

그림과 함수 플로팅

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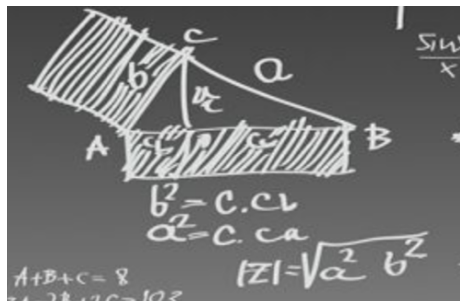
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1 Introduction to graphics in L^AT_EX

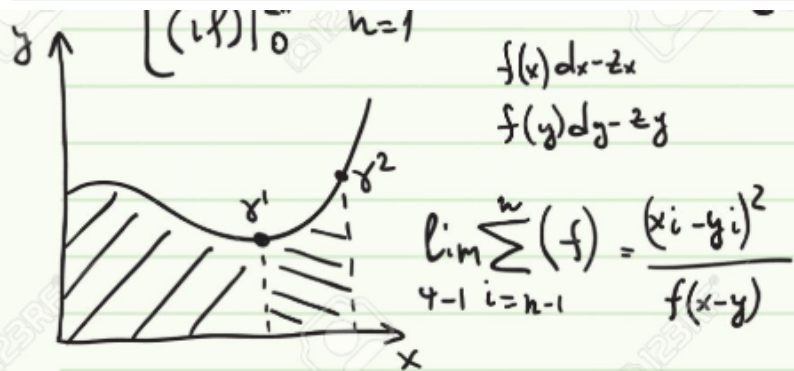
```
\usepackage{graphicx}  
\includegraphics[width=...]{filename}  
  
\usepackage{pstricks}  
  
\usepackage{tikz}
```

1.1 \includegraphics

```
\includegraphics[width=.4\linewidth]{handdrawn1}
```



\includegraphics [width=.7\linewidth] {handdrawn1}



$$\int_{|z-a|=R} \frac{dz}{(z-a)^n} = \int_0^{2\pi} \frac{R^i e^{i\phi}}{R^n e^{in\phi}} d\phi = R^{1-n} \int_0^{2\pi} \dots$$

1.2 pstricks vs. tikz

```
%% \usepackage{pstricks} % dvi -> ps -> pdf
\psline(-1,0)(1,0)
\pscircle(0,0){2pt}
```

first try of drawing

first try of drawing

~~first try of drawing~~

first\pscircle(0,0){2pt} of drawing

~~first try of drawing~~

first\tikz{\draw (0,0) circle (2pt);} of drawing

~~first try of drawing~~

first\tikz[baseline]{\draw (0,0) circle (2pt);} of drawing

~~first try of drawing~~

first\tikz[overlay]{\draw (0,0) circle (2pt);} of drawing

```
%%\usepackage{tikz}
```

```
\tikz { \draw (0,0) circle (2pt) ; }
```

```
\tikz[overaly]{ \draw (0,0) circle (2pt) ; }
```

```
\begin{tikzpicture}[overlay] < tikz codes > \end{tikzpicture}
```


1.3 environments: pspicture vs. tikzpicture

pspicture

```
모든 날이\psframe(0,0)(1,.5)
        \psline(0,0)(1,0)\ 좋았다.
```

너와 함께한 시간 모두 눈부셨다. 날이
좋아서 날이 ~~좋지~~ 않아서 날이 적당해서
모든 날이 ~~좋았다~~.

```
모든 날이\begin{pspicture}(0,0)(1,.5)
        \psline(0,0)(1,0)
        \end{pspicture} 좋았다.
```

너와 함께한 시간 모두 눈부셨다. 날이
좋아서 날이 ~~좋지~~ 않아서 날이 적당해서
모든 날이  좋았다.

tikz

```
모든 날이\begin{tikzpicture}
        \draw (0,0) rectangle (1,.5);
        \draw (0,0) -- (1,1);
        \end{tikzpicture} 좋았다.
```

너와 함께한 시간 모두 눈부셨다. 날이
좋아서 날이 ~~좋지~~ 않아서 날이 적당해서


모든 날이  좋았다.

```
모든 날이\begin{tikzpicture}[overlay]
        ...
        \end{tikzpicture} 좋았다.
```

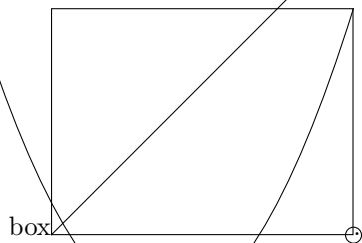
너와 함께한 시간 모두 눈부셨다. 날이
좋아서 날이 ~~좋지~~ 않아서 날이 적당해서
모든 날이 ~~좋았다~~.

\useasboundingbox

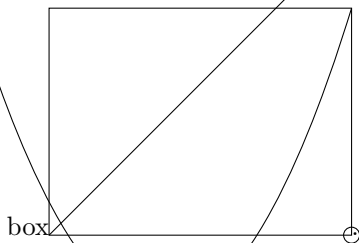
```
모든 날이\begin{tikzpicture}
        \useasboundingbox (0,0) rectangle (1,.5);
        ...
        \end{tikzpicture} 좋았다.
```

너와 함께한 시간 모두 눈부셨다. 날이
좋아서 날이 ~~좋지~~ 않아서 날이 적당해서
모든 날이  좋았다.

1.4 `\useasboundingbox` (not for beginners)



```
%% pstricks codes
box\begin{pspicture}(4,3)
\psset{linewidth=.4pt}
\psframe(4,3)
\psline(0,0)(5,5)
\parabola(-1,3)(1.5,-1)
\pscicle(4,0){3pt}
\end{pspicture}.
```



```
%% tikz codes
box\begin{tikzpicture}
\useasboundingbox (0,0) rectangle (4,3);
\draw (0,0) rectangle (4,3);
\draw (0,0) -- (5,5);
\draw (-1,3) parabola bend (1.5,-1) (4,3);
\draw (4,0) circle (3pt);
\end{tikzpicture}.
```

Remark: `\useasboundingbox` is an abbreviation of `\path[use as bounding box]`.

TikZ from now on

1.5 `\tikz` and `tikzpicture` environment

```
%% package load
\usepackage{tikz}

%% command
\tikz[<option>]{<tikz codes>}

%% environment
\begin{tikzpicture}[<option>]
  <tikz codes>
\end{tikzpicture}
```

Do not forget ; at the end of every path.

