $\langle dimension\rangle$ between the points. In this case, you get the point that is $\langle dimension\rangle$ away from $\langle p\rangle$ on the straight line to $\langle q\rangle$.

We know that the point G is on the way from B to F. The distance is given by the radius of the circle H. Here is the code for computing H:



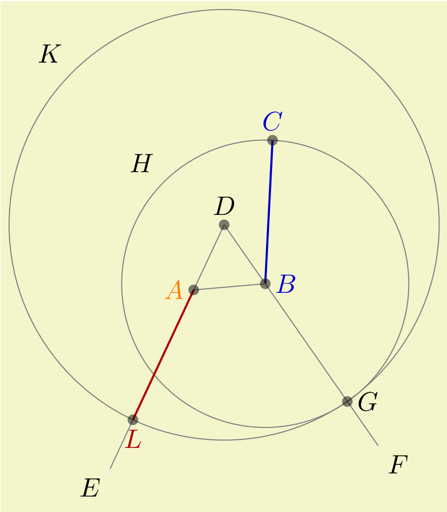

```
  \node (H) [label=135:$H$,draw,circle through=(C)] at (B) {};
  \path let \p1 = ($ (B) - (C) $) in
    coordinate [label=left:$G$] (G) at ($ (B) ! veclen(\x1,\y1) ! (F) $);
  \fill[red,opacity=.5] (G) circle (2pt);
```

However, there is a simpler way: We can simply name the path of the circle and of the line in question and then use `name intersections` to compute the intersections.




```
  \node (H) [name path=H,label=135:$H$,draw,circle through=(C)] at (B) {};
  \path [name path=B--F] (B) -- (F);
  \path [name intersections={of=H and B--F,by={[label=left:$G$]G}}];
  \fill[red,opacity=.5] (G) circle (2pt);
```

1.2.3 The Complete Code

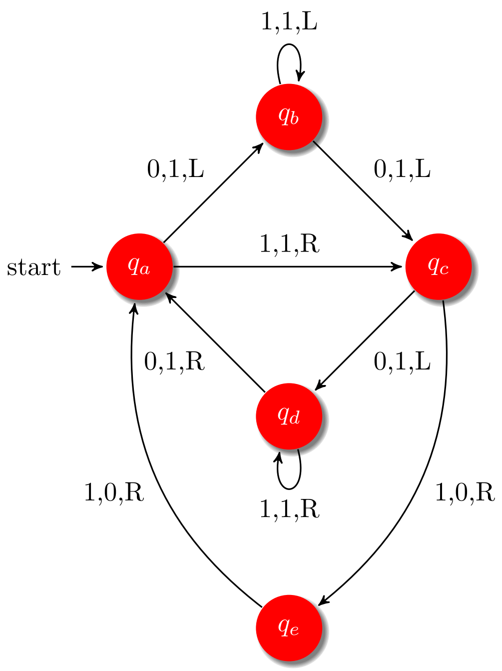



```
\begin{tikzpicture}[thick,help lines/.style={thin,draw=black!50}]
  \def\A{\textcolor{orange}{$A$}}   \def\B{\textcolor{input}{$B$}}
  \def\C{\textcolor{input}{$C$}}    \def\D{$D$}
  \def\E{$E$}                       \def\F{$F$}
  \def\G{$G$}                       \def\H{$H$}
  \def\K{$K$}                       \def\L{\textcolor{output}{$L$}}

  \colorlet{input}{blue!80!black}    \colorlet{output}{red!70!black}

  \coordinate [label=left:\A]  (A) at ($ (0,0) + .1*(rand,rand) $);
  \coordinate [label=right:\B] (B) at ($ (1,0.2) + .1*(rand,rand) $);
  \coordinate [label=above:\C] (C) at ($ (1,2) + .1*(rand,rand) $);

  \draw [input] (B) -- (C);
  \draw [help lines] (A) -- (B);

  \coordinate [label=above:\D] (D) at ($ (A)!.5!(B) ! {sin(60)*2} ! 90:(B) $);

  \draw [help lines] (D) -- ($ (D)!3.75!(A) $) coordinate [label=-135:\E] (E);
  \draw [help lines] (D) -- ($ (D)!3.75!(B) $) coordinate [label=-45:\F] (F);

  \node (H) at (B) [name path=H,help lines,circle through=(C),draw,label=135:\H] {};
  \path [name path=B--F] (B) -- (F);
  \path [name intersections={of=H and B--F,by={[label=right:\G]G}}];

  \node (K) at (D) [name path=K,help lines,circle through=(G),draw,label=135:\K] {};
  \path [name path=A--E] (A) -- (E);
  \path [name intersections={of=K and A--E,by={[label=below:\L]L}}];

  \draw [output] (A) -- (L);

  \foreach \point in {A,B,C,D,G,L}
    \fill [black,opacity=.5] (\point) circle (2pt);

  % \node ...
\end{tikzpicture}
```

