A Short Introduction to PostScript

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What is PostScript ?

- Postscript is a *language* to describe graphic objects (& text)
- It is a *vector format*
  - Shapes, characters,.. are defined in an *exact*, mathematical way → objects / characters can be scaled, magnified, rotated... without loss of quality
  - Other vector formats are, for instance: *pdf* (portable data format) and *svg* (scalable vector graphics)
- Postscript is a *programming* language
  - Complex graphics can be described quickly and efficiently
  - They can be *parameterized* and changed *easily*
- Postscript devices (printers) must be intelligent, because they must *interpret* the language
  - Otherwise, the host computer must do the translation.
    Most often using the (free) tool ‘ghostscript’

Why Use & Know About Postscript ?

- *Simple manual* generation of ***high quality*** graphics
- Graphics can be *parameterized*
- *Automatic* generation of graphics from within other programs
- Small files
- *Exact* dimensions

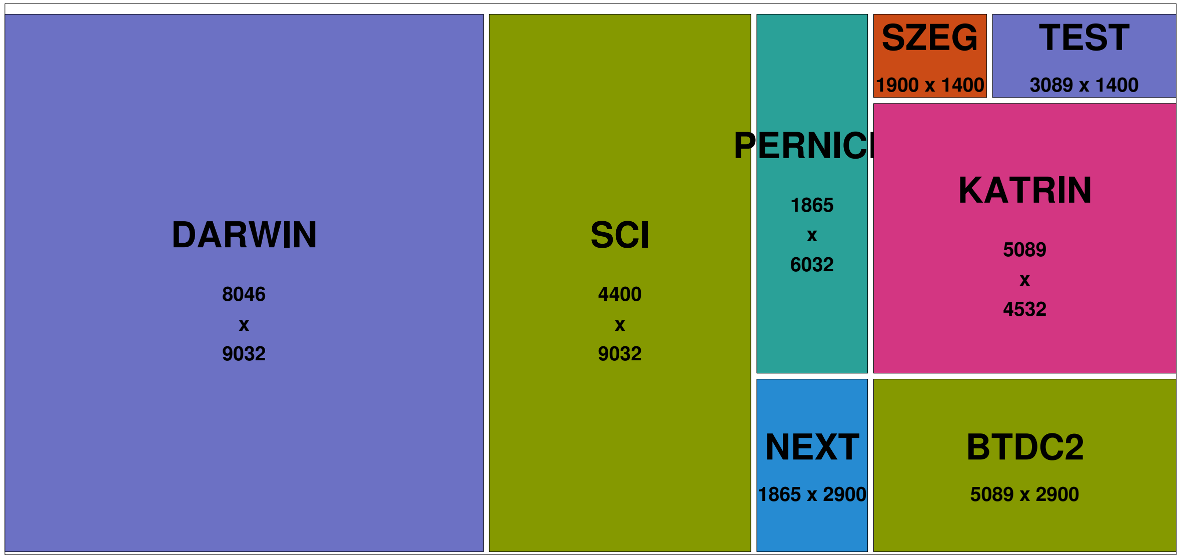
- Postscript is (still) common for LaTeX
- Sometimes, modification of available .ps or .eps files is required
  - Change a font
  - Modify colors or line width
  - Add water mark

- Many concepts are used in other languages (pdf, swift)

- Generating Graphics can be fun !

Examples

- Arrangement of chips in a 'reticle' ('to scale'):



DARWIN 8046 x 9032

SCI 4400 x 9032

PERNICI 1865 x 6032

SZEG 1900 x 1400

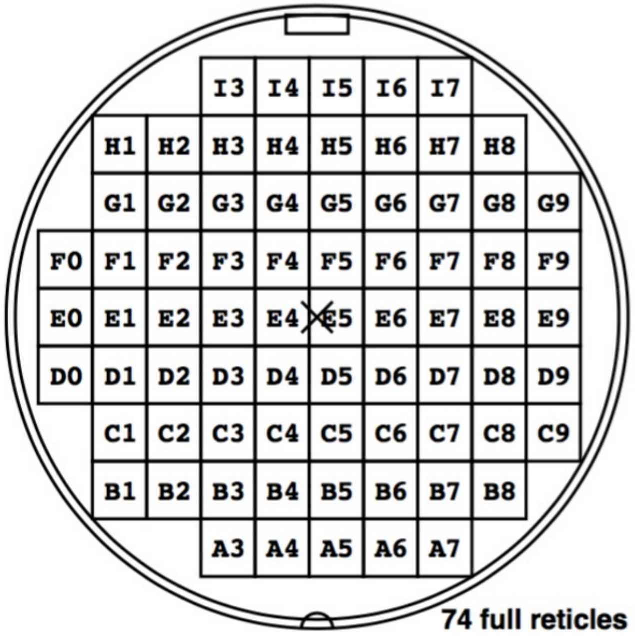
TEST 3089 x 1400

KATRIN 5089 x 4532

NEXT 1865 x 2900

BTDC2 5089 x 2900

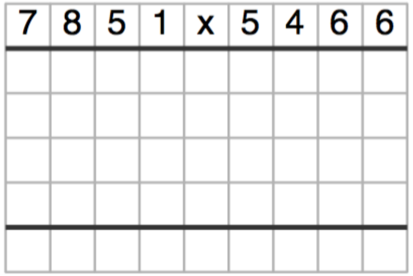
Reticles on a wafer



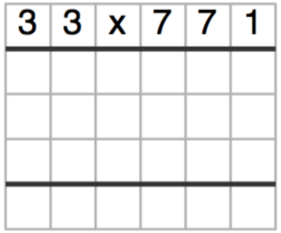
I3 I4 I5 I6 I7
H1 H2 H3 H4 H5 H6 H7 H8
G1 G2 G3 G4 G5 G6 G7 G8 G9
F0 F1 F2 F3 F4 F5 F6 F7 F8 F9
E0 E1 E2 E3 E4 E5 E6 E7 E8 E9
D0 D1 D2 D3 D4 D5 D6 D7 D8 D9
C1 C2 C3 C4 C5 C6 C7 C8 C9
B1 B2 B3 B4 B5 B6 B7 B8
A3 A4 A5 A6 A7

74 full reticles

- Math exercises for your kids (with random generator):