2 Path, stroke and fill

```
\path (0,0) -- (0,1) -- (1,1) -- (1,0) -- (0,0);
```

```
\path [draw] (0,0) -- (0,1) -- (1,1) -- (1,0) -- (0,0);
```

```
\path [fill] (0,0) -- (0,1) -- (1,1) -- (1,0) -- (0,0);
```

2.1 path and draw

`\path`: a sequence of straight lines and curves connected

`\path`

```
\begin{tikzpicture}
% \path [use as bounding box] (0,0) rectangle (1,1);
\path (0,0) -- (0,1) -- (1,1) -- (1,0) -- (0,0);
\end{tikzpicture}
```

`\path[draw]`

```
\begin{tikzpicture}
\path [draw] (0,0) -- (0,1) -- (1,1) -- (1,0) -- (0,0);
\end{tikzpicture}
```



`\draw`

```
%% cycle
\begin{tikzpicture}
\draw (0,0) -- (0,1) -- (1,1) -- (1,0) -- cycle;
\end{tikzpicture}
```



2.2 path and fill

`\path[fill]`

```
\begin{tikzpicture}
\path [fill] (0,0) -- (0,1) -- (1,1) -- (1,.5);
\end{tikzpicture}
```



`\path[fill=<color>]`

```
\begin{tikzpicture}
\path [fill=green] (0,0) -- (0,1) -- (1,1) -- (1,.5);
\end{tikzpicture}
```



`\path[draw,fill=<color>]`

```
\begin{tikzpicture}
\path [draw,fill=green] (0,0) -- (0,1) -- (1,1) -- (1,.5);
\end{tikzpicture}
```



`\path[draw=<color>,fill=<color>]`

```
\begin{tikzpicture}
\path [draw=blue,fill=green] (0,0) -- (0,1) -- (1,1) -- (1,.5);
\end{tikzpicture}
```



2.3 abbreviations: `\fill`, `\filldraw`

`\fill = \path[fill]`

```
\begin{tikzpicture}
\fill [green] (0,0) -- (0,1) -- (1,1) -- (1,.5);
\end{tikzpicture}
```



`\fill[draw]`

```
\begin{tikzpicture}
\fill [draw,green] (0,0) -- (0,1) -- (1,1) -- (1,.5);
\end{tikzpicture}
```



`\filldraw = \fill[draw] = \path[fill,draw]`

```
\begin{tikzpicture}
\filldraw [green] (0,0) -- (0,1) -- (1,1) -- (1,.5);
\end{tikzpicture}
```



`\filldraw`

```
\begin{tikzpicture}
\filldraw [blue,fill=green] (0,0) -- (0,1) -- (1,1) -- (1,.5);
\end{tikzpicture}
```

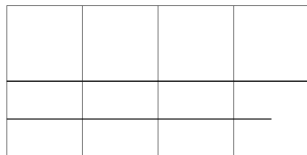









3 Lines

```
\draw (0,0) -- (4,0);
```

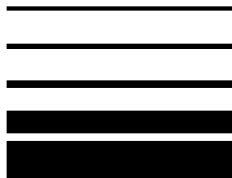
3.1 lines and line width

```
\begin{tikzpicture}
\draw [help lines] (0,-1) grid (4,1);
\draw (0,0) -- (4,0);
\draw [thin] (0,-.5) -- (3.5,-.5);
\end{tikzpicture}
```



ultra thin		0.1pt
very thin		0.2pt
thin		0.4pt (default)
semithick		0.6pt
thick		0.8pt
very thick		1.2pt
ultra thick		1.6pt

```
\begin{tikzpicture}
\draw [ultra thick] (0,0) -- (3,0);
\draw [line width=2pt] (0,-.5) -- (3,-.5);
\draw [line width=1mm] (0,-1) -- (3,-1);
\draw [line width=3mm] (0,-1.5) -- (3,-1.5);
\draw [line width=5mm] (0,-2) -- (3,-2);
\end{tikzpicture}
```








3.2 line styles

```

\begin{tikzpicture}
\draw [solid] (0,0) -- (3,0);
\draw [dotted] (0,-.5) -- (3,-.5);
\draw [dashed] (0,-1) -- (3,-1);
\draw [dash dot] (0,-1.5) -- (3,-1.5);
\draw [dash dot dot] (0,-2) -- (3,-2);
\end{tikzpicture}




```

 solid (default)
 dotted
 dashed
 dash dot
 dash dot dot

```

% densely, loosely
\begin{tikzpicture}[line width=.8pt]
\draw [densely dashed] (0,.5) -- (3,.5);
\draw [dashed] (0,0) -- (3,0);
\draw [loosely dashed] (0,-.5) -- (3,-.5);
\end{tikzpicture}




```

 densely dashed
 dashed
 loosely dashed

```

% densely, loosely
\begin{tikzpicture}[line width=.8pt]
\draw [densely dotted] (0,.5) -- (3,.5);
\draw [dotted] (0,0) -- (3,0);
\draw [loosely dotted] (0,-.5) -- (3,-.5);
\end{tikzpicture}

```

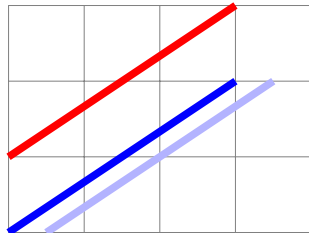
 densely dotted
 dotted
 loosely dotted

3.3 colors and shifts (xshift, yshift, shift)

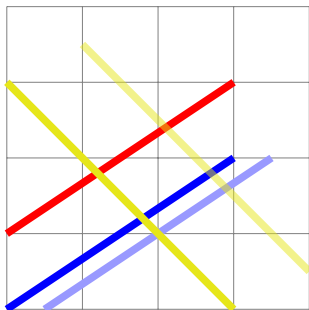
```
\begin{tikzpicture}
\draw [blue] (0,0) -- (4,0);
\draw [red,yshift=-5mm] (0,0) -- (4,0);
\end{tikzpicture}
```



```
\begin{tikzpicture}[line width=1mm]
\draw [help lines] (0,0) grid (4,3);
\draw [blue] (0,0) -- (3,2);
\draw [red,yshift=10mm] (0,0) -- (3,2);
\draw [blue!30,xshift=.5cm] (0,0) -- (3,2);
\end{tikzpicture}
```