Part II
安装和配置

by Till Tantau

这部分介绍如何安装该系统。通常已经有人帮你装好了，所以你可以跳过这部分；但是如果事与愿违，你是那个不得不自己安装的可怜的家伙，那么请阅读这一部分。



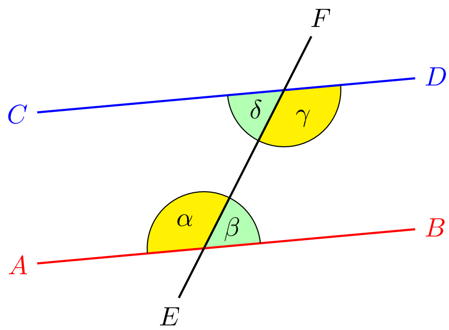
The current candidate for the busy beaver for five states. It is presumed that this Turing machine writes a maximum number of 1's before halting among all Turing machines with five states and the tape alphabet $\{0, 1\}$. Proving this conjecture is an open research problem. 中文测试

```
\begin{tikzpicture}[->,>=stealth',shorten >=1pt,auto,node distance=2.8cm,on grid,semithick,
                    every state/.style={fill=red,draw=none,circular drop shadow,text=white}]

  \node[initial,state] (A)                    {$q_a$};
  \node[state]         (B) [above right=of A] {$q_b$};
  \node[state]         (D) [below right=of A] {$q_d$};
  \node[state]         (C) [below right=of B] {$q_c$};
  \node[state]         (E) [below=of D]       {$q_e$};

  \path (A) edge              node {0,1,L} (B)
            edge              node {1,1,R} (C)
        (B) edge [loop above] node {1,1,L} (B)
            edge              node {0,1,L} (C)
        (C) edge              node {0,1,L} (D)
            edge [bend left]  node {1,0,R} (E)
        (D) edge [loop below] node {1,1,R} (D)
            edge              node {0,1,R} (A)
        (E) edge [bend left]  node {1,0,R} (A);

   \node [right=1cm,text width=8cm] at (C)
   {
     The current candidate for the busy beaver for five states. It is
     presumed that this Turing machine writes a maximum number of
     $1$'s before halting among all Turing machines with five states
     and the tape alphabet $\{0, 1\}$. Proving this conjecture is an
     open research problem. 中文测试
   };
\end{tikzpicture}
```

Part III

Ti*k*Z ist *kein* Zeichenprogramm

by Till Tantau



When we assume that AB and CD are parallel, i. e., $AB \mathbin{\|} CD$, then $\alpha = \delta$ and $\beta = \gamma$.

```
\begin{tikzpicture}[angle radius=.75cm]

  \node (A) at (-2,0)    [red,left]    {$A$};
  \node (B) at ( 3,.5)    [red,right]   {$B$};
  \node (C) at (-2,2)  [blue,left]   {$C$};
  \node (D) at ( 3,2.5)  [blue,right] {$D$};
  \node (E) at (60:-5mm) [below]      {$E$};
  \node (F) at (60:3.5cm)  [above]      {$F$};

  \coordinate (X) at (intersection cs:first line={(A)--(B)}, second line={(E)--(F)});
  \coordinate (Y) at (intersection cs:first line={(C)--(D)}, second line={(E)--(F)});

  \path
    (A) edge [red, thick]  (B)
    (C) edge [blue, thick] (D)
    (E) edge [thick]       (F)
      pic ["$\alpha$",  draw, fill=yellow]   {angle = F--X--A}
      pic ["$\beta$",   draw, fill=green!30] {angle = B--X--F}
      pic ["$\gamma$",  draw, fill=yellow]   {angle = E--Y--D}
      pic ["$\delta$",  draw, fill=green!30] {angle = C--Y--E};

  \node at ($ (D)!.5!(B) $) [right=1cm,text width=6cm,rounded corners,fill=red!20,inner sep=1ex]
    {
      When we assume that $\color{red}AB$ and $\color{blue}CD$ are
      parallel, i.\,e., ${\color{red}AB} \mathbin{\|} \color{blue}CD$,
      then $\alpha = \delta$ and $\beta = \gamma$.
    };
\end{tikzpicture}
```

Part IV
Graph Drawing

by Till Tantau et al.