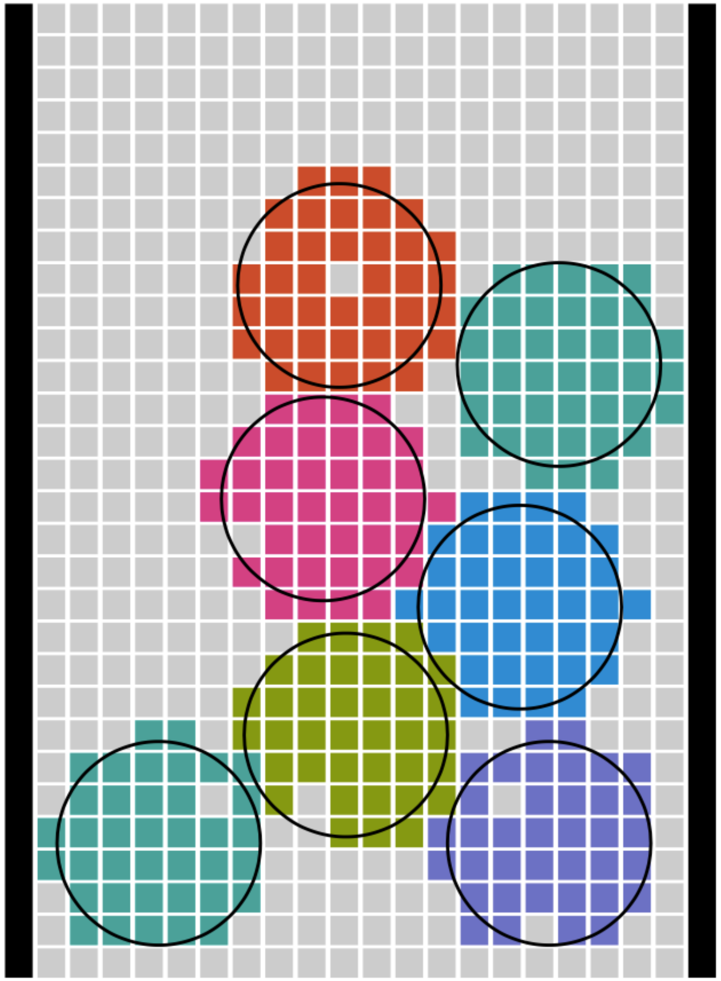
7 8 5 1 x 5 4 6 6



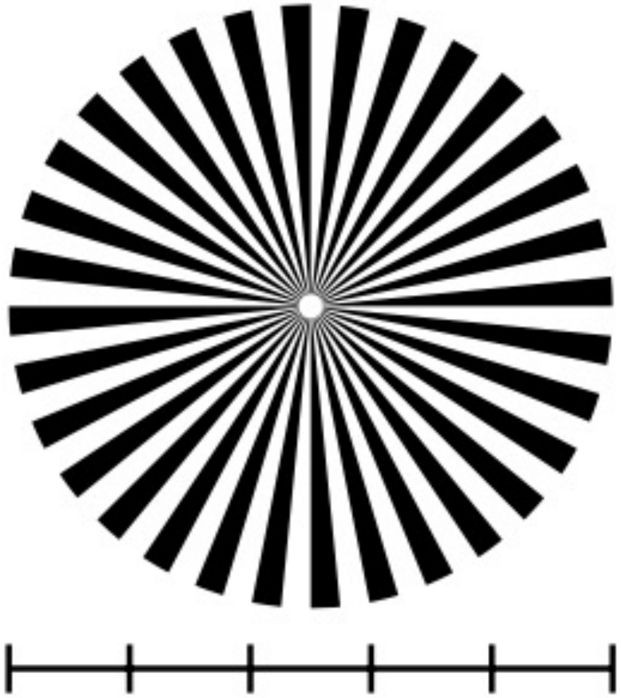
3 3 x 7 7 1

More Examples

- Illustration of a sensor readout

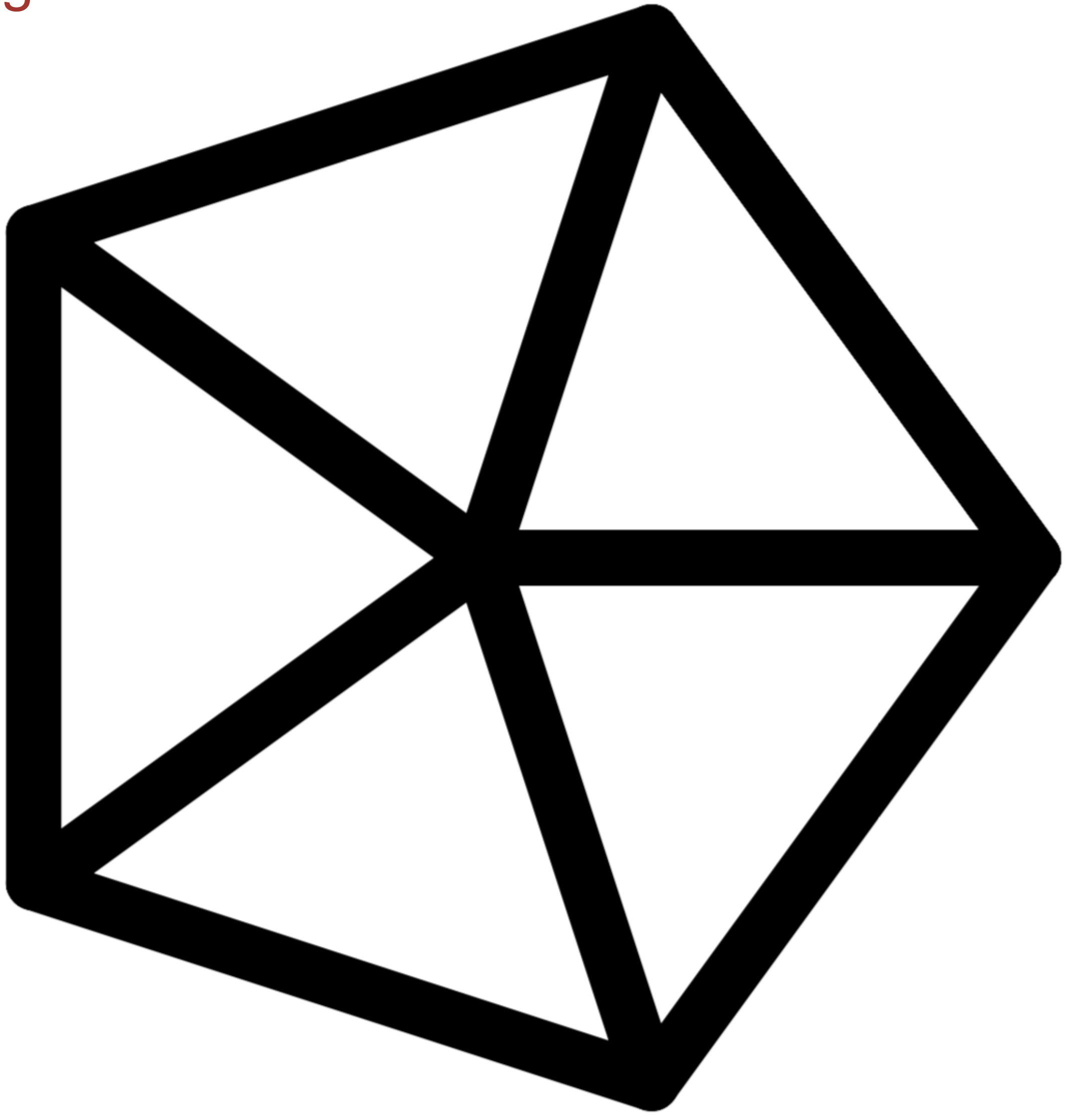


Siemensstern



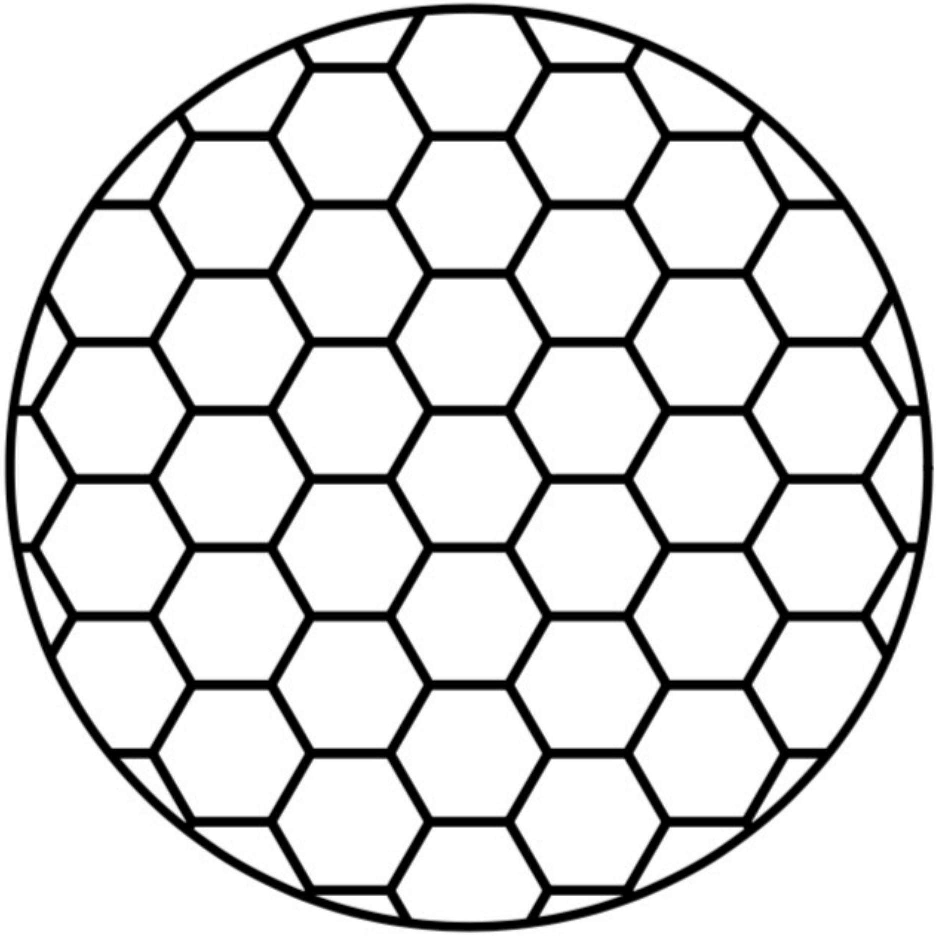
More Examples

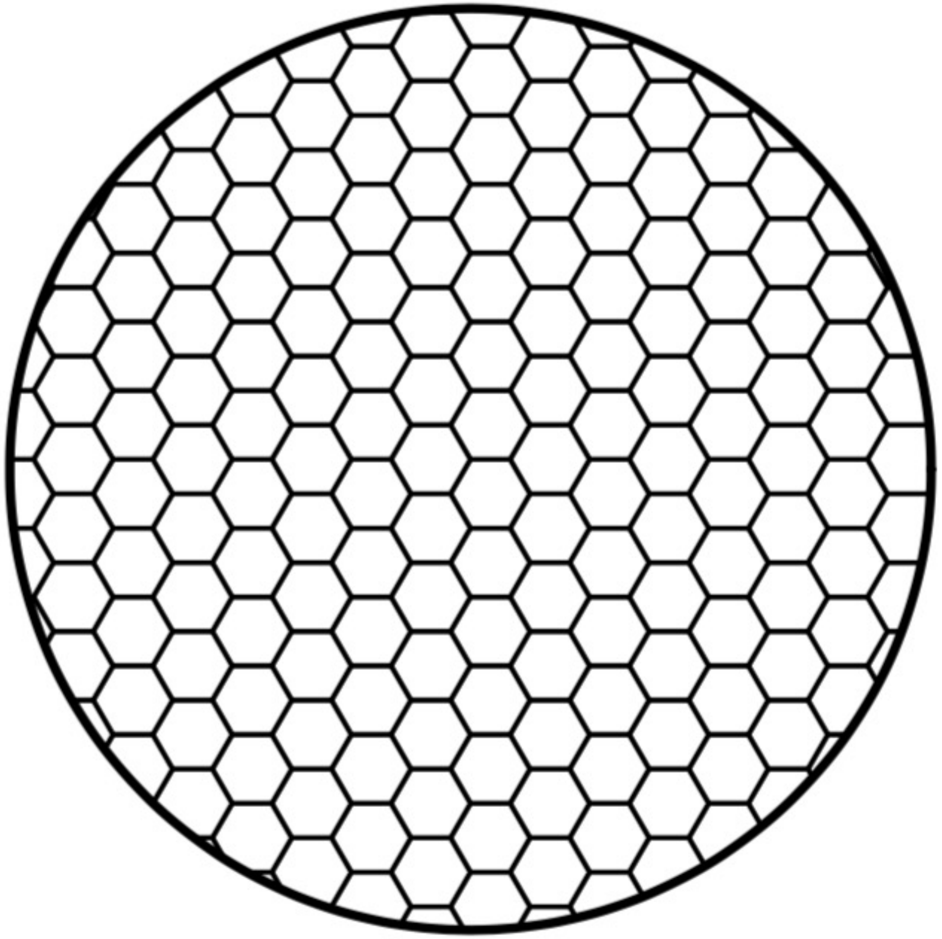
- Any Angle. Exact:



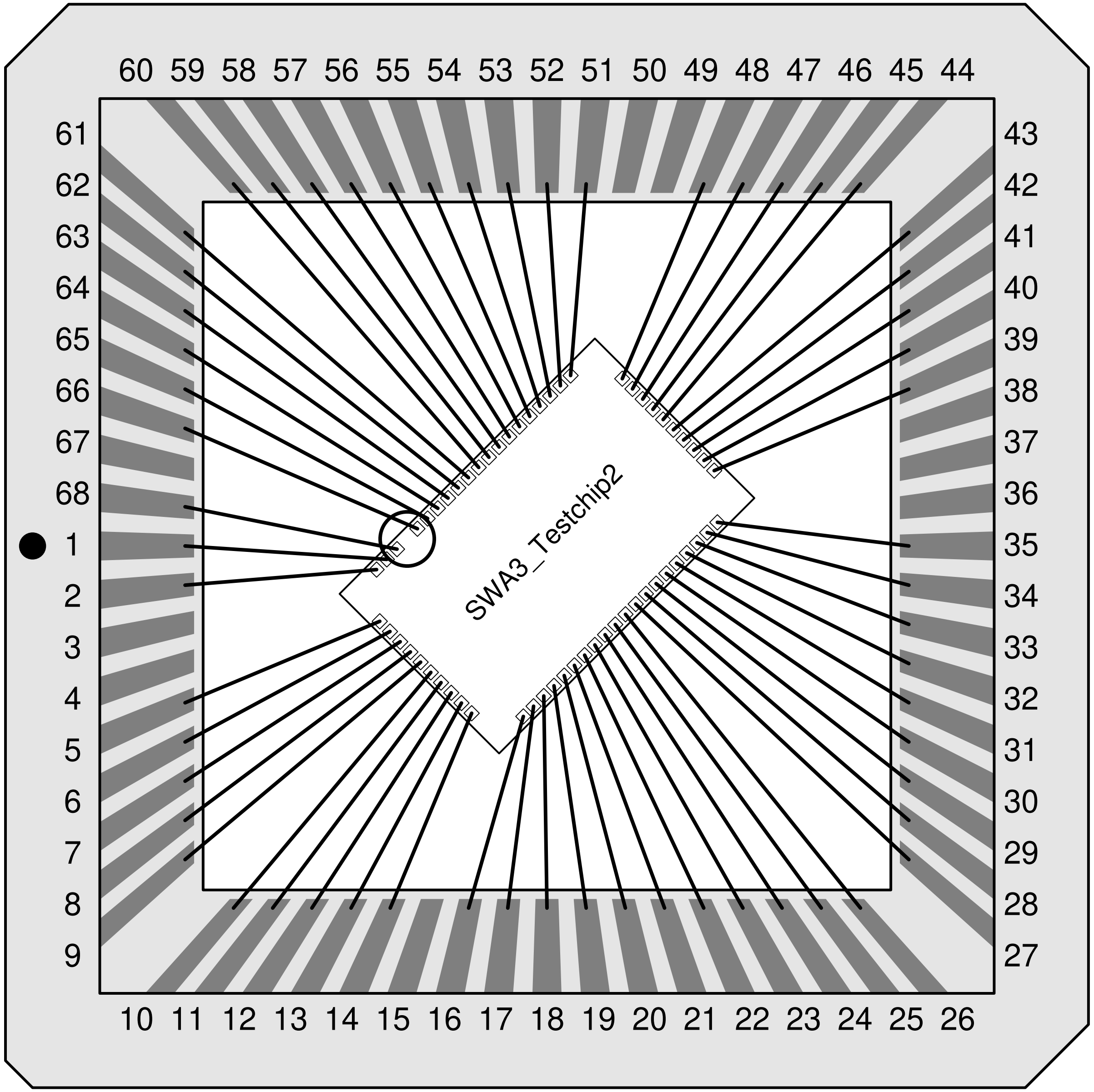
More Examples

- Exact Dimensions, exact clipping:





More Examples



What is the drawback ?

- Postscript is used less and less (replaced by pdf)
- Importing .eps in other documents is often difficult
  - It is simple in LaTeX (pdfLaTeX requires .pdf, but conversion from .eps → .pdf is simple and robust)
- Conversions often lead to quality loss.

- Why not pdf?
  - pdf is *much* more complicated!
  - A ‘minimal’ pdf file is already lengthy
  - Hard to do ‘by hand’ because bytes need to be counted!

  - See the (short) intro to pdf later in the lecture…

(Viewing .eps on Mac ≥ Monterey/Ventura)

- Native support for viewing .eps on Mac has been stopped 🤬
- From https://community.adobe.com/t5/illustrator-discussions/eps-files-not-showing-preview-in-finder/m-p/13333766/page/2#M342867

- Copy the "Illustrator.qlgenerator" from "/System/Library/QuickLook" to your desktop or any other folder you have read/write access to.
- Open "Illustrator.qlgenerator" by right clicking it and select "Show package contents".
- Open "Info.plist" in the "Contents" folder with a text editor.
- Find the line "<string>com.adobe.illustrator.ai-image</string>"
- Insert "<string>com.adobe.encapsulated-postscript</string>" below it with the same indentation and save the "Info.plist" file.
- Copy "Illustrator.qlgenerator" to "*Mac HD*/Library/QuickLook"

Getting Information

- Postscript Language Reference Manual (‘PLRM’)
  - https://www.adobe.com/jp/print/postscript/pdfs/PLRM.pdf
  - Very complete, ‘easy to read’, 800 pages
- Language Tutorial and Cookbook (the ‘Blue Book’)
  - https://cupdf.com/document/poastscript-language-bluebook.html?page=10
  - (no pdf found any more…)
- Language Program Design (the ‘Green Book’):
  - (no pdf found any more…)
- Many Web sites of good quality (see Lecture Page)

Caveat

- These slides have grown over the years to '*my own reference manual*' for PostScript:
  - When I forget syntax details, I find here all I need to do my drawings..
- This is *sometimes too detailed* information for a start…
  - There are many slides with titles in parenthesis which I will skip
  - …mostly….

LET'S GO….

Simple Example 1: Triangle + Circle

```
%!PS
 newpath
  10  10 moveto
 100  10 lineto
  50 100 lineto
 closepath

stroke

 100 100
 10
 0 360 arc fill

showpage
```

start a new shape

start at (10/10)