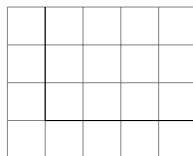


```
%% shift, opacity
\begin{tikzpicture}[line width=1mm]
\draw [help lines] (0,0) grid (4,4);
\draw [blue] (0,0) -- (3,2);
\draw [red,yshift=10mm] (0,0) -- (3,2);
\draw [blue!40,xshift=.5cm] (0,0) -- (3,2);
\draw [blue!10!yellow] (0,3) -- (3,0);
\draw [blue!10!yellow,shift={(1,.5)},opacity=.5]
(0,3) -- (3,0);
\end{tikzpicture}
```



3.4 axes

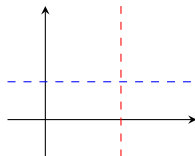
```
\begin{tikzpicture}[scale=.5]
\draw [help lines] (-1,-1) grid (4,3);
\draw (0,3) -- (0,0) -- (4,0);
\end{tikzpicture}
```



```
%% arrows
\begin{tikzpicture}[scale=.5]
%\draw [help lines] (-1,-1) grid (4,3);
\draw [->] (-1,0) -- (4,0);
\draw [->] (0,-1) -- (0,3);
\end{tikzpicture}
```



```
%% >=stealth/latex
\begin{tikzpicture}[scale=.5,>=stealth]
%\draw [help lines] (-1,-1) grid (4,3);
\draw [->] (-1,0) -- (4,0);
\draw [->] (0,-1) -- (0,3);
\draw [dashed,blue,yshift=1cm] (-1,0) -- (4,0);
\draw [dashed,red,xshift=20mm] (0,-1) -- (0,3);
\end{tikzpicture}
```



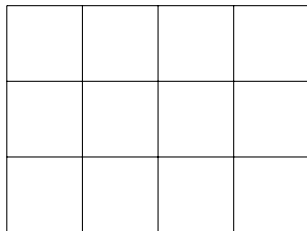
4 Grids and help lines

```
\draw (0,0) grid (4,3);
```

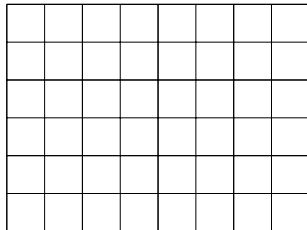
```
\draw [help lines] (0,0) grid (4,3);
```

4.1 grids

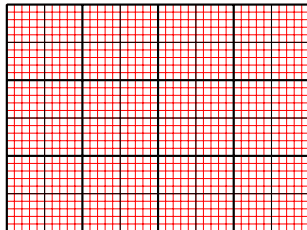
```
\begin{tikzpicture}  
\draw (0,0) grid (4,3);  
\end{tikzpicture}
```



```
\begin{tikzpicture}  
\draw [step=.5cm,very thin] (0,0) grid (4,3);  
\draw (0,0) grid (4,3);  
\end{tikzpicture}
```

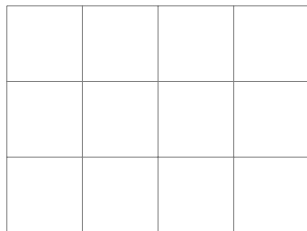


```
\begin{tikzpicture}  
\draw [step=1mm,red,ultra thin] (0,0) grid (4,3);  
\draw [step=.5cm] (0,0) grid (4,3);  
\draw [thick] (0,0) grid (4,3);  
\end{tikzpicture}
```



4.2 help lines

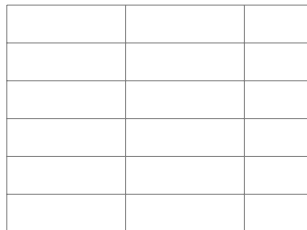
```
\begin{tikzpicture}  
\draw [help lines] (0,0) grid (4,3);  
\end{tikzpicture}
```



```
\begin{tikzpicture}  
\draw [help lines,step=5mm,densely dotted,blue]  
      (0,0) grid (4,3);  
\end{tikzpicture}
```



```
\begin{tikzpicture}  
\draw [help lines,xstep=.5*pi,ystep=5mm]  
      (0,0) grid (4,3);  
\end{tikzpicture}
```



5 Dots and circles

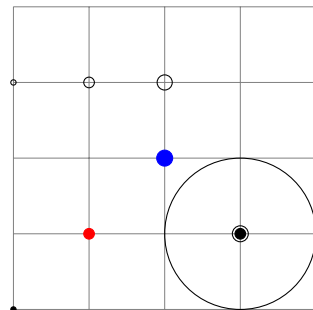
```
\draw (0,0) circle (2pt);
```

```
\draw (0,0) node [draw,circle] {};
```

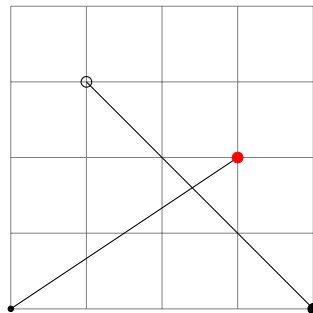
```
\draw (0,0) node [draw,circle,inner sep=0pt,minimum size=4pt] {};
```

5.1 dots and circles

```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,4);
\draw (0,3) circle (1pt);
\draw (1,3) circle (2pt);
\draw (2,3) circle (1mm);
\filldraw (0,0) circle (1pt);
\filldraw [red] (1,1) circle (2pt);
\filldraw [blue] (2,2) circle (3pt);
\filldraw (3,1) circle (2pt);
\draw (3,1) circle (3pt);
\draw (3,1) circle (1cm);
\end{tikzpicture}
```

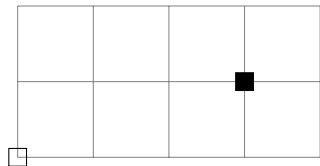


```
\begin{tikzpicture}
\filldraw [help lines] (0,0) grid (4,4);
\draw (0,0) -- (3,2);
\filldraw (0,0) circle (1pt);
\filldraw [red] (3,2) circle (2pt);
\draw (1,3) -- (4,0);
\draw (1,3) circle (2pt);
\filldraw (4,0) circle (2pt);
\end{tikzpicture}
```