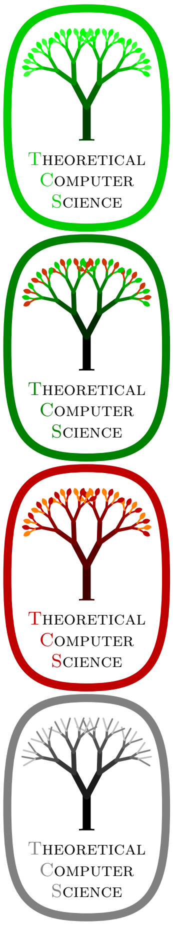
Graph drawing algorithms do the tough work of computing a layout of a graph for you. Ti*k*Z comes with powerful such algorithms, but you can also implement new algorithms in the Lua programming language.

You need to use LuaTeX to typeset this part of the manual (and, also, to use algorithmic graph drawing).

Part V
Libraries

by Till Tantau

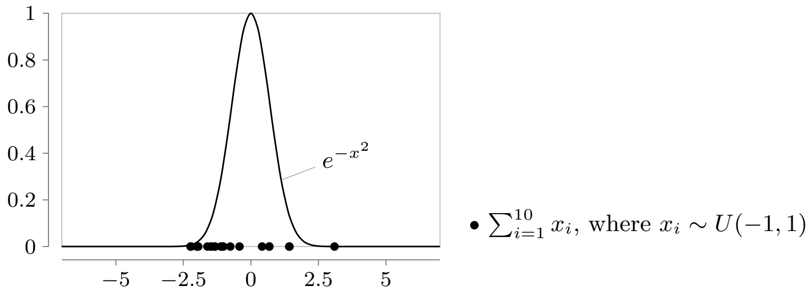
In this part the library packages are documented. They provide additional predefined graphic objects like new arrow heads or new plot marks, but sometimes also extensions of the basic PGF or Ti*k*Z system. The libraries are not loaded by default since many users will not need them.




```
\tikzset{
  ld/.style={level distance=#1},lw/.style={line width=#1},
  level 1/.style={ld=4.5mm, trunk,          lw=1ex ,sibling angle=60},
  level 2/.style={ld=3.5mm, trunk!80!leaf a,lw=.8ex,sibling angle=56},
  level 3/.style={ld=2.75mm,trunk!60!leaf a,lw=.6ex,sibling angle=52},
  level 4/.style={ld=2mm,   trunk!40!leaf a,lw=.4ex,sibling angle=48},
  level 5/.style={ld=1mm,   trunk!20!leaf a,lw=.3ex,sibling angle=44},
  level 6/.style={ld=1.75mm,leaf a,         lw=.2ex,sibling angle=40},
}
\pgfarrowsdeclare{leaf}{leaf}
  {\pgfarrowsleftextend{-2pt} \pgfarrowsrightextend{1pt}}
{
  \pgfpathmoveto{\pgfpoint{-2pt}{0pt}}
  \pgfpatharc{150}{30}{1.8pt}
  \pgfpatharc{-30}{-150}{1.8pt}
  \pgfusepathqfill
}

\newcommand{\logo}[5]
{
  \colorlet{border}{#1}
  \colorlet{trunk}{#2}
  \colorlet{leaf a}{#3}
  \colorlet{leaf b}{#4}
  \begin{tikzpicture}
    \scriptsize\scshape
    \draw[border,line width=1ex,yshift=.3cm,
          yscale=1.45,xscale=1.05,looseness=1.42]
      (1,0) to [out=90, in=0]    (0,1)  to [out=180,in=90]  (-1,0)
            to [out=-90,in=-180] (0,-1) to [out=0,  in=-90] (1,0) -- cycle;

    \coordinate (root) [grow cyclic,rotate=90]
    child {
      child [line cap=round] foreach \a in {0,1} {
        child foreach \b in {0,1} {
          child foreach \c in {0,1} {
            child foreach \d in {0,1} {
              child foreach \leafcolor in {leaf a,leaf b}
                { edge from parent [color=\leafcolor,-#5] }
        } } }
      } edge from parent [shorten >=-1pt,serif cm-,line cap=butt]
    };

    \node [align=center,below] at (0pt,-.5ex)
    { \textcolor{border}{T}heoretical \\ \textcolor{border}{C}omputer \\
      \textcolor{border}{S}cience };
  \end{tikzpicture}
}
\begin{minipage}{3cm}
  \logo{green!80!black}{green!25!black}{green}{green!80}{leaf}\\
  \logo{green!50!black}{black}{green!80!black}{red!80!green}{leaf}\\
  \logo{red!75!black}{red!25!black}{red!75!black}{orange}{leaf}\\
  \logo{black!50}{black}{black!50}{black!25}{}
\end{minipage}
```