draw lines

connect to start

show outline

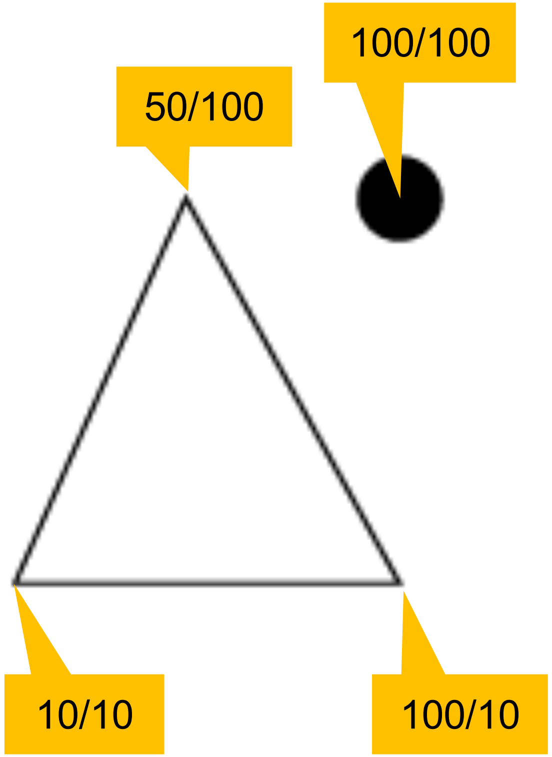
x/y = 100/100

radius = 10

start/stop angle

fill the arc

print everything

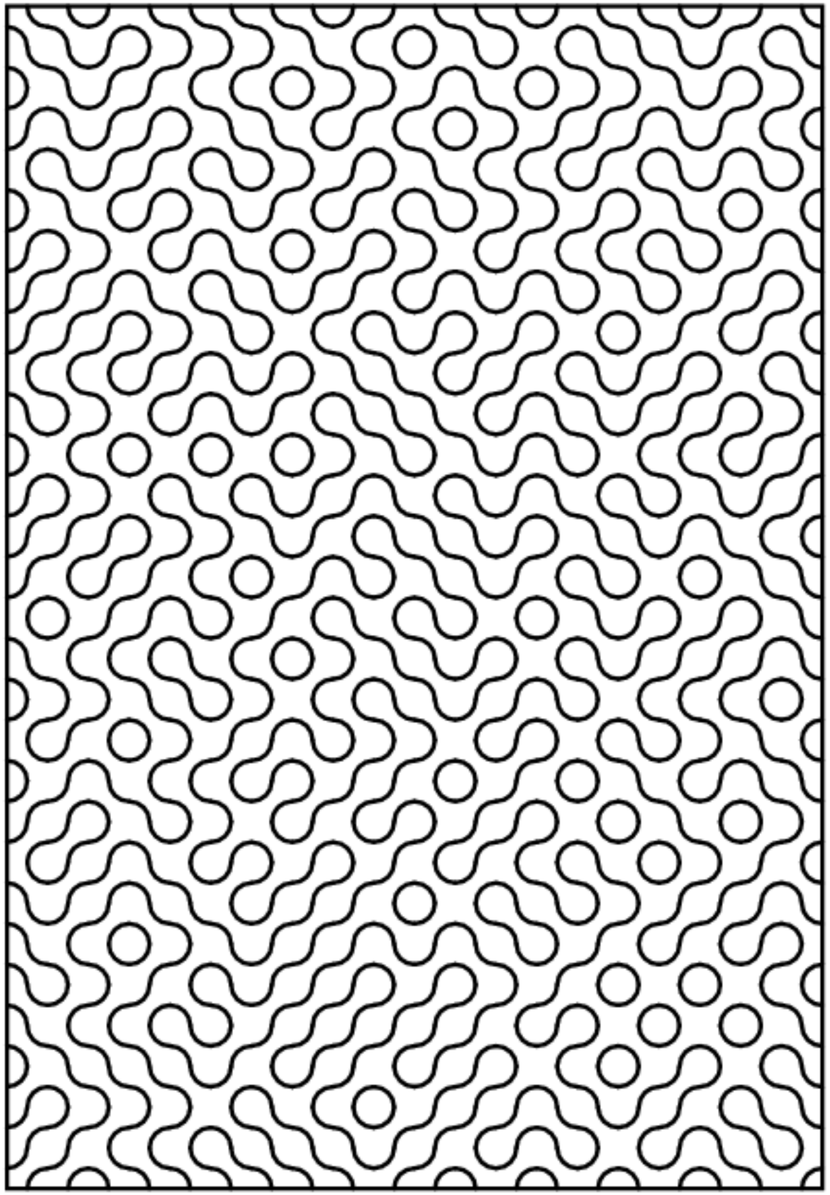


Viewing Postscript Files

- On Linux machines, files can be viewed with
  - gv (on the CIP Pool machines)
  - evince (on the CIP Pool machines)
  - ghostview, okkular, ShowView, GSView,…
  - ...there is always a viewer...
- On windows
  - Ghostview (must be installed, I do not know about new versions of Windows…)
- On MAC
  - Using Preview (for .eps) … requires patch on earlier page…
- Always need GhostScript to interpret the language
  - GhostScript is also used to convert ps/eps → pdf, png, jpg…

Advanced Example 2: Truchet Pattern

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 595 842

2.835 dup scale
5 4 translate 1 setlinecap
0 0 200 290 rectstroke
100 145 translate

/W 10 def /W2 { W 2 div } bind def

/DRAWUNIT {
  gsave  translate rotate
 W2 neg W2 neg W2   0  90 arc stroke
 W2 W2 W2 180 270 arc stroke
  grestore
} def

-95 W 95 {
  /x exch def
  -140 W 140 {
    /y exch def
    rand 4 mod 90 mul  x y  DRAWUNIT
  } for
} for

showpage
```



File Structure

- File **MUST** start with `%!PS` (may add PS - version number)
  - If forgotten, (most) printers will output (a lot of) ASCII stuff…
- PostScript is *CaseSensitive*!
- Blanks and Line breaks are *irrelevant*

- Comments
  - In-Line comments start with

```
% … commented code here …
```

  - Larger code blocks can be commented with

```
false {
 … commented code here …
} if
```

- Files have extension *.ps*
- To actually *print*, the file ***must*** end with `showpage`

eps Files

- .eps files contains some *additional* meta-information
- These 'encapsulated postscript files’ have extension **.eps**
- .eps type is announced in first line by EPSF text:

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 595 842
…
```

- All eps meta information is added as comment with '%%'

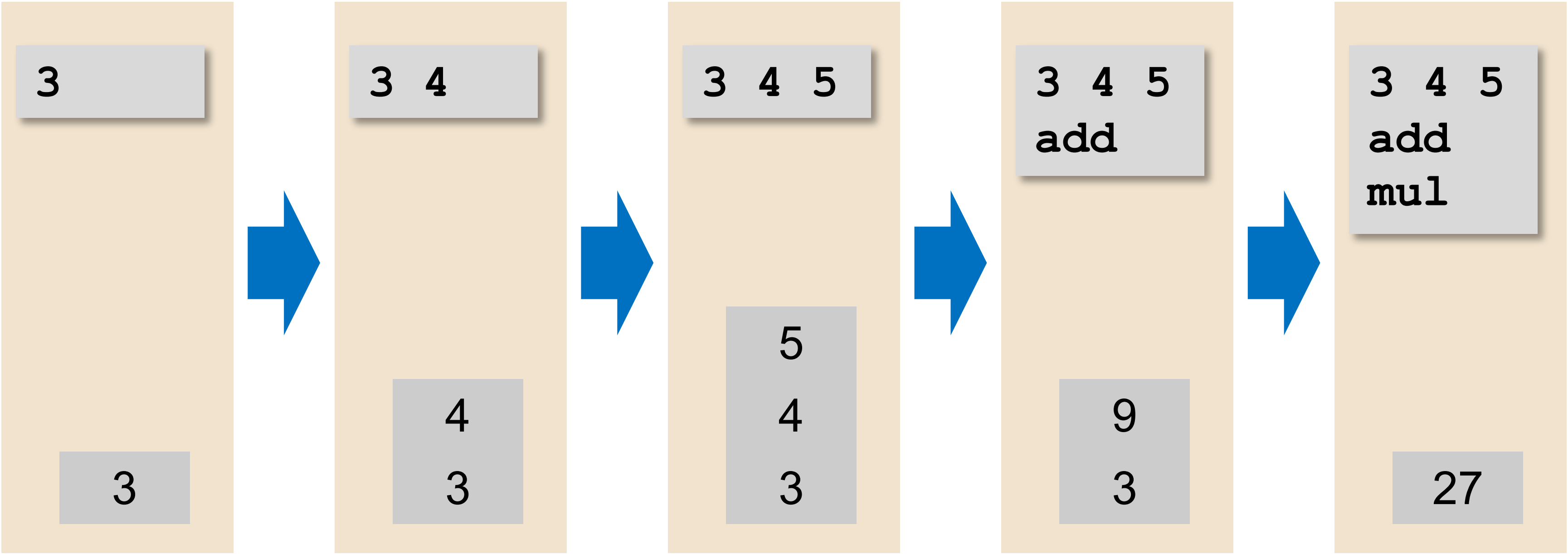
- Most important (and the only *required*) information:
  size of the viewing area = BoundingBox:
- parameters (in integer postscript units) are:

```
%%BoundingBox: x_botleft y_botleft x_topright y_topright
```

- **Best always use .eps !!!**

The Stack

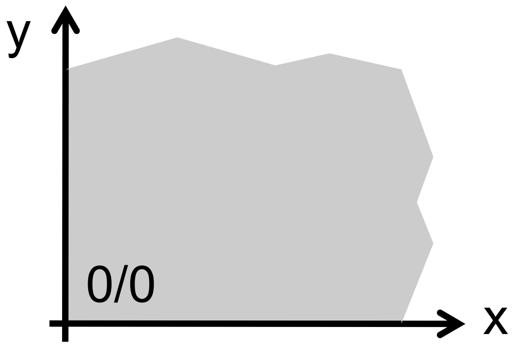
- PostScript uses
  - a stack (Last In - First out)
  - RPN (Reverse Polish Notation) = UPN (Umgekehrt Poln. Notation): Operands are put to stack **first**, operator is **last**
- Example `3 4 5 add mul` → (4+5) × 3



- Operators can have *1 or more* arguments

Coordinate System, Lengths and Points

- Origin (0/0) is ***BOTTOM LEFT***
- X is to the *RIGHT*
- Y is *UPWARD*



- 1 PostScript Unit = 1 Point = **1/72 inch = 0.353 mm**
  - (1 inch = 1 Zoll = 2.54 cm exactly)

- Convert *mm* to *point* by multiplying with 72 / 25.4 = 2.835..
- By defining the command (see later...)

```
/mm { 2.835 mul } def
```

you can just write

```
15 mm
```

in your code!

- Later we will use the `scale` command to change units...

The Page / Sheet Size

- ‘sheet’ size & orientation (in .ps) are undefined.
  - They depend on the ‘viewer’ or printer
  - (This is a drawback. This is better in .eps and .pdf!)

- The sheet size can be ‘fixed’ as a ‘bounding box’ using an eps command, see before…
  - **`%!PS-Adobe-3.0 EPSF-3.0`**
  - **`%%BoundingBox: llx lly urx ury`**

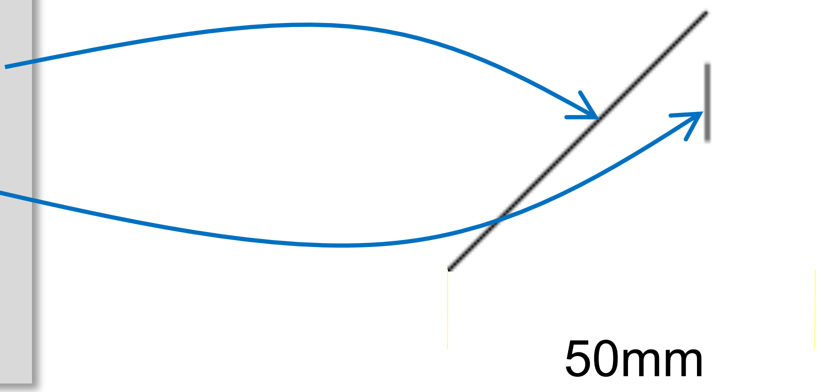
    (***`llx`*** = lower left x, … using *integer postscript* units)

- A4 (portrait) paper has
  - width = 210 mm = 595.28... points
  - height = 297 mm = 841.89... points
  - **`%%BoundingBox: 0 0 595 842    % A4 portrait`**

Hello World

- Shapes / Outlines are defined as *paths*.
  A *path* is a sequence of straight lines / bends / gaps / …
- **`x y moveto`** **moves** the ‚pen' to coordinate [x y]
- **`x y lineto`** **draws** a line **from the last point** to [x y]
- **`stroke`** executes the **path** drawing

```
%!PS
0 0 moveto
100 100 lineto
100 80 moveto
100 50 lineto
stroke
showpage
```



  - Remember: 100 Units = 100 × 0.353 mm = 35.3 mm
- **`rmoveto`** and **`rlineto`** are *relative* to the *last* point
- Note: You **MUST** first move to *somex somey*!

Drawing and Filling Paths

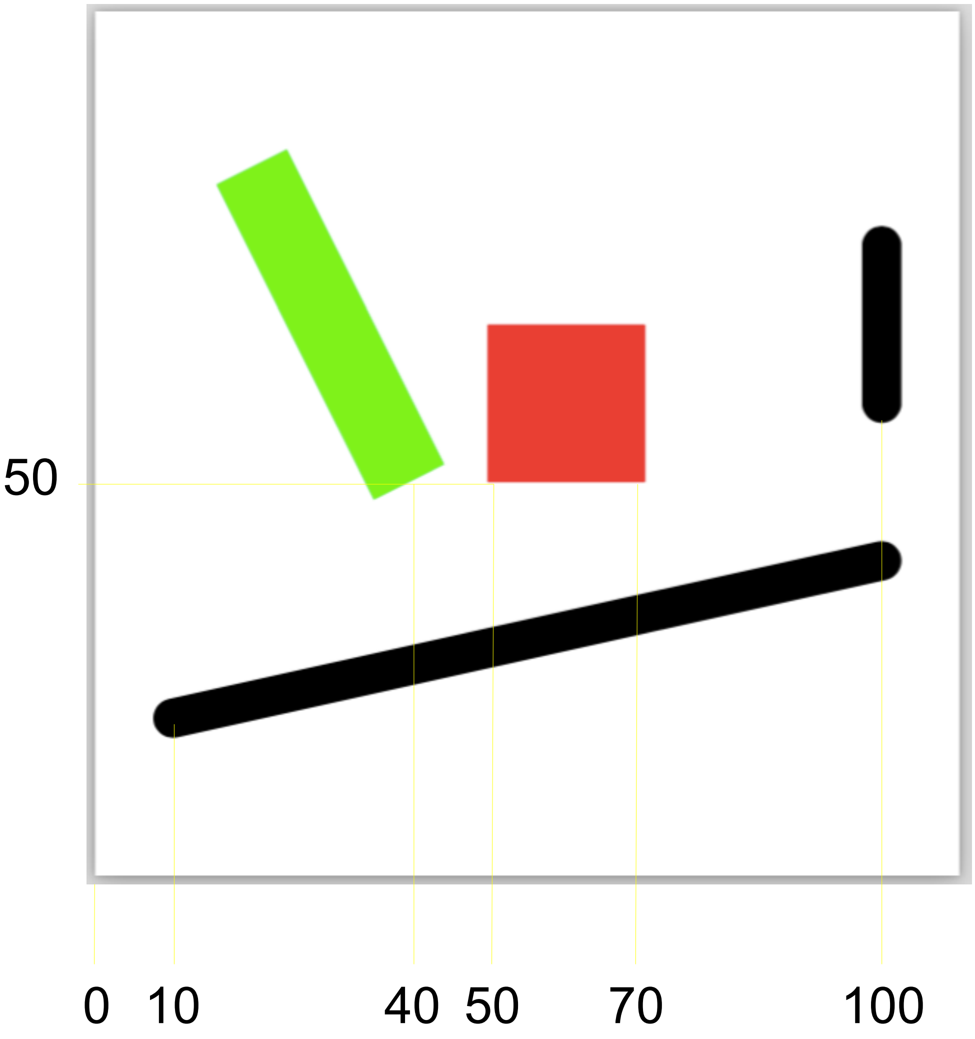
- A path *can* be started with **`newpath`**
- The command **`closepath`** connects the last active point to the starting point (see Example 1 on slide 10)
- A path can be used for further operations (e.g. clipping,…)
- Using a path is not always necessary