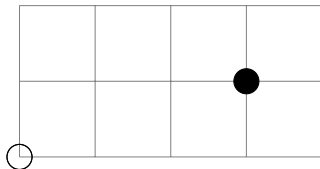


5.2 node dots

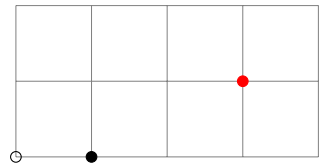
```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,2);
\draw (0,0) node [draw] {};
\draw (3,1) node [draw,fill] {};
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,2);
\draw (0,0) node [draw,circle] {};
\draw (3,1) node [draw,fill,circle] {};
\draw (0,0) node [draw,circle,minimum size=4pt] {};
\end{tikzpicture}
```



```
%%\tikzset{my node dot/.style=
%% {draw,circle,minimum size=4pt,inner sep=0pt}}
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,2);
\draw (0,0) node [my node dot] {};
\draw (1,0) node [my node dot,fill] {};
\draw (3,1) node [my node dot,fill,red] {};
\end{tikzpicture}
```



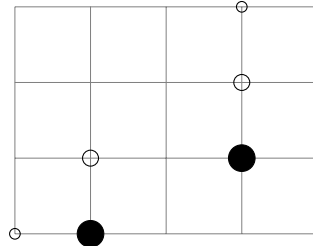
5.3 making your life easier

Using my own styles

```
\tikzset{my style/.style={my options}}
```

Using my own macros

```
%% predefined macros:  
%% \mydot,\mydotfill,\mynodedot,\mynodedotfill  
\begin{tikzpicture}  
\draw[help lines] (0,0) grid (4,3);  
\mydot(0,0);  
\mydot(1,1)(3pt);  
\mydotfill(1,0)(5pt);  
\mynodedot(3,3);  
\mynodedot(3,2)(3pt);  
\mynodedotfill(3,1)(5pt);  
\end{tikzpicture}
```



Defining my own macros

```
%% \usepackage{xparse}
\NewDocumentCommand\mydot{ r() D(){2pt} }
{ \draw (#1) circle (#2)
}

\NewDocumentCommand\mydotfill{ r() D(){2pt} }
{ \draw [fill] (#1) circle (#2)
}

\NewDocumentCommand\mynodedot{ r() D(){2pt} }
{ \draw (#1)
  node [draw,circle,inner sep=0pt,minimum size=2*#2] {}
}

\NewDocumentCommand\mynodedotfill{ r() D(){2pt} }
{ \draw (#1)
  node [draw,circle,inner sep=0pt,black,fill=black,
  minimum size=2*#2] {}
}
```

6 Adding texts and labelling

```
\draw (0,0) node [right] {Hello!};
```

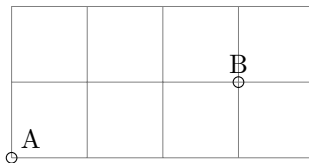
```
\node at (0,0) [right] {Hello!};
```

6.1 node

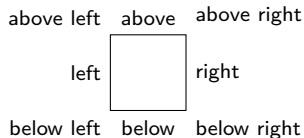
```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,2);
\draw (0,0) node [right] {Hello!};
\node at (1,1) { 킷! };
\draw (3,2) node [draw] { 삐짐! };
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,2);
\draw (0,0) circle (2pt);
\draw (0,0) node [above right] {A};
\draw (3,1) circle (2pt) node [above] {B};
\end{tikzpicture}
```

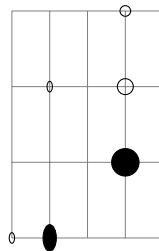


```
\begin{tikzpicture}[font={\sffamily\footnotesize}]
\draw (0,0) rectangle (1,1);
\draw (0,0) node [below left] {below left};
\draw (1,1) node [above right] {above right};
\draw (1,.5) node [right] {right};
<...codes...>
\end{tikzpicture}
```



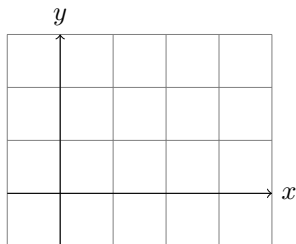
6.2 dots vs. node dots

```
%%\usepackage{tikz}
%%\tikzset{my node dot/.style=
%% {draw,circle,minimum size=4pt,inner sep=0pt}}
\begin{tikzpicture}[xscale=.5]
\draw[help lines] (0,0) grid (4,3);
\draw (0,0) circle (2pt);
\draw (1,2) circle (2pt);
\filldraw (1,0) circle (5pt);
\draw (3,3) node
[my node dot,minimum size=2*2pt] {};
\draw (3,2) node
[my node dot,minimum size=2*3pt] {};
\draw (3,1) node
[my node dot,minimum size=2*5pt,fill] {A};
\end{tikzpicture}
```

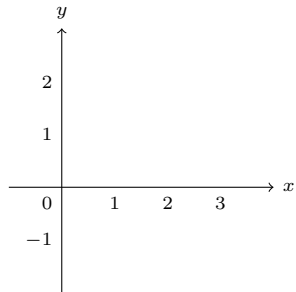


6.3 axes with labels

```
%% arrows
\begin{tikzpicture}[scale=.7]
\draw [help lines] (-1,-1) grid (4,3);
\draw [->] (-1,0) -- (4,0) node [right] {$x$};
\draw [->] (0,-1) -- (0,3) node [above] {$y$};
\end{tikzpicture}
```



```
%% arrows
\begin{tikzpicture}[scale=.7,font=\scriptsize]
%\draw [help lines] (-1,-3) grid (4,3);
\draw [->] (-1,0) -- (4,0) node [right] {$x$};
\draw [->] (0,-2) -- (0,3) node [above] {$y$};
\draw (0,0) node [below left] {0};
\draw (1,0) node [below] {1};
\draw (2,0) node [below] {2};
\draw (3,0) node [below] {3};
\draw (0,1) node [left] {1};
\draw (0,2) node [left] {2};
\draw (0,-1) node [left] {$-1$};
\end{tikzpicture}
```