Part VI
Data Visualization

by Till Tantau

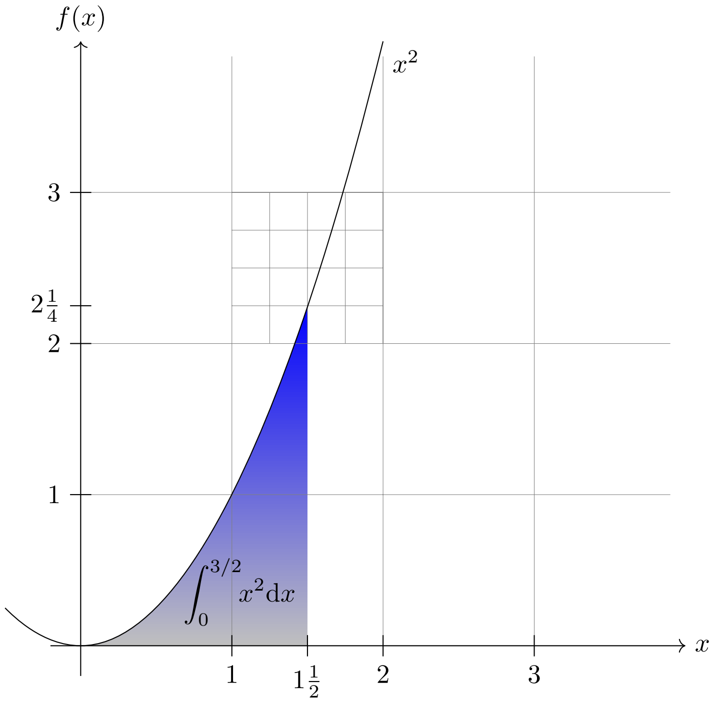



```
\tikz \datavisualization [scientific axes=clean]
[
  visualize as smooth line=Gaussian,
  Gaussian={pin in data={text={$e^{-x^2}$},when=x is 1}}
]
data [format=function] {
  var x : interval [-7:7] samples 51;
  func y = exp(-\value x*\value x);
}
[
  visualize as scatter,
  legend={south east outside},
  scatter={
    style={mark=*,mark size=1.4pt},
    label in legend={text={
        $\sum_{i=1}^{10} x_i$, where $x_i \sim U(-1,1) $}}}
]
data [format=function] {
  var i : interval [0:1] samples 20;
  func y = 0;
  func x = (rand + rand + rand + rand + rand +
            rand + rand + rand + rand + rand);
};
```