- To draw a path (or sequence of **`moveto`** / **`lineto`** commands)
  - **`stroke`** draws the **outline**
    - the *width* of the line can be set with **`value setlinewidth`**
    - the shape of the line *end* can be set with **`value setlinecap`**
    - the shape of corners is set with **`value setlinejoin`**.
  - **`fill`** fills the **inner part** with the presently selected color
- **`x y w h rectstroke`** is a shortcut to draw a rectangle

- Color can be set with **`r g b setrgbcolor`** (r,g,b = 0.0 … 1.0) or with **`g setgray`** (for gray values)

One More Example

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 110 110

10  20 moveto   100 40 lineto
100 60 moveto   100 80 lineto
5 setlinewidth  1 setlinecap
stroke

newpath
 50 50 moveto     20   0 rlineto
  0 20 rlineto  -20   0 rlineto
closepath
1 0 0 setrgbcolor
fill

40 50 moveto      20 90 lineto
0  setlinecap 10 setlinewidth
0 1 0 setrgbcolor
stroke
showpage
```

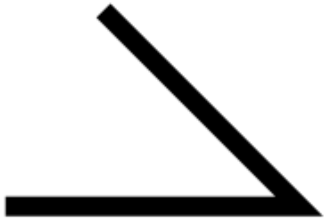


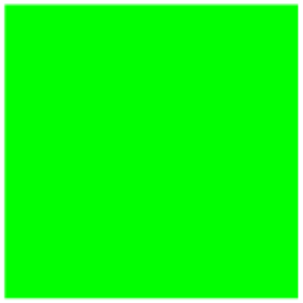
Working in Linux on the CIP Pool

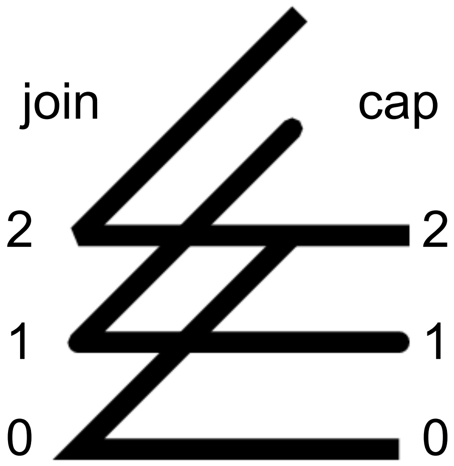
- Log in on one of the CIP Pools machines
  - chose a shell (I use Gnome)
- To work remote, use a browser and url `https://physik1.kip.uni-heidelberg.de` (or `physik2` or `physik3`)
- Create a subdirectory with `mkdir DIRNAME`
- Move to the subdirectory with `cd DIRNAME`
- Edit files for instance with `gedit filename.eps &`
- View your file with `evince filename.eps &`

Exercise 1

- Draw a line from (10,10) to (40, 10) to (20,30)
  - Change the width of the line
  - Play with shape of the line ends and the shape of the corners (use values 0…2 and a ‘thick’ line).
  - Can you find out the difference between cap = 0 and 2?
- Draw a square of 30 units size with its lower left corner at (50,10)
  - Use `moveto` and `lineto`
  - Use also `newpath` and `closepath`
  - Fill the square with green color







Mathematics

- PostScript knows several mathematical functions.
- Remember RPN: first `operand(s)`, then `operator`
  - `x y sub` → x - y. Also: `add`, `mul`, `div`, `idiv`, `mod`
  - `x neg` → -x
  - `x abs` → |x|. Also: `round`, `floor`
  - `x sin` → sin(x). Also: `cos`, (no `tan`), `ln`, `log`, `sqrt`
  - `x y atan` → arctan(x/y), 4 quadrants. ***Note*** 2 arguments!

- Angles are given (as floats) in *degrees* (i.e. 0…360)

- Examples:
  - (2 + 3) × 4 → `2 3 add 4 mul`
  - 2 + 3 × 4 → `2 3 4 mul add`
  - Sqrt (3 + 4) → `3 4 add sqrt`

(Random Numbers)

- Random (integer) numbers can be obtained with
  - **`rand`** → random *integer* number

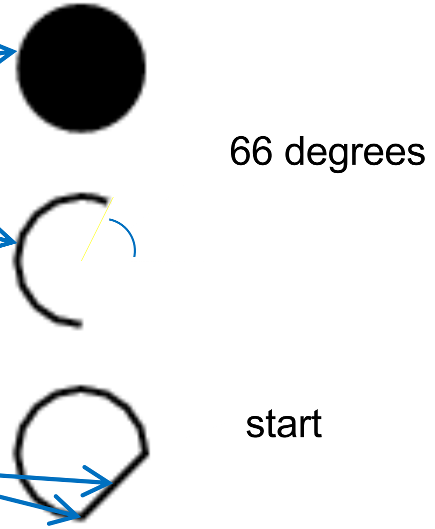
- A seed can be set with
  - **`value srand`**

- To obtain a different seed every time you 'run' (print) the postscript file, you can use a command that returns an integer time (in ms):
  - **`realtime`** → *integer* time value on stack
  - **`realtime srand`** → initialize with new value at each run

Drawing Arcs

- Arcs (parts of circles) are defined using **`x y radius phistart phistop arc`**
- Angles are in degrees, relative to *x-axis*
- **`arc`** turns *counter clock wise,* **`arcn`** turns *clock wise*
- They can be **`filled`** or **`stroked`**.
- Example:

```
%!PS
20 80 10 0 360  arc fill
20 50 10 66 270 arc stroke

newpath
20 20 10 0 270 arc
closepath
stroke

showpage
```



Defining Constants & Functions

- Defining a ‘fix’ constant:
  - `/name` *`value`* `def`
  - Example: `/PI 3.141 def`
- Defining a ‘calculated’ constant:
  - `/name` *`commands`* `def`
  - Example: `/TWO_PI  PI 2 mul  def`
- Defining a *function* (executed when called):
  - `/name { commands } def`
  - Example: `/ADDFIVE { 5 add } def`
    `3 ADDFIVE` → 8
- What happens?
  - The pair (name definition) is stored in a *dictionary* by **`def`**
  - (There are several different dictionaries for different tasks…)

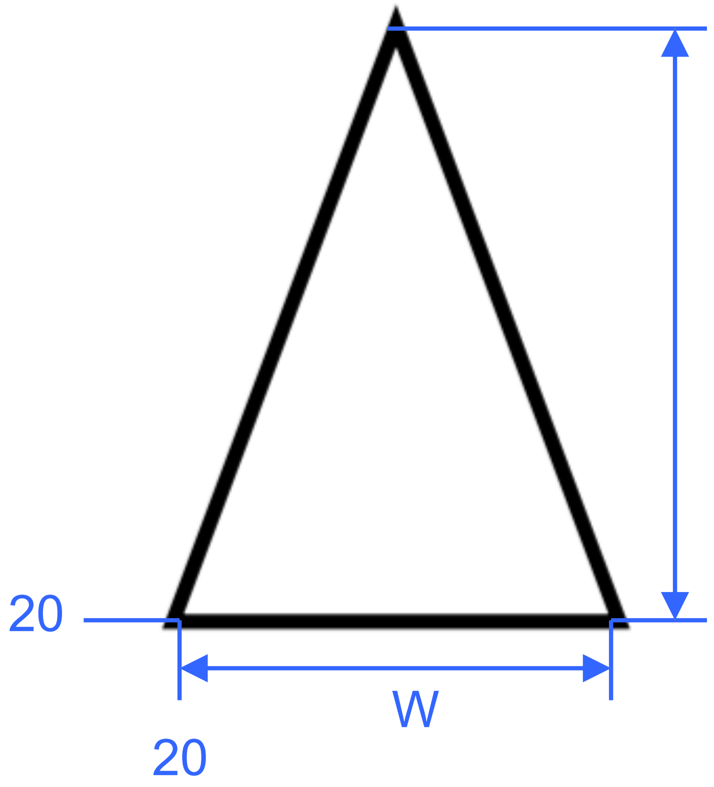
Example

- Understand in this example how the arguments of ‘lineto’ are constructed!
  - Note that the shift to (20,20) can be done more elegantly using the `translate` command, see later..

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 70 80

/W 30 def
/H 40 def

newpath
20 20 moveto
20 W add   20 lineto
20 W 2 div add   20 H add lineto
closepath
stroke

showpage
```

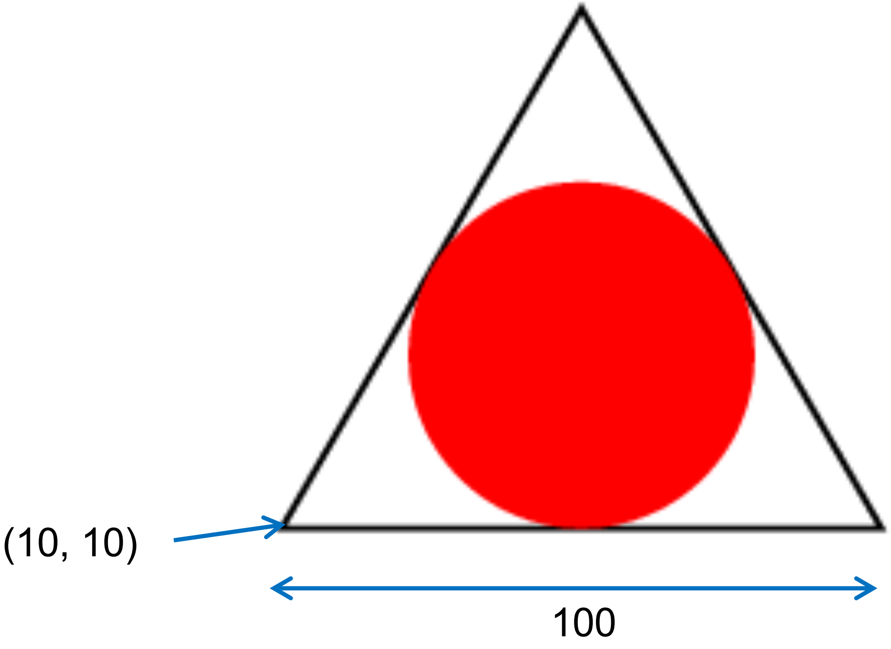
x coordinate of the top point

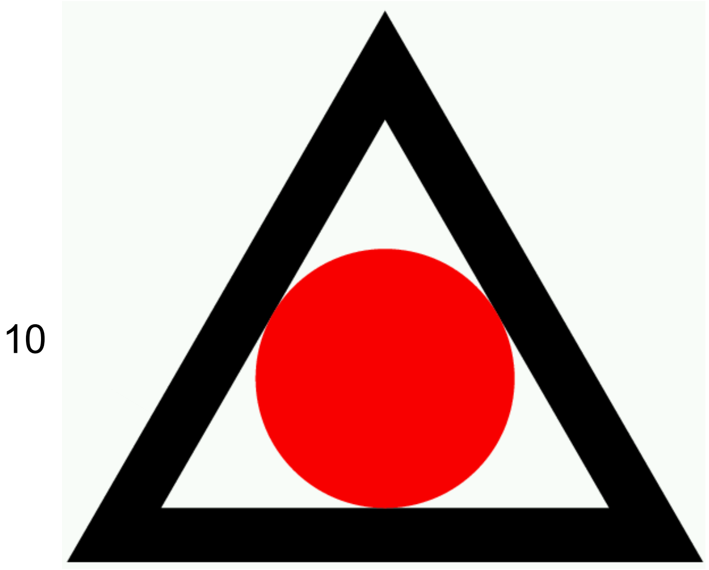
y coordinate of the top point



Exercise 2

- Draw a triangle with *equal* sides
  - Start at (10,10), side length =100. Use a variable: /W 100 def
  - You have to do so some simple math for find the height H. Do it in postscript!
- Make the lines wide (for instance 10 points)
- Add a red, filled circle in the center which *just* touches the lines





Manipulating the Stack: `pop`, `dup`, `exch`

`pop`

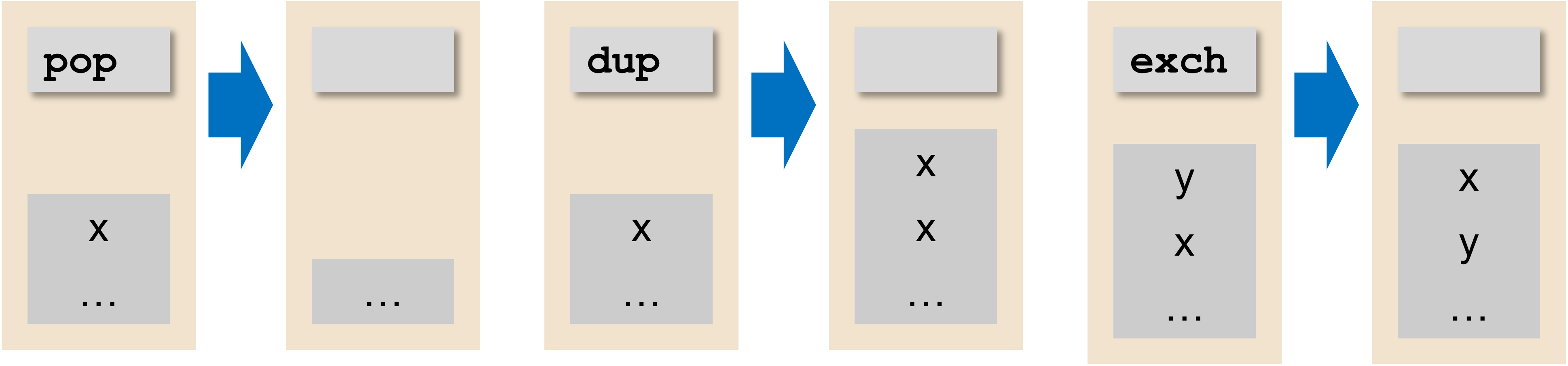
drop top element:

`dup`

duplicate top element:

`exch`

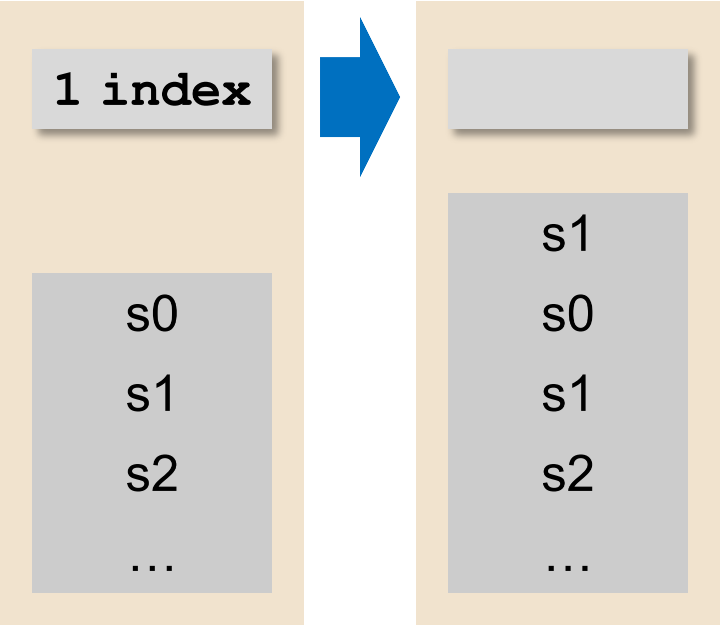
swap topmost elements:



(Manipulating the Stack: `index,copy`)

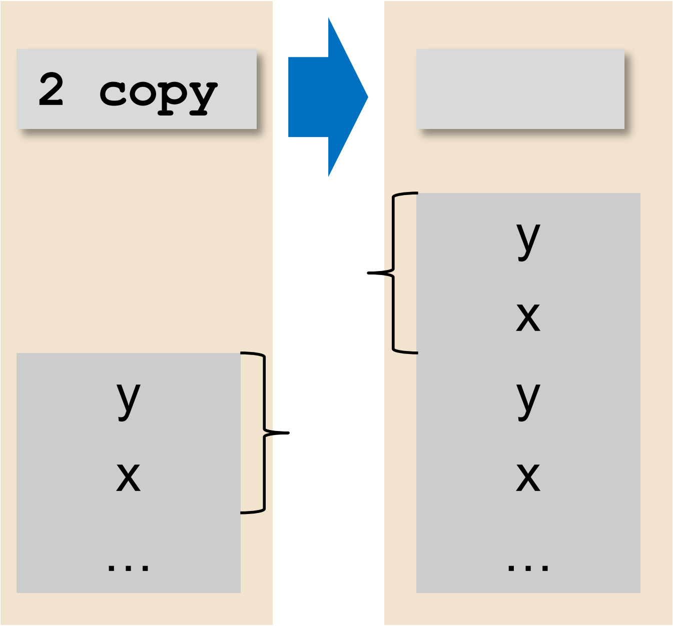
`n index`

copy t-th element (top index = 0):



`n copy`

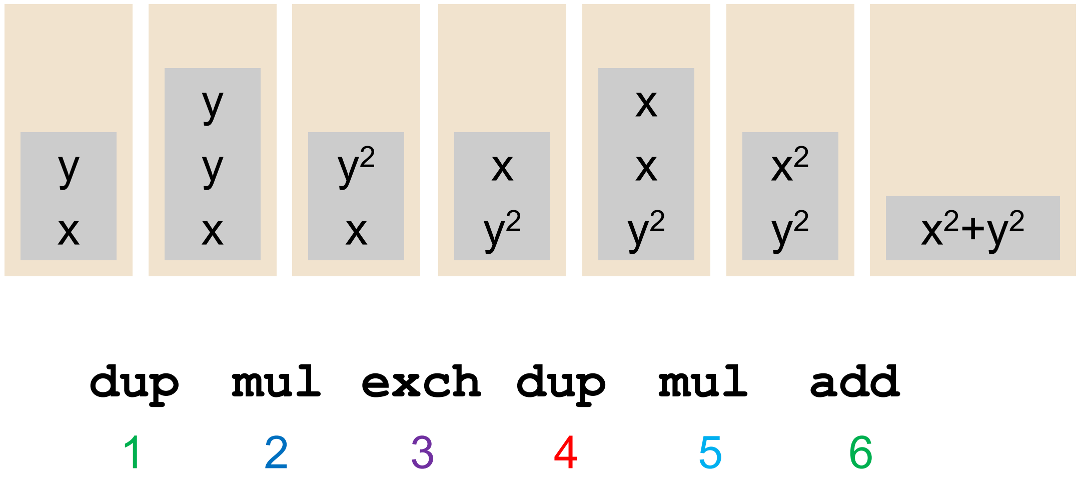
duplicate *n* elements:



Passing Values to Functions

- Parameters are passed *on the stack*
  - They can be used using stack manipulation commands
  - Example: Define DIST(x,y) = sqrt(x^2+y^2).
  - Assume x,y on stack:

```
/DIST {
   dup   %1
   mul   %2
   exch  %3
   dup   %4
   mul   %5
   add   %6
   sqrt
} def
```



- Usage: `3.2 1.7 DIST` → 3.6235
- Note: Functions can remove parameters or leave the stack intact. Stack over- / under-flows are very common mistakes!

Defining and Assigning Local Variables

- Values on the stack can be assigned to local variables:
  - **`/NAME exch def`**
  - (assume **`x`** is on the stack, then **`x /NAME exch`** leads to **`/NAME x`**, so that the **`def`** works normally)

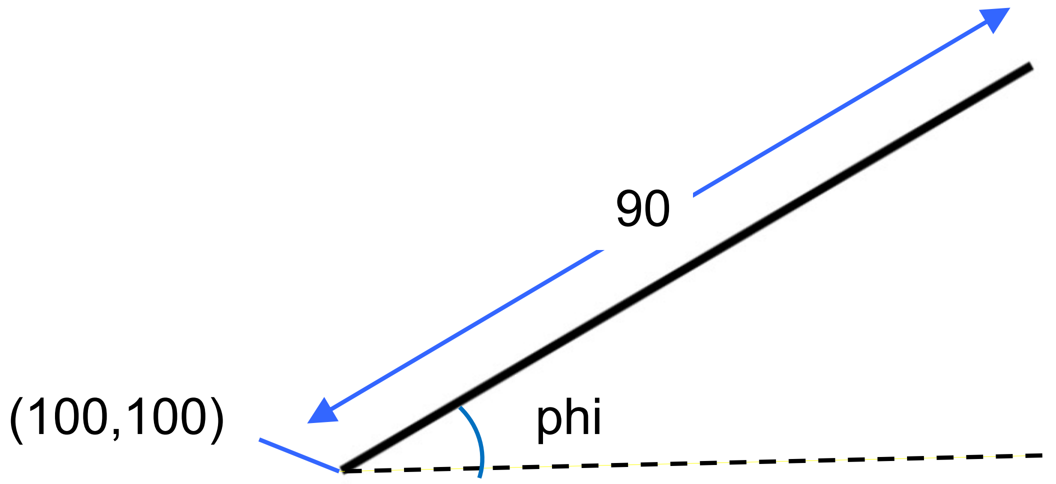
- Example: Define DIST(x,y) = sqrt(x^2+y^2)

```
/DIST {
  /y exch def   % topmost argument first!
  /x exch def   % now the stack is empty!
  x x mul       % on stack: x²
  y y mul       % on stack: x² y²
  add
  sqrt
} def
```

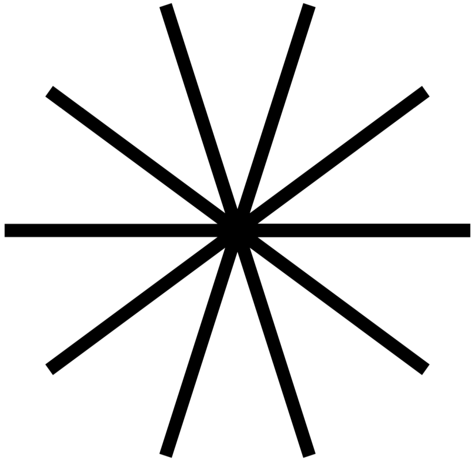
- This is much less efficient, because names must be looked up in a 'Dictionary'. (Furthermore, the variables are global!)

Exercise 3a

- Define a function **`LINE`** which draws a line of length 90 in an angle phi (on stack), starting at 100/100:

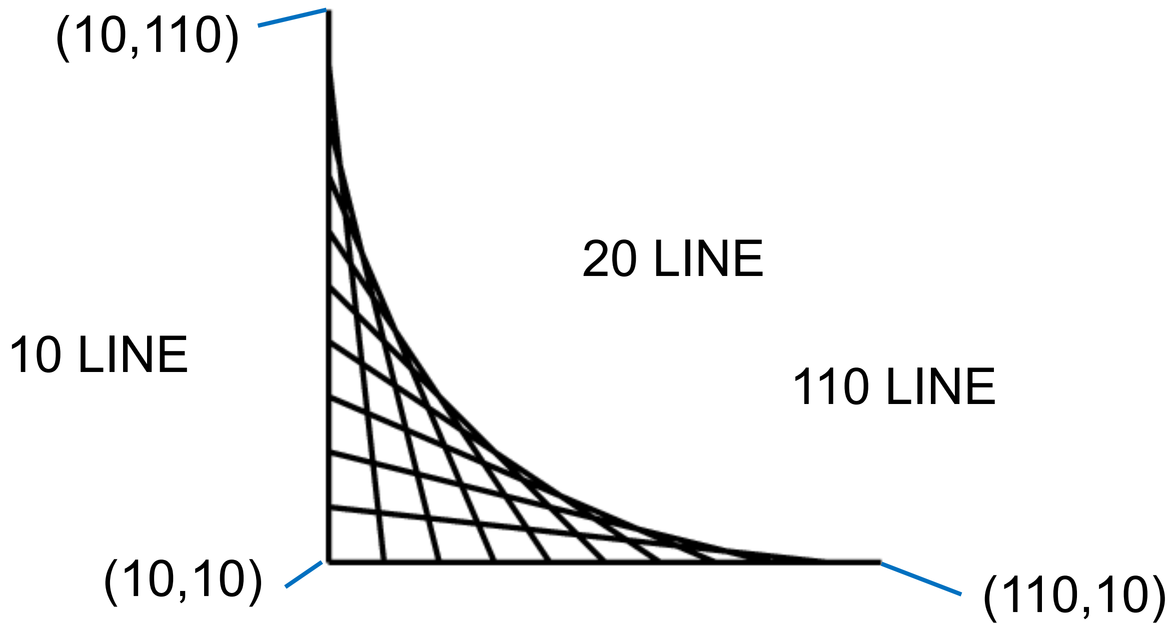


- Make a star by calling **`LINE`** several times



(Exercise 3b)

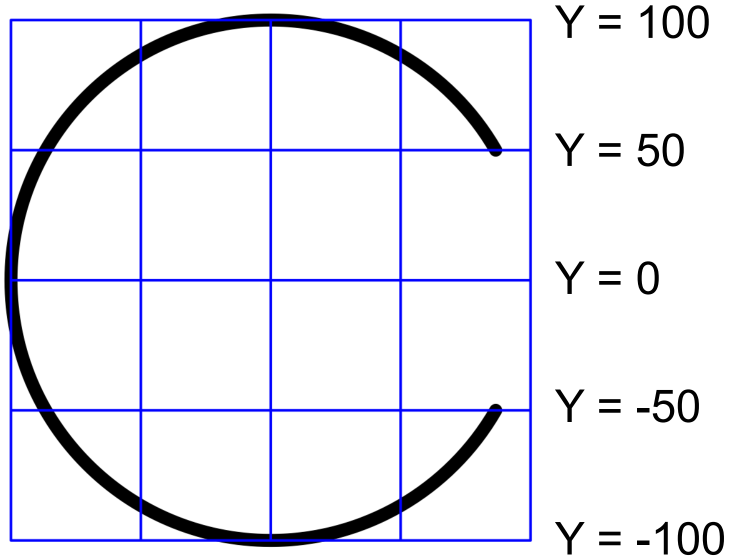
- Draw the following picture:



- First draw (a few) individual lines
- Next, define a function **`LINE`** which gets *one* value from the stack which indicates the *start of the line on the x-axis*.
- The drawing is then done by a sequence of **`LINE`** commands:
  `10 LINE   20 LINE   30 LINE` …