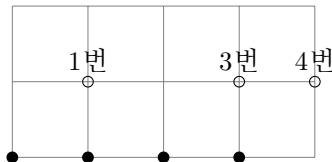


7 Repeating: `\foreach`

```
\foreach \myx in {1,2,3}
{
  \filldraw (\myx,0) circle (2pt);
}
```


7.1 \foreach

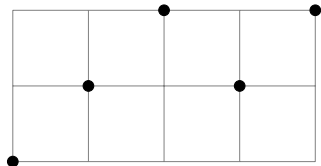
```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,2);
\foreach \x in {0,1,3,2}
  \filldraw (\x,0) circle (2pt);
\foreach \x in {1,3,4}
  \draw (\x,1) circle (2pt) node [above] {\x 번};
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw [help lines,shift={(.5,.5)}]
(0,0) grid (4,3);
\foreach \x in {1,2,3,4}
  \foreach \y in {1,2,3}
    \draw (\x,\y) node {\x,\y};
\end{tikzpicture}
```

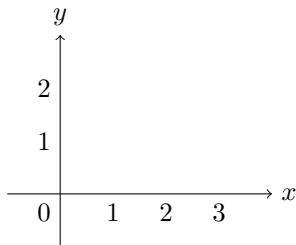
1,3	2,3	3,3	4,3
1,2	2,2	3,2	4,2
1,1	2,1	3,1	4,1

```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,2);
\foreach \x in {(0,0),(1,1),(2,2),(3,1),(4,2)}
  \filldraw \x circle (2pt);
\end{tikzpicture}
```

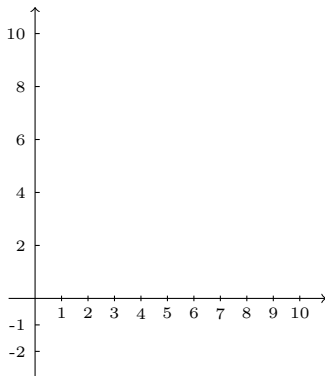


7.2 \foreach: axes

```
\begin{tikzpicture}[scale=.7]
\draw [->] (-1,0) -- (4,0) node [right] {$x$};
\draw [->] (0,-1) -- (0,3) node [above] {$y$};
\draw (0,0) node [below left] {0};
\foreach \x in {1,2,3}
  \draw (\x,0) node [below] {\x};
\foreach \x in {1,2}
  \draw (0,\x) node [left] {\x};
\end{tikzpicture}
```



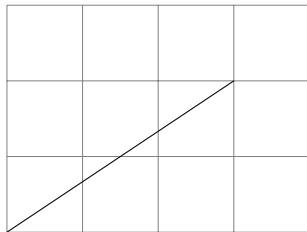
```
\begin{tikzpicture}[scale=.35,font=\tiny]
\draw [->] (-1,0) -- (11,0);
\draw [->] (0,-3) -- (0,11);
\foreach \x in {1,2,...,10}
  { \draw (\x,0) node [below] {\x};
    \draw (\x,-3pt) -- (\x,3pt);
  }
\foreach \x in {-2,-1,2,4,...,10}
  { \draw (0,\x) node [left] {\x};
    \draw (0,\x) -- (5pt,\x);
  }
\end{tikzpicture}
```



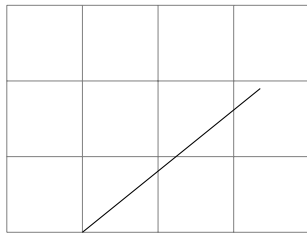
8 Coordinates: basics

8.1 Cartesian coordinates

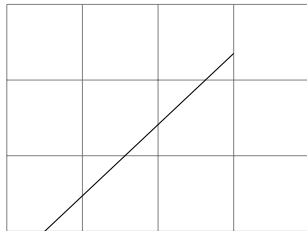
```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,3);
\coordinate (A) at (0,0);
\coordinate (B) at (3,2);
\draw (A) -- (B);
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,3);
\coordinate (A) at (-1+2,0);
\coordinate (B) at (3cm+10pt,2cm-1mm);
\draw (A) -- (B);
\end{tikzpicture}
```

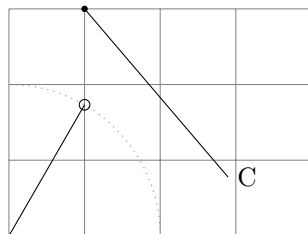


```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,3);
\coordinate (A) at ([xshift=5mm]0,0);
\coordinate (B) at ([yshift=10pt]3,2);
\draw (A) -- (B);
\end{tikzpicture}
```



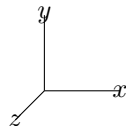
8.2 polar coordinates

```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,3);
\draw [dotted,gray] (2,0) arc (0:90:2);
\coordinate (A) at (60:2);
\draw (0,0) -- (A);
\draw (A) circle (2pt);
\filldraw (1,3) circle (1pt);
\draw (1,3) -- (15:3) node [right] {C};
\end{tikzpicture}
```



3D coordinates

```
\begin{tikzpicture}
\draw (0,0,0) -- (1,0,0) node {$x$};
\draw (0,0,0) -- (0,1,0) node {$y$};
\draw (0,0,0) -- (0,0,1) node {$z$};
\end{tikzpicture}
```



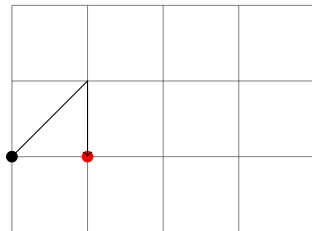
9 Relative coordinates

```
\draw (0,0) -- +(1,1) -- +(0,1);
```

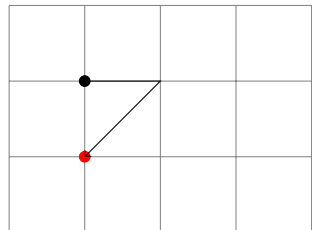
```
\draw (0,0) -- ++(1,1) -- +(0,1);
```

9.1 relative coordinates

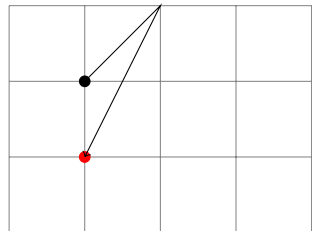
```
\begin{tikzpicture}
\draw[help lines](0,0) grid (4,3);
\filldraw[red] (1,1) circle (2pt);
\draw [->] (1,1) (0,1) -- +(1,1) -- (1,1);
\mydotfill(0,1); % liftpen, moveto, lineto
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,3);
\filldraw[red] (1,1) circle (2pt);
\draw [->] (1,1) +(0,1) -- +(1,1) -- (1,1);
\mydotfill(1,2);
\end{tikzpicture}
```