Part VII
Utilities

by Till Tantau

The utility packages are not directly involved in creating graphics, but you may find them useful nonetheless. All of them either directly depend on PGF or they are designed to work well together with PGF even though they can be used in a stand-alone way.




```
\begin{tikzpicture}[scale=2]
  \shade[top color=blue,bottom color=gray!50] (0,0) parabola (1.5,2.25) |- (0,0);
  \draw (1.05cm,2pt) node[above] {$\displaystyle\int_0^{3/2} \!\!x^2\mathrm{d}x$};

  \draw[help lines] (0,0) grid (3.9,3.9)
       [step=0.25cm]      (1,2) grid +(1,1);

  \draw[->] (-0.2,0) -- (4,0) node[right] {$x$};
  \draw[->] (0,-0.2) -- (0,4) node[above] {$f(x)$};

  \foreach \x/\xtext in {1/1, 1.5/1\frac{1}{2}, 2/2, 3/3}
    \draw[shift={(\x,0)}] (0pt,2pt) -- (0pt,-2pt) node[below] {$\xtext$};

  \foreach \y/\ytext in {1/1, 2/2, 2.25/2\frac{1}{4}, 3/3}
    \draw[shift={(0,\y)}] (2pt,0pt) -- (-2pt,0pt) node[left] {$\ytext$};

  \draw (-.5,.25) parabola bend (0,0) (2,4) node[below right] {$x^2$};
\end{tikzpicture}
```

Part VIII

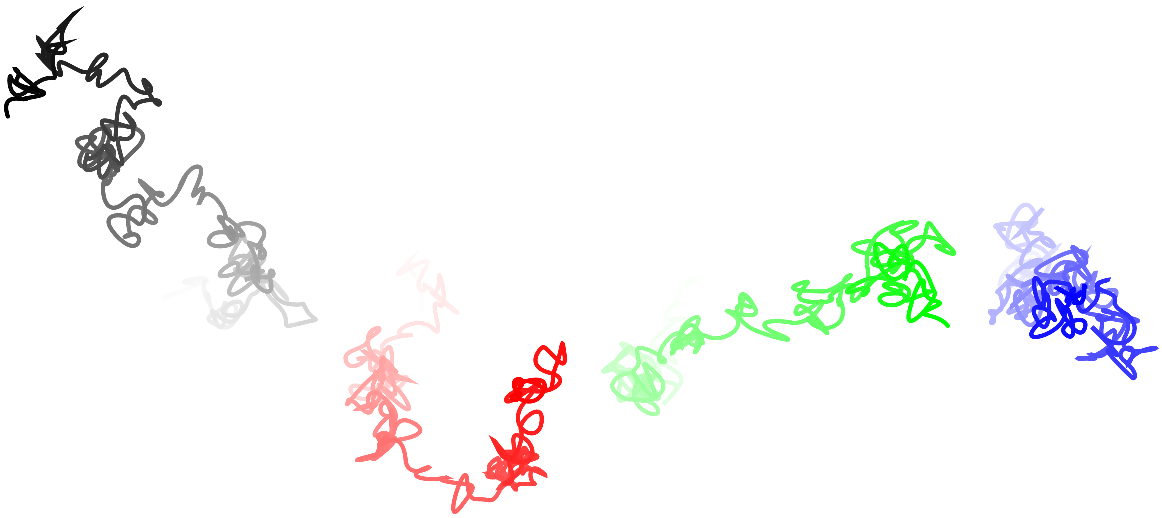
Mathematical and Object-Oriented Engines

by Mark Wibrow and Till Tantau

PGF comes with two useful engines: One for doing mathematics, one for doing object-oriented programming. Both engines can be used independently of the main PGF.

The job of the mathematical engine is to support mathematical operations like addition, subtraction, multiplication and division, using both integers and non-integers, but also functions such as square-roots, sine, cosine, and generate pseudo-random numbers. Mostly, you will use the mathematical facilities of PGF indirectly, namely when you write a coordinate like `(5cm*3,6cm/4)`, but the mathematical engine can also be used independently of PGF and Ti*k*Z.