Exercise 3c

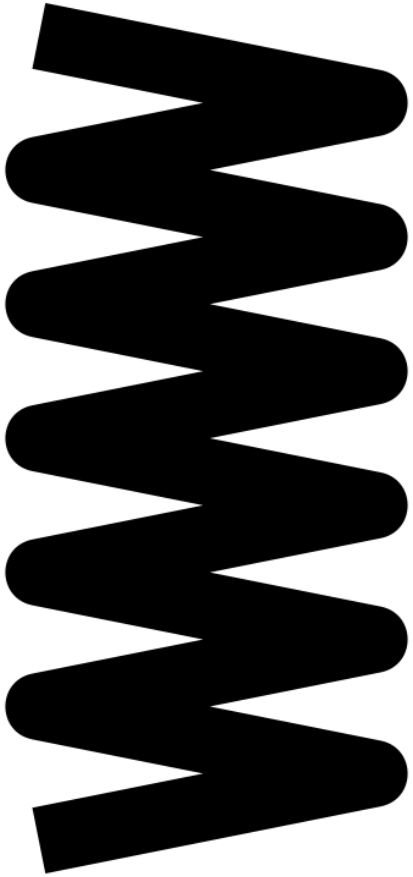
- There is no standard Arcus Cosine function available..
- In the internet, you find:
  arccos x = pi/2 - arctan (x / sqrt(1 - x^2))
- Define a function!
  - Remember that Postscript uses degrees, not radian
- Try it out:
  Draw a circle of radius 100 which ends exactly at y=50



Repeat

- Do something several times:
- **`count { `*`…commands…`*` } repeat`**

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 7 14

1 setlinejoin
1 1 moveto

6
{5 1 rlineto -5 1 rlineto}
repeat

stroke

showpage
```

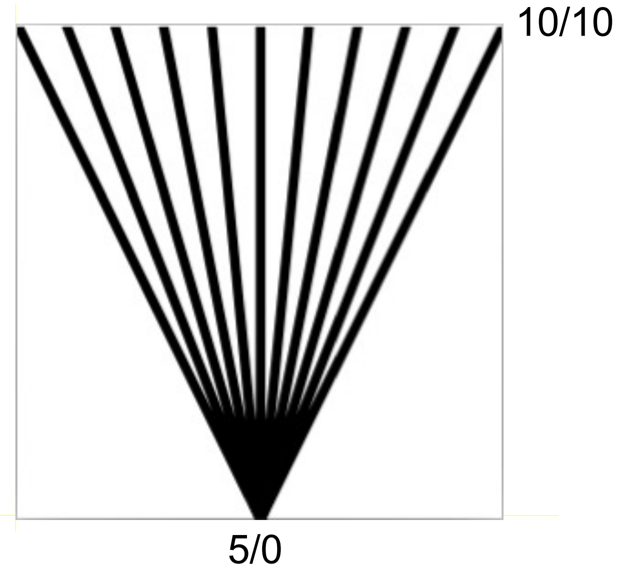


Loops

- If we want to so something different in each loop, we need a loop counter
- **istart istep imax { …*commands*… } for**
  - The loop value is put on the stack in each iteration (istart, istart+istep, istart+2 istep, …, *including* imax)
  - Then the commands are called
    They MUST consume (remove) the value from the stack
  - The loop variable can be assigned with **/i exch def**
- Example:

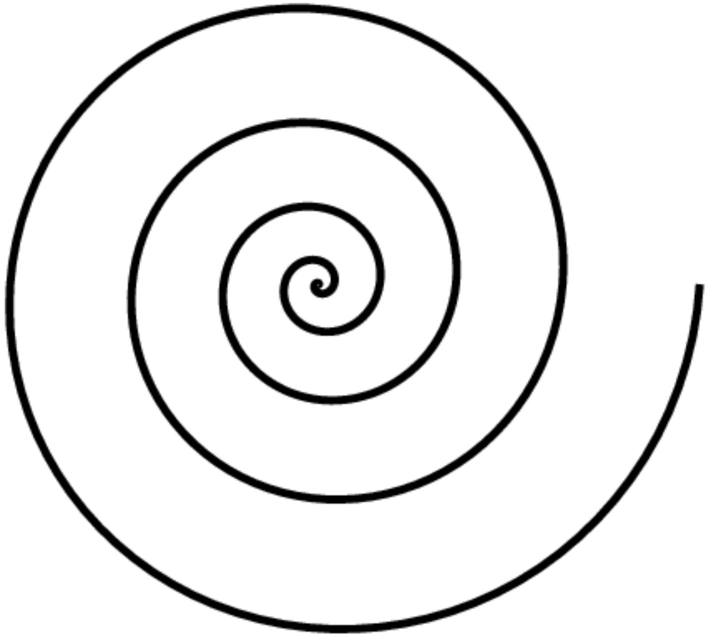
```
%!PS
0.2 setlinewidth
0 1 10 {
  5  0 moveto
    10 lineto
} for
stroke
showpage
```

Here we use the sweep variable which is still on the stack!!!



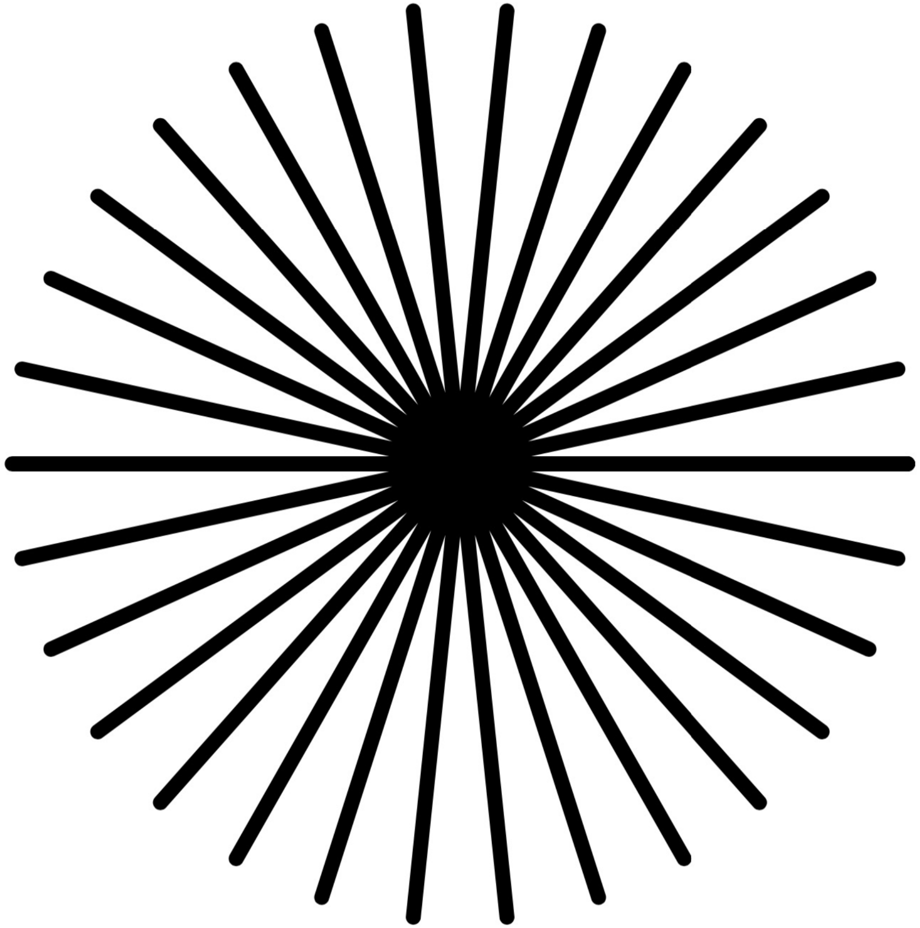
Loops: Another Example

```
%!PS
/X0   50 def             % center position
/Y0   50 def
/RMAX 48 def             % outer radius
/NTURN 5 def             % number of turns

/PHIMAX 360 NTURN mul def % maximal angle

X0 Y0 moveto             % start in center
0 10 PHIMAX {
  /phi exch def          % keep loop var.
                         % (drop from stack!)
  phi PHIMAX div         % get a value from 0 to 1
  dup mul RMAX mul       % square and scale
  dup                    % we need this for x and y
  phi cos mul X0 add     % this is x
  exch                   % get radius on top of stack
  phi sin mul Y0 add     % this is y
  lineto                 % draw a line
} for
stroke
showpage
```



Exercise 4a

- Modify exercise 3a using a for-loop for calling **`LINE`**
- Play with the increment

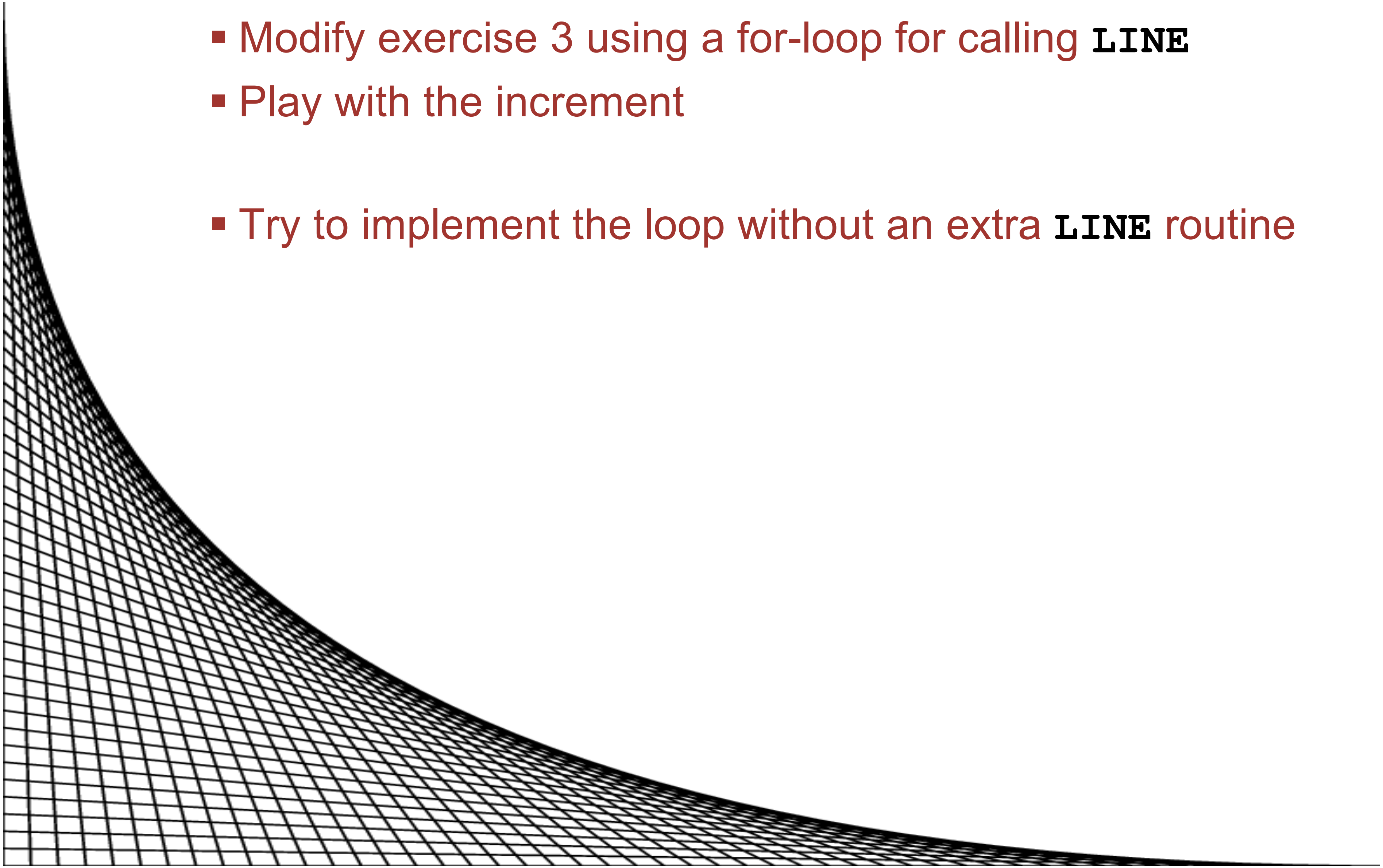


- Try to implement the loop without an extra **`LINE`** routine

Exercise 4b

- Modify exercise 3 using a for-loop for calling **`LINE`**
- Play with the increment

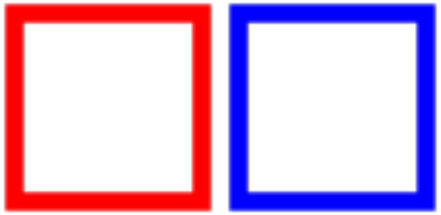
- Try to implement the loop without an extra **`LINE`** routine



Conditionals

- Conditional expression are possible
  - ***boolval* {…*commands*…} if**
  - ***boolval* {…*cmds_true*…} {…*cmds_false*…} ifelse**
- Boolean values can be
  - **true**
  - **false**
  - **x y eq**
  - **x y gt**
  - **bool1 bool2 or**
  - **bool not**
  - …

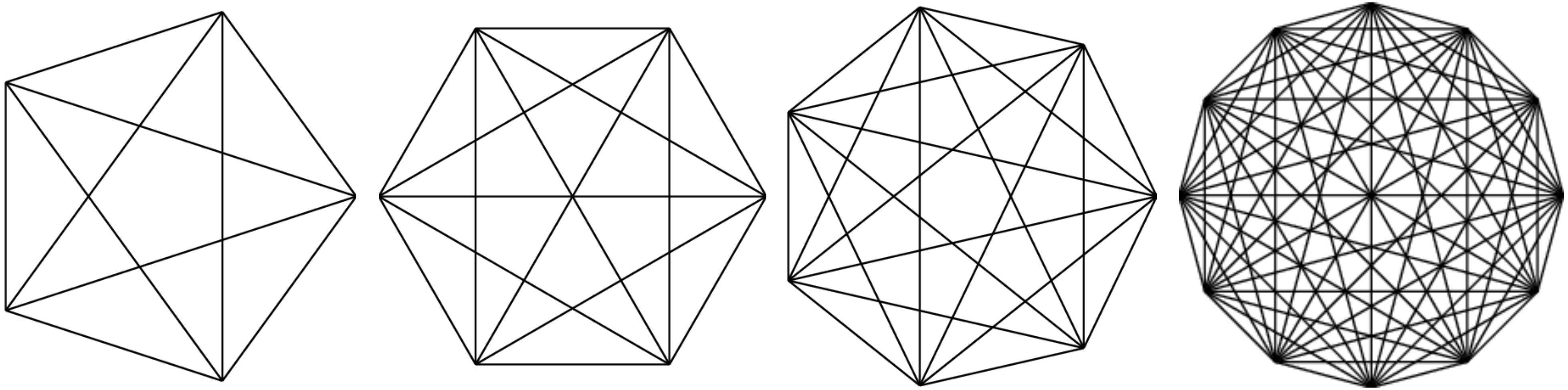
```
%!PS
/BOX { % Assume bool value on stack
 {1 0 0} {0 0 1} ifelse setrgbcolor
 0 0 10 10 rectstroke
} def