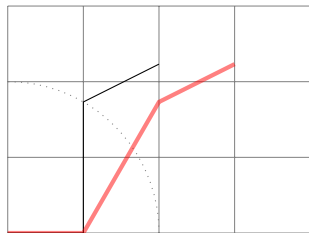


```
\begin{tikzpicture}
\draw[help lines] (0,0) grid (4,3);
\filldraw[red] (1,1) circle (2pt);
\draw [->] (1,1) ++(0,1) -- +(1,1) -- (1,1);
\mydotfill(1,2);
\end{tikzpicture}
```

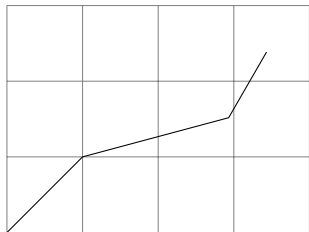


9.2 turn

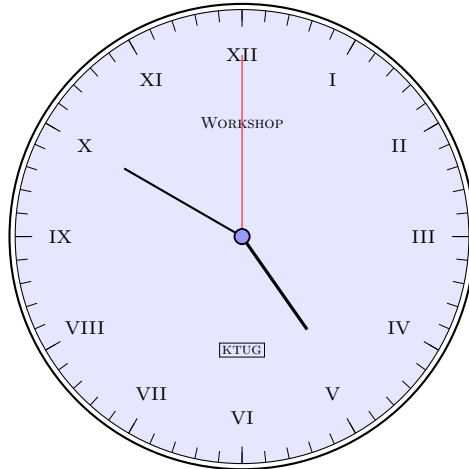
```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,3);
\draw [dotted,gray] (2,0) arc (0:90:2);
\draw (0,0) -- (1,0) -- (60:2cm) -- +(1,.5);
\draw [ultra thick,red,opacity=.5]
      (0,0) -- (1,0) -- ([turn]60:2cm) -- +(1,.5);
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,3);
\draw (0,0) -- (1,1) --
      ([turn]-30:2cm) --
      ([turn]45:1);
\end{tikzpicture}
```



9.3 example: when can I go home?



```

\begin{tikzpicture}
\def\Romantime#1{%
  \scriptsize\MakeUppercase{\romannumeral #1}
}
\draw [thick] (0,0) circle (2.05cm);
\draw [fill=blue!10] (0,0) circle (2cm);
\draw (90:1) node {\tiny\textsc{Workshop}};
\draw (-90:1) node [draw,ultra thin,inner sep=1pt] {\tiny\textsc{ktug}};
\draw [very thick] (0,0) -- (-55:1);      % hour hand
\draw [thick] (0,0) -- (150:1.2);        % minute hand
\draw [very thin,red] (0,0) -- (90:1.6); % second hand
\draw [fill=blue] (0,0) circle (2pt);
\draw [fill=blue!40] (0,0) circle (1.8pt);
%% minutes
\foreach \ang in {90,84,78,...,-264}
  \draw [ultra thin] (\ang:2) -- (\ang:1.9);
%% hours
\foreach \ang [count=\t] in {60,30,0,...,-270}
{ \draw (\ang:2) -- (\ang:1.85);
  \draw (\ang:1.6) node {\Romantime \t};
}
\end{tikzpicture}

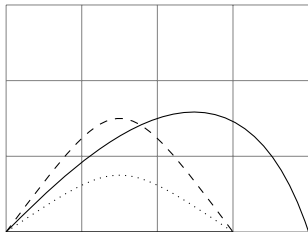
```

10 Curves

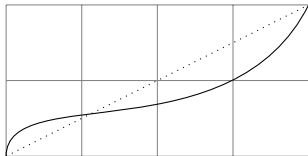
```
\draw (0,0) .. controls (1,1) and (3,0) .. (4,2);  
\draw plot [smooth,tension=1] { (0,3) (1,1) (4,0) };
```

10.1 basic curves

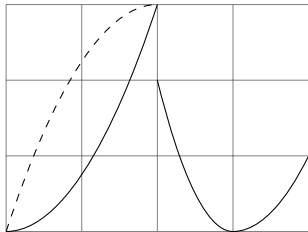
```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,3);
\draw      (0,0) -- (3,0);
\draw [dotted] (0,0) .. controls (1.5,1) .. (3,0);
\draw [dashed] (0,0) .. controls (1.5,2) .. (3,0);
\draw (0,0) .. controls (1,1) and (3,3) .. (4,0);
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,2);
\draw [dotted] (0,0) -- (4,2);
\draw (0,0) .. controls (0,1) and (3,0) .. (4,2);
\end{tikzpicture}
```

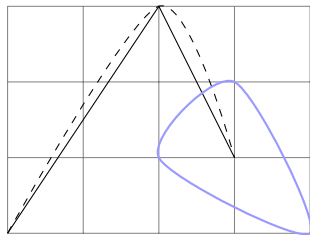


```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,3);
\draw (0,0) parabola (2,3);
\draw [dashed] (0,0) parabola [bend at end] (2,3);
\draw (2,2) parabola bend (3,0) (4,1);
\end{tikzpicture}
```

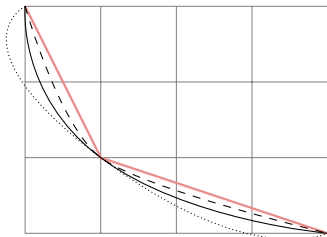


10.2 plot coordinates

```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,3);
\draw plot coordinates {(0,0) (2,3) (3,1)};
\draw [dashed] plot [smooth]
coordinates {(0,0) (2,3) (3,1)};
\draw [blue!40,thick] plot [smooth cycle]
coordinates {(2,1) (3,2) (4,0)};
\end{tikzpicture}
```

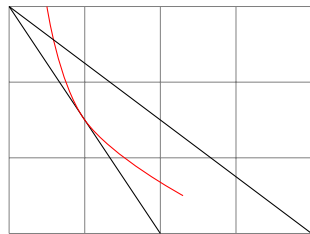


```
%% smooth, tension
\begin{tikzpicture}
\useasboundingbox (0,0) rectangle (4,3);
\draw [help lines] (0,0) grid (4,3);
\draw [red!50,thick] plot [smooth,tension=0]
coordinates {(0,3) (1,1) (4,0)};
\draw [dashed] plot [smooth]
coordinates {(0,3) (1,1) (4,0)};
\draw plot [smooth,tension=1]
coordinates {(0,3) (1,1) (4,0)};
\draw [densely dotted] plot [smooth,tension=1.8]
coordinates {(0,3) (1,1) (4,0)};
\end{tikzpicture}
```