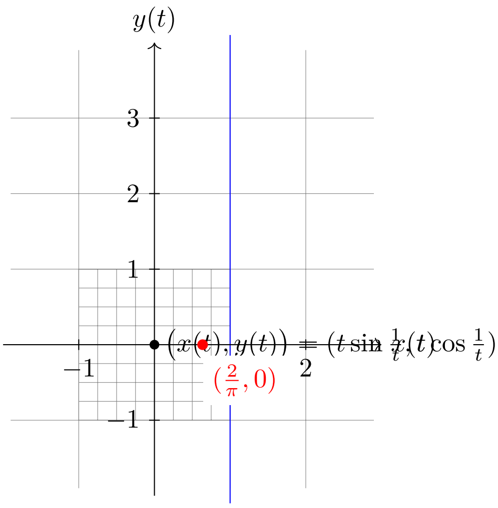
The job of the object-oriented engine is to support simple object-oriented programming in TEX. It allows the definition of *classes* (without inheritance), *methods*, *attributes* and *objects*.



```
\pgfmathsetseed{1}
\foreach \col in {black,red,green,blue}
{
  \begin{tikzpicture}[x=10pt,y=10pt,ultra thick,baseline,line cap=round]
    \coordinate (current point) at (0,0);
    \coordinate (old velocity) at (0,0);
    \coordinate (new velocity) at (rand,rand);

    \foreach \i in {0,1,...,100}
    {
      \draw[\col!\i] (current point)
      .. controls ++([scale=-1]old velocity) and
                 ++(new velocity) .. ++(rand,rand)
         coordinate (current point);
      \coordinate (old velocity) at (new velocity);
      \coordinate (new velocity) at (rand,rand);
    }
  \end{tikzpicture}
}
```

Part IX
The Basic Layer

by Till Tantau




```
\begin{tikzpicture}
  \draw[gray,very thin] (-1.9,-1.9) grid (2.9,3.9)
          [step=0.25cm] (-1,-1) grid (1,1);
  \draw[blue] (1,-2.1) -- (1,4.1); % asymptote

  \draw[->] (-2,0) -- (3,0) node[right] {$x(t)$};
  \draw[->] (0,-2) -- (0,4) node[above] {$y(t)$};

  \foreach \pos in {-1,2}
    \draw[shift={(\pos,0)}] (0pt,2pt) -- (0pt,-2pt) node[below] {$\pos$};

  \foreach \pos in {-1,1,2,3}
    \draw[shift={(0,\pos)}] (2pt,0pt) -- (-2pt,0pt) node[left] {$\pos$};

  \fill (0,0) circle (0.064cm);
  \draw[thick,parametric,domain=0.4:1.5,samples=200]
    % The plot is reparameterised such that there are more samples
    % near the center.
    plot[id=asymptotic-example] function{(t*t*t)*sin(1/(t*t*t)),(t*t*t)*cos(1/(t*t*t))}
    node[right] {$\bigl(x(t),y(t)\bigr) = (t\sin \frac{1}{t}, t\cos \frac{1}{t})$};

  \fill[red] (0.63662,0) circle (2pt)
    node [below right,fill=white,yshift=-4pt] {$(\frac{2}{\pi},0)$};
\end{tikzpicture}
```

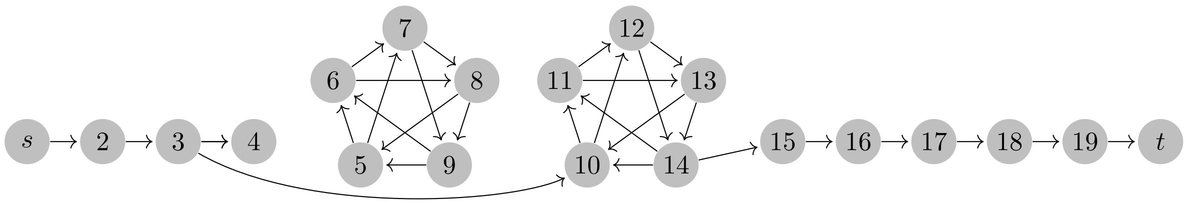
Part X
The System Layer

by Till Tantau

This part describes the low-level interface of PGF, called the *system layer*. This interface provides a complete abstraction of the internals of the underlying drivers.