1   1 translate true  BOX
12 0 translate false BOX

showpage
```



- Can be used to comment out larger parts of code

Exercise 5

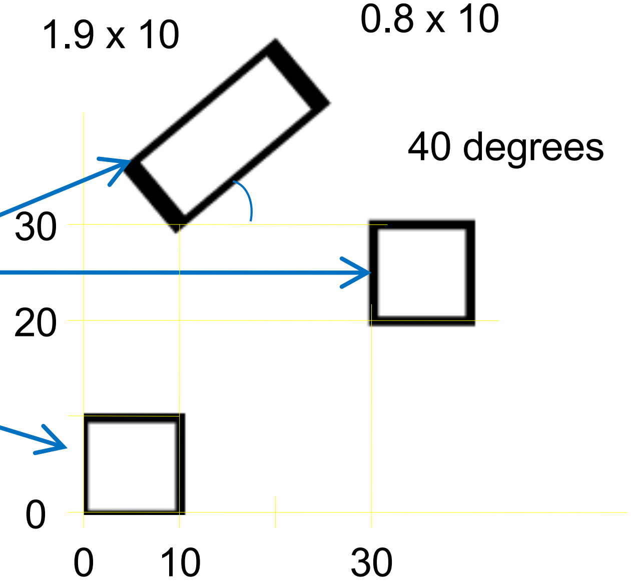
- This exercise is inspired by a problem in the ‘Mathekalender’ which offers a mathematics competition every year before Christmas at http://www.mathekalender.de
- Draw an N-fold polygon with all inner connections…
  - Use a double loop with 2 indices for the corners
  - Use a function to convert corner index to x/y (using trigonometry)



Translating and Scaling Things

- The coordinate system can be *translated*, *scaled* and *rotated* at any time.
- New transformations are ‘added on top’
  - **x y translate**
  - **x y scale** % negative arguments are allowed → flip
  - **phi rotate** % angle in degree, as always

```
%!PS
/BOX {
  0 0 10 10 rectstroke
} def

BOX
30 20 translate BOX
-20 10 translate
40 rotate
1.9 0.8 scale
BOX
showpage
```



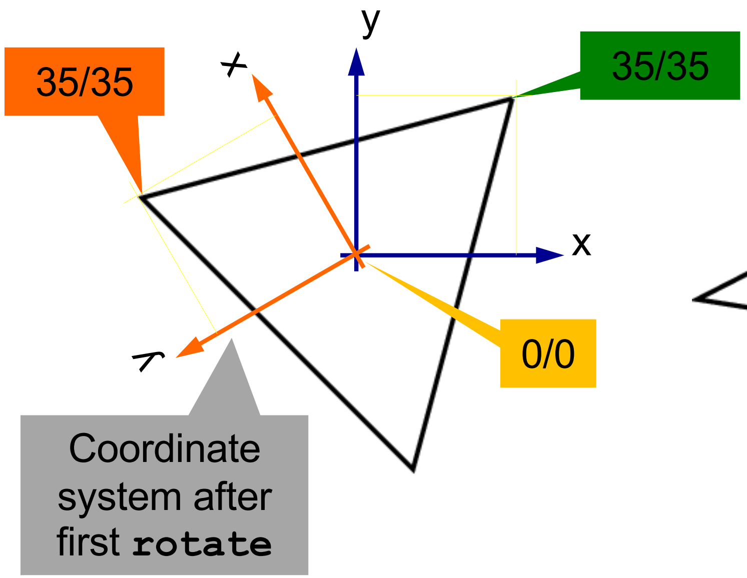
Applications of Coordinate Transformations

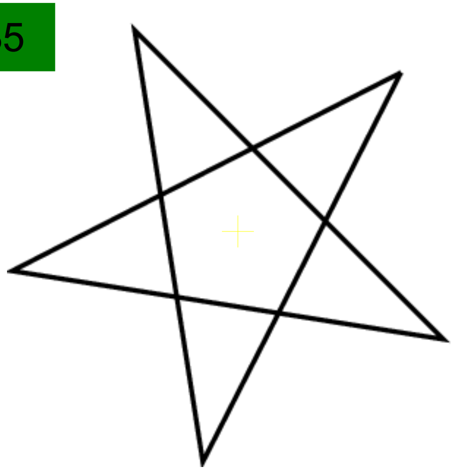
- Coordinate Transformations can simplify code *a lot*:

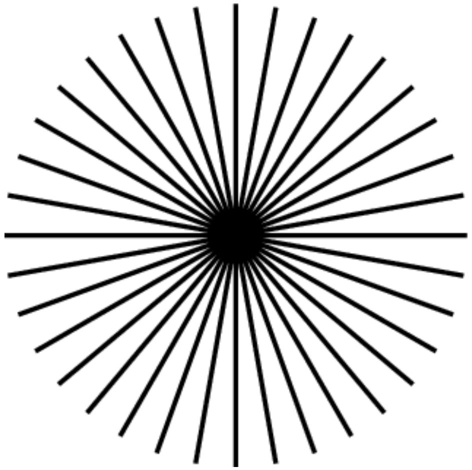
```
35 35 moveto
3 {
  120 rotate
  35 35 lineto
} repeat
stroke
```

```
35 35 moveto
5 {
  144 rotate
  35 35 lineto
} repeat
stroke
```

```
0 0 moveto
36 {
   50 0 lineto
    0 0 moveto
  10 rotate
} repeat
stroke
```







Converting Orientation and Units

- With

```
%!PS
2.835 dup scale      % now one unit is 1 mm
5 dup translate      % shift by 5/5 mm to center
0.1 setlinewidth     % line width is 0.1mm
newpath              % draw a frame around A4
  0   0 moveto       % (in portait format)
  0 287 lineto
200 287 lineto
200   0 lineto
closepath
stroke
100 143.5 translate  % move origin to the center
```

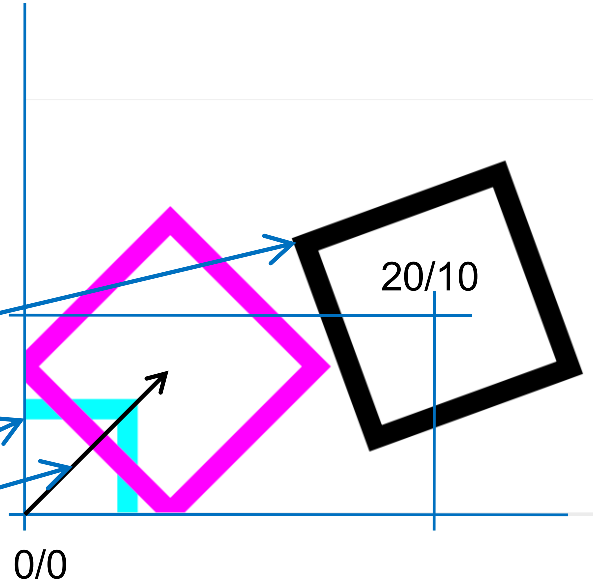
drawing can start in the center, in mm units.

- A frame is drawn around a A4 sheet.

Saving the Graphic State

- Temporary scaling / translating… operations often lead to 'corrupt' coordinate systems
- The graphics state can be remembered with **`gsave`** and restored with **`grestore`**
- Example:

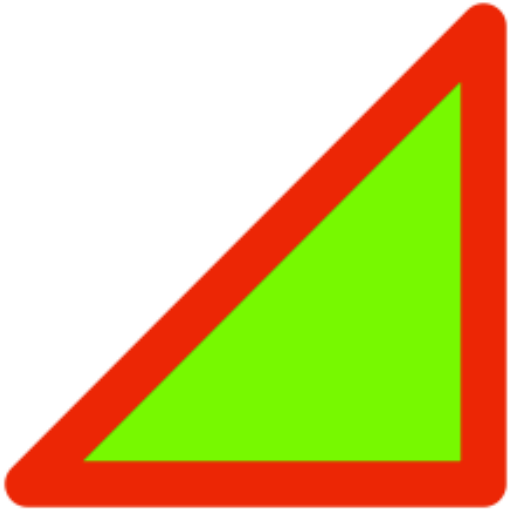
```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 30 20
/BOX { -5 -5 10 10 rectstroke } def

gsave
20 10 translate
10 rotate
0 setgray BOX % black box
grestore
0 1 1 setrgbcolor BOX % magenta

45 rotate
10 0 translate
1 0 1 setrgbcolor BOX % pink
```



Re-using a Path

- A path is part of the graphics state
- It can be ‘saved’ with gsave

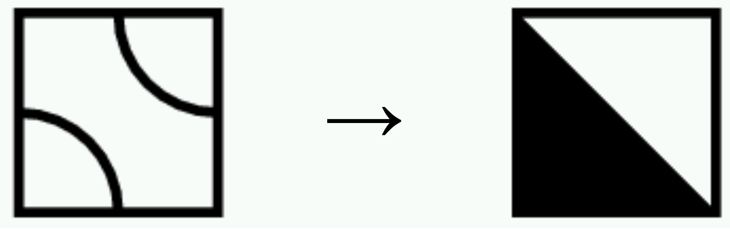
```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 10 10

0.5 setlinewidth
1 1 translate 1 setlinejoin

newpath
0 0 moveto 5 0 lineto 5 5 lineto
closepath

gsave
0 1 0 setrgbcolor fill % green fill
grestore

1 0 0 setrgbcolor stroke % red outline
showpage
```



Exercise 6

- Understand how the Truchet Pattern on page 16 works
- Copy the code and play around
  - Change the number of tiles
  - Change the size of the tiles

- Replace the rounded tile by a triangle



Drawing Text

- Strings are delimited by `()`. Example: `(text)`
- A **font** must be selected before you can start drawing:
  - `/name findfont` (or `currentfont`) — put font '*name*' to stack (height is 1 unit)
    Some font names:
    - `Times-Roman`
    - `Helvetica-Bold`
    - `Courier`
  - `value scalefont` — resize (multiply) font (leave on stack)
  - `setfont` — use it from now on (remove from stack)

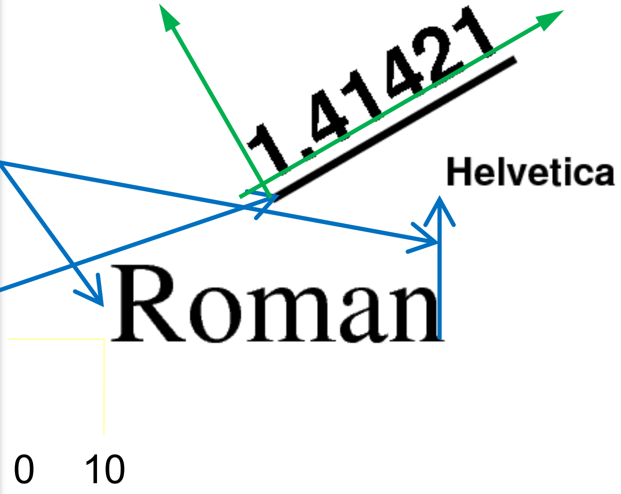
See also: selectfont

- Print a string (which is on the stack): `show`
  - start at current point. Current point moves to end of string!
  - Example: `0 0 moveto (Hello World) show`
- Convert a number to a string: `value 10 string cvs`
- Get width of a string: `strval stringwidth` (gets x *and* y)
  - Note: y is always zero and must often be `pop`ed

Drawing Text: Example

- Example:

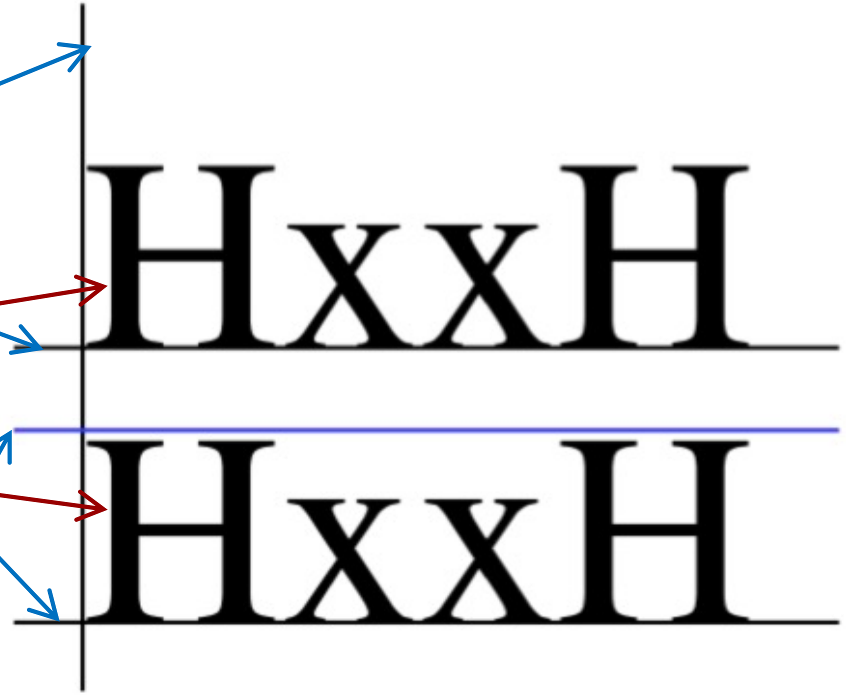
```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 80 70

10 10 translate 0 0 moveto
/Times-Roman findfont
15 scalefont setfont (Roman) show

0 20 rmoveto
/Helvetica-Bold findfont
5 scalefont setfont (Helvetica) show

/x 2 sqrt 10 string cvs def

20 20 translate 30 rotate
0 0 moveto
currentfont 2 scalefont setfont
x show
0 -2 moveto
x stringwidth rlineto stroke

showpage
```



(A Detail: Font Size)

- Font height is from baseline to baseline
- **Character height** is ~ 0.7 x font height (depending on font)

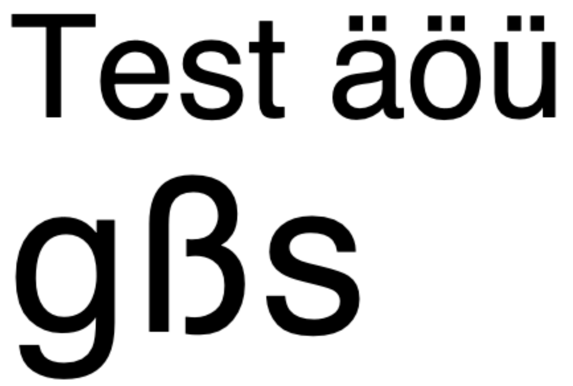
```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 70 60

10 10 translate

/FF 20 def
/Times-Roman findfont
FF scalefont setfont

0.3 setlinewidth
 0  -5 moveto 0 50 rlineto stroke
-5  FF moveto 60 0 rlineto stroke
-5   0 moveto 60 0 rlineto stroke

0 FF moveto (HxxH) show
0  0 moveto (HxxH) show

0 0 1 setrgbcolor
-5  FF 0.7 mul moveto 60 0 rlineto stroke

showpage
```



(Special Characters)

- The default character set does not contain special characters like ä,ö,ß,..
- This can be solved by assigning another character encoding to a font (see page 283 in PS Reference):

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 200 100

/Helvetica findfont dup length
dict begin {def} forall
/Encoding ISOLatin1Encoding def currentdict end
/HelveticaNew exch definefont pop

/HelveticaNew findfont  20 scalefont setfont
20 50 moveto
(äöü) show

/HelveticaNew findfont  30 scalefont setfont
20 20 moveto
(gßs) show

showpage
```



```
Test äöü
gßs
```

Exercise 7

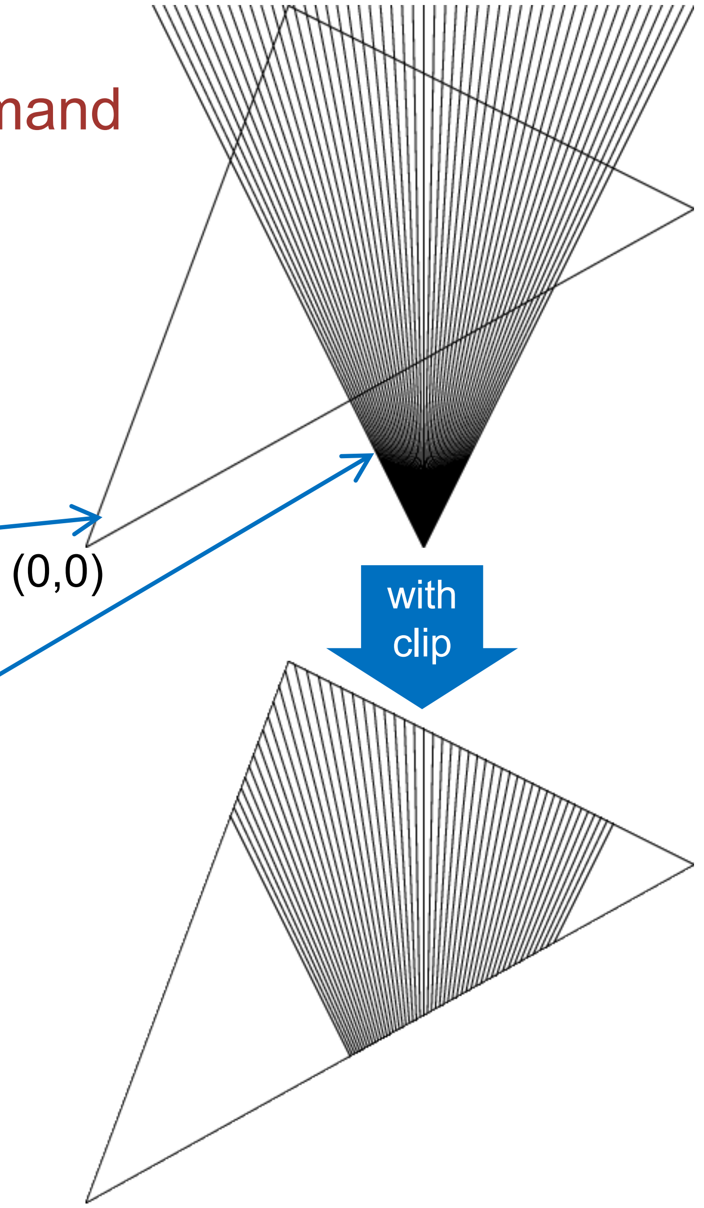
- Draw a box from (10,10) to (50,30)
- Print some text *centered* in the box
  - Use **`stringwidth`** to get the x- and y size of the text
  - Unfortunately, the y size is zero and cannot be used!
    Use the font height you have chosen instead.

(Advanced Topic: Clipping)

- A path can be used to restrict the drawing area using the **`clip`** command
- **`initclip`** clears the clipping path

construct clipping path

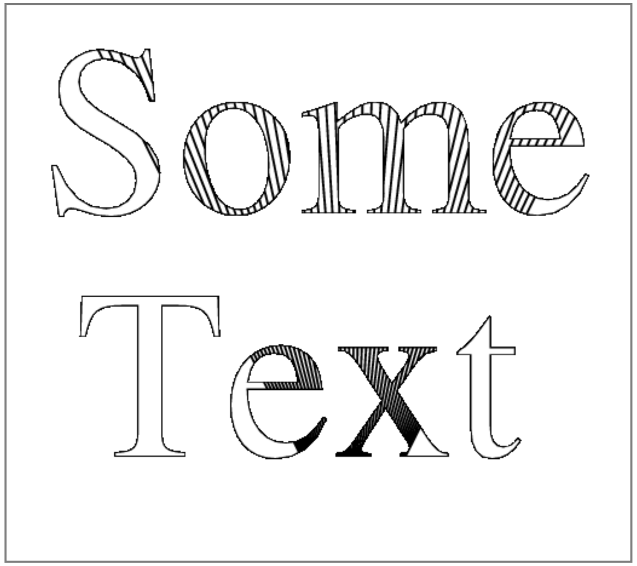
```
%!PS
0.2 setlinewidth

newpath 0 0 moveto
30 80 lineto 90 50 lineto
closepath
clip

0 2 100 {
  50 0 moveto 100 lineto
} for
stroke

showpage
```



(For fun: charpath)

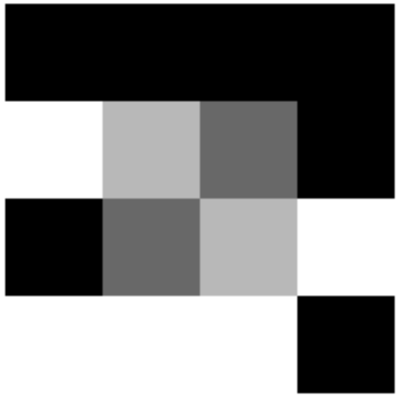
- The outline of characters can be converted to a path using the **`charpath`** command. (Needs extra bool argument)
- Example using **`clip`**:

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 90 80
0.3 setlinewidth

/Times-Roman findfont
35 scalefont setfont
 5 50 moveto (Some) false charpath
10 15 moveto (Text) false charpath

clip

0 2 100 {
  50  0 moveto
    100 lineto
} for
stroke

showpage
```



(Advanced: Bit Maps)

- The command **`image`** draws a bit map in a *unit square*
  - To change size: scale in x- and y
- Parameters of **`image`** are:
  - Number of pixels in x
  - Number of pixels in y
  - Bits per pixel
  - A rotation matrix (not explained here..)
  - A function to get the values. Simplest case is a list of values
- Similar command is **`colorimage`**
  - It has some more parameters…



```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 100 100

10 10 translate % move image to middle of page
80 80 scale     % make image one inch on a side
4 4 2 [4 0 0 4 0 0] {<fc1be400>} image
showpage
```

We need
4 x 4 x 2 = 32 bit

(Example for colorimage)

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 102 102

1 1 translate
100 100 scale

/picstr 6 string def

2 2 4 [2 0 0 -2 0 2]
{ currentfile picstr readhexstring pop}
false 3
colorimage
f000080f0088

showpage
```

NX NY bits_per_col

colors separate ?

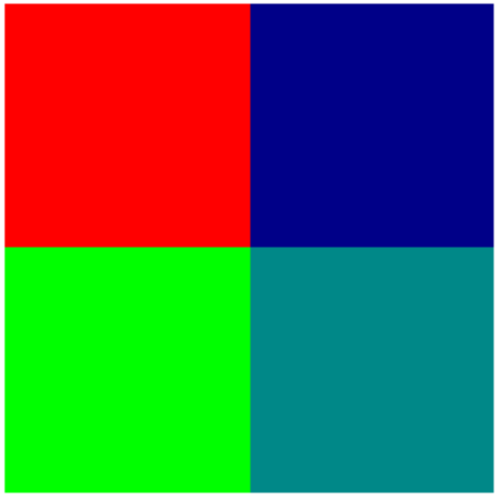
Function to create a string of NX x NCOL characters

matrix

NCOL

Function to retrieve data from file

Data: 2 x 2 x 4 x 3 bit = 12 Byte



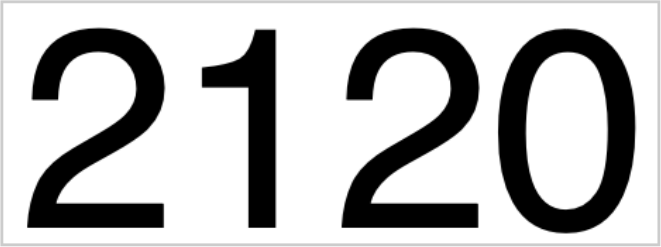
Stack Underflow

- A very common error is **stack underflow**
  - Not enough arguments on stack
- Debugging help:

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox:  0 0 35 13

/PrintStackFillState
{count 10 string cvs show} def

/Helvetica findfont 15 scalefont setfont
1 1 moveto

1 2      PrintStackFillState
Add      PrintStackFillState
Dup      PrintStackFillState
pop pop  PrintStackFillState

showpage
```

Count returns number of entries on stack

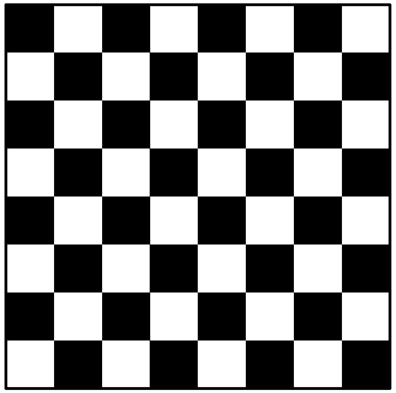
Output:

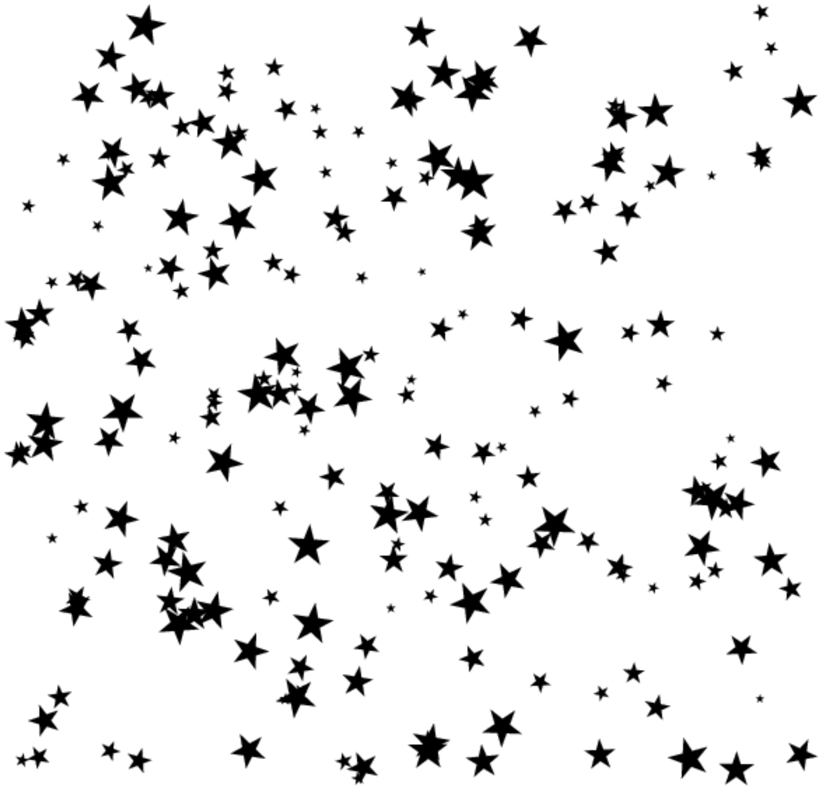