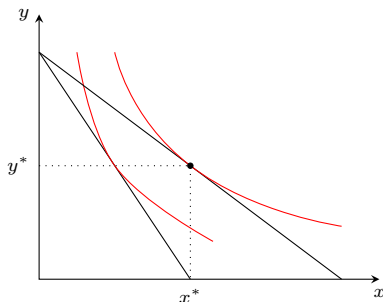


10.3 example: a tangent curve to a line

```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,3);
\draw (0,3) -- (2,0);
\draw [red] plot [smooth,tension=.7]
  coordinates {(0.5,3) (1,1.5) (2.3,.5)};
\draw (0,3) -- (4,0);
\end{tikzpicture}
```



```
\begin{tikzpicture}[>=stealth,font=\scriptsize]
\useasboundingbox (0,0) rectangle (4,3);
\draw [<->] (0,3.5) node [left] {$y$} --
  (0,0) -- (4.5,0) node [below] {$x$};
\draw (0,3) -- (2,0);
\draw [red] plot [smooth,tension=.7]
  coordinates {(0.5,3) (1,1.5) (2.3,.5)};
\draw (0,3) -- (4,0);
\draw [red] plot [smooth,tension=1]
  coordinates {(1,3) (2,1.5) (4,.7)};
\draw [dotted] (0,1.5) node [left] {$y^*$} --
  (2,1.5) -- (2,0) node [below] {$x^*$};
\filldraw (2,1.5) circle (1pt);
\end{tikzpicture}
```

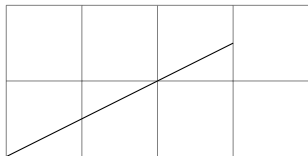


11 Plotting functions

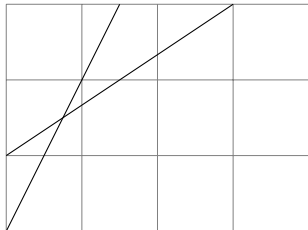
```
\draw plot [domain=0:3] {\x,{.5*\x}};
```

11.1 plotting your own functions

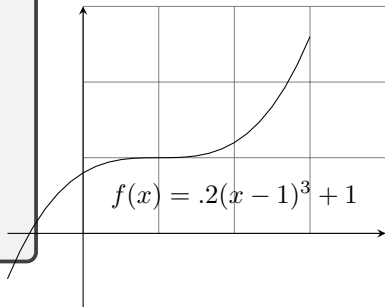
```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,2);
\draw plot [domain=0:3] (\x,{.5*\x});
\end{tikzpicture}
```



```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (4,3);
\draw plot [domain=0:3] (\x,{(2/3)*\x+1});
\draw plot [domain=0:1.5,variable=\var] (\var,2*\var);
\end{tikzpicture}
```



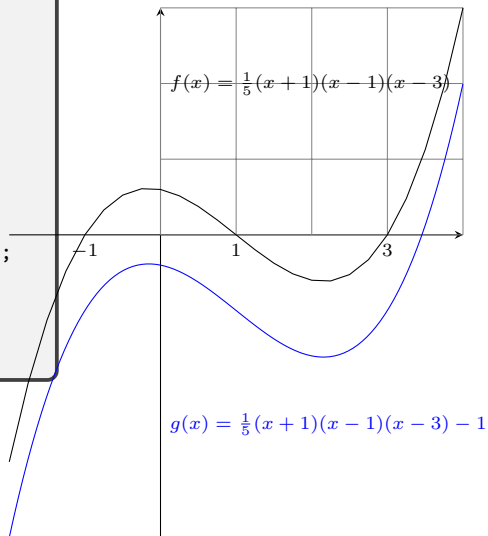
```
\begin{tikzpicture}[>=stealth]
\useasboundingbox (0,0) rectangle (4,3);
\draw [help lines] (0,0) grid (4,3);
\draw [->] (-1,0) -- (4,0);
\draw [->] (0,-1) -- (0,3);
\draw plot [domain=-1:3] (\x,{.2*(\x-1)^3+1});
\draw (2,.5) node {$f(x)=.2(x-1)^3+1$};
\end{tikzpicture}
```




```

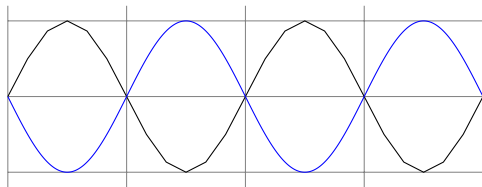
\begin{tikzpicture}[>=stealth,font=\scriptsize]
\useasboundingbox (0,0) rectangle (4,3);
\draw [->] (-2,0) -- (4,0);
\draw [->] (0,-4) -- (0,3);
\def\Fx{.2*(\x+1)*(\x-1)*(\x-3)}
\draw [help lines] (0,0) grid (4,3);
\draw plot [domain=-2:4] (\x,{\Fx});
\foreach \x in {-1,1,3}
  \draw (\x,0) node [below] {\$ \x \$};
\draw (0,2) node [right]
  {\$f(x)=\frac{1}{5}(x+1)(x-1)(x-3)\$};
\draw [blue] plot
  [domain=-2:4,samples=100] (\x,{\Fx-1});
\draw (0,-2.5) node [right,blue]
  {\$g(x)=\frac{1}{5}(x+1)(x-1)(x-3)-1\$};
\end{tikzpicture}

```

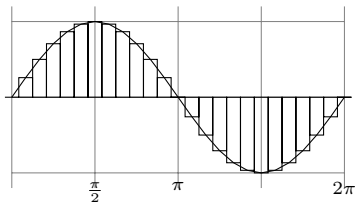


11.2 some internal functions

```
\begin{tikzpicture}
\draw [help lines,xstep=.5*pi]
      (0,-1.2) grid (2*pi,1.2);
\def\Fx{sin(2*\x r)}
\def\Gx{-sin(deg(2*\x))}
\draw plot [domain=0:2*pi] (\x,{\Fx});
\draw [blue] plot
      [domain=0:2*pi,samples=500] (\x,{\Gx});
\end{tikzpicture}
```