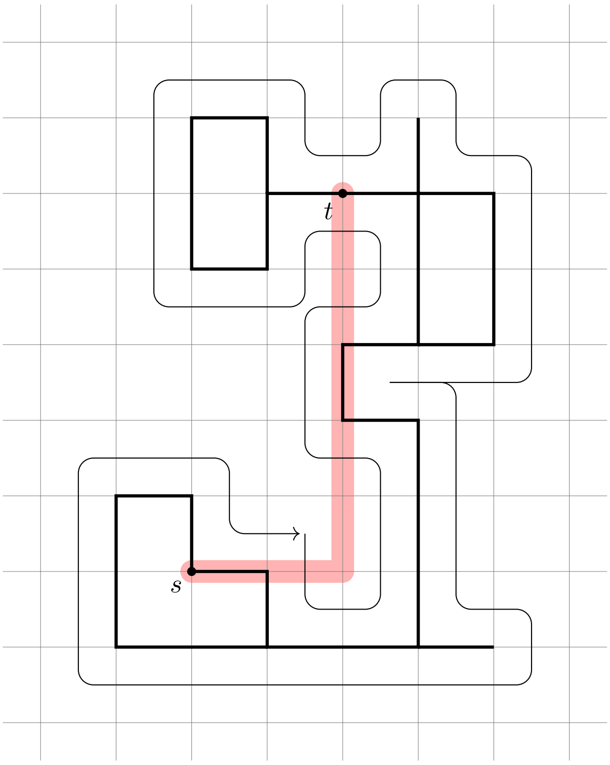
Unless you intend to port PGF to another driver or unless you intend to write your own optimized frontend, you need not read this part.

In the following it is assumed that you are familiar with the basic workings of the `graphics` package and that you know what TeX-drivers are and how they work.




```
\begin{tikzpicture}
  [shorten >=1pt,->,
   vertex/.style={circle,fill=black!25,minimum size=17pt,inner sep=0pt}]

  \foreach \name/\x in {s/1, 2/2, 3/3, 4/4, 15/11, 16/12, 17/13, 18/14, 19/15, t/16}
    \node[vertex] (G-\name) at (\x,0) {$\name$};

  \foreach \name/\angle/\text in {P-1/234/5, P-2/162/6, P-3/90/7, P-4/18/8, P-5/-54/9}
    \node[vertex,xshift=6cm,yshift=.5cm] (\name) at (\angle:1cm) {$\text$};

  \foreach \name/\angle/\text in {Q-1/234/10, Q-2/162/11, Q-3/90/12, Q-4/18/13, Q-5/-54/14}
    \node[vertex,xshift=9cm,yshift=.5cm] (\name) at (\angle:1cm) {$\text$};

  \foreach \from/\to in {s/2,2/3,3/4,3/4,15/16,16/17,17/18,18/19,19/t}
    \draw (G-\from) -- (G-\to);

  \foreach \from/\to in {1/2,2/3,3/4,4/5,5/1,1/3,2/4,3/5,4/1,5/2}
    { \draw (P-\from) -- (P-\to); \draw (Q-\from) -- (Q-\to); }

  \draw (G-3) .. controls +(-30:2cm) and +(-150:1cm) .. (Q-1);
  \draw (Q-5) -- (G-15);
\end{tikzpicture}
```

Part XI
References and Index




```
\begin{tikzpicture}
  \draw[line width=0.3cm,color=red!30,line cap=round,line join=round] (0,0)--(2,0)--(2,5);
  \draw[help lines] (-2.5,-2.5) grid (5.5,7.5);
  \draw[very thick] (1,-1)--(-1,-1)--(-1,1)--(0,1)--(0,0)--
    (1,0)--(1,-1)--(3,-1)--(3,2)--(2,2)--(2,3)--(3,3)--
    (3,5)--(1,5)--(1,4)--(0,4)--(0,6)--(1,6)--(1,5)
    (3,3)--(4,3)--(4,5)--(3,5)--(3,6)
    (3,-1)--(4,-1);
  \draw[below left] (0,0) node(s){$s$};
  \draw[below left] (2,5) node(t){$t$};
  \fill (0,0) circle (0.06cm) (2,5) circle (0.06cm);
  \draw[->,rounded corners=0.2cm,shorten >=2pt]
    (1.5,0.5)-- ++(0,-1)-- ++(1,0)-- ++(0,2)-- ++(-1,0)-- ++(0,2)-- ++(1,0)--
    ++(0,1)-- ++(-1,0)-- ++(0,-1)-- ++(-2,0)-- ++(0,3)-- ++(2,0)-- ++(0,-1)--
    ++(1,0)-- ++(0,1)-- ++(1,0)-- ++(0,-1)-- ++(1,0)-- ++(0,-3)-- ++(-2,0)--
    ++(1,0)-- ++(0,-3)-- ++(1,0)-- ++(0,-1)-- ++(-6,0)-- ++(0,3)-- ++(2,0)--
    ++(0,-1)-- ++(1,0);
\end{tikzpicture}
```