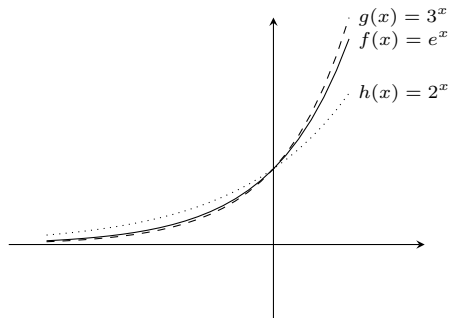


```
\begin{tikzpicture}[xscale=.7,font=\scriptsize]
\draw [help lines,xstep=.5*pi]
      (0,-1.2) grid (2*pi,1.2);
\def\Fx{sin(\x r)}
\draw [domain=0:2*pi] plot
      [ybar,bar width=7.4pt] (\x,{\Fx});
\draw plot [domain=0:2*pi] (\x,{\Fx});
\draw (.5*pi,-1)
      node [below] { $\frac{\pi}{2}$ };
\draw (pi,-1) node [below] { $\pi$ };
\draw (2*pi,-1) node [below] { $2\pi$ };
\end{tikzpicture}
```



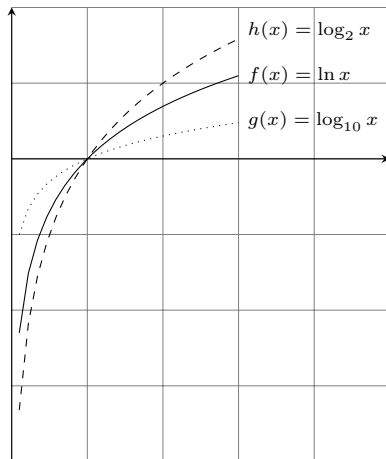
exponential function

```
\begin{tikzpicture}[>=stealth,font=\scriptsize]
\draw [->] (-3.5,0) -- (2,0);
\draw [->] (0,-1) -- (0,3);
\def\Fx{exp(\x)}
\def\Gx{2^\x}
\def\Hx{3^\x}
\draw plot [domain=-3:1] (\x,{\Fx});
\draw [dotted] plot [domain=-3:1] (\x,{\Gx});
\draw [dashed] plot [domain=-3:1] (\x,{\Hx});
\draw (1,3) node [right] {$g(x)=3^x$};
\draw (1,2.7) node [right] {$f(x)=e^x$};
\draw (1,2) node [right] {$h(x)=2^x$};
\end{tikzpicture}
```



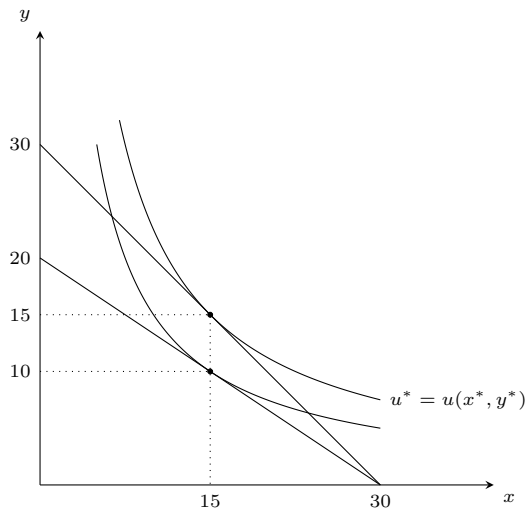
logarithmic function

```
\begin{tikzpicture}[>=stealth,font=\scriptsize]
\draw [help lines] (0,-4) grid (5,2);
\draw [->] (0,0) -- (5,0);
\draw [->] (0,-4) -- (0,2);
\def\Fx{\ln(\x)}
\def\Gx{\log10(\x)}
\def\Hx{\log2(\x)}
\draw plot [domain=.1:3] (\x,{\Fx});
\draw [dotted] plot [domain=.1:3] (\x,{\Gx});
\draw [dashed] plot [domain=.1:3] (\x,{\Hx});
\draw (3,.5) node [right]
    {$g(x)=\log_{10}x$};
\draw (3,1.1) node [right] {$f(x)=\ln x$};
\draw (3,1.7) node [right] {$h(x)=\log_2 x$};
\end{tikzpicture}
```



11.3 example: utility maximization

Consider a consumer whose preference relation is represented by the utility function $u(x, y) = xy$. Suppose that prices and income are $p_x = 2$, $p_y = 3$, and $m = 60$, respectively. What is the consumer's utility maximizing consumption? Now suppose that the price of y decreases by 1. What is the new utility maximizing consumption?



```

%% utility maximization
\begin{tikzpicture}[scale=.15,>=stealth,font=\scriptsize]
% axes
\draw [->] (0,0) -- (40,0) node [below right] {$x$};
\draw [->] (0,0) -- (0,40) node [above left] {$y$};
% defining functions
\def\Bgt{-(2/3)*\x+20}
\def\BgtA{-\x+30}
\def\Ux{150/\x}
\def\Uxa{225/\x}
% drawing functions
\draw plot [domain=0:30] (\x,{\Bgt});
\draw plot [domain=5:30,samples=200] (\x,{\Ux});
\draw plot [domain=0:30] (\x,{\BgtA});
\draw plot [domain=7:30,samples=200] (\x,{\Uxa}) node [right] {$u^*=u(x^*,y^*)$};
% ticks and labels
\foreach \x in {15,30}
  \draw (\x,0) node [below] {\x};
\foreach \y in {10,15,20,30}
  \draw (0,\y) node [left] {\y};
% lines and dots
\draw [dotted] (0,15) -- (15,15) -- (15,0);
\draw [dotted] (0,10) -- (15,10);
\filldraw (15,10) circle (6pt);
\filldraw (15,15) circle (6pt);
\end{tikzpicture}

```

12 References

- TikZ& PGF, Manual for Version 3.0.1a, (available at <https://ctan.org/pkg/pgf?lang=en>).
- 경제학자를 위한 TikZ, (available at <http://wiki.ktug.org/wiki/wiki.php/LaTeXWorkshop/2017#s-3>).
- PSTricks를 이용한 함수의 플로팅: 효용극대화 모형을 중심으로, <http://ajt.ktug.org/2007/0101ischo.pdf>.
- PSTricks 좌표의 이해와 활용: 경제학 모형의 함수 플로팅을 중심으로, <http://ajt.ktug.org/2010/0402ischo.pdf>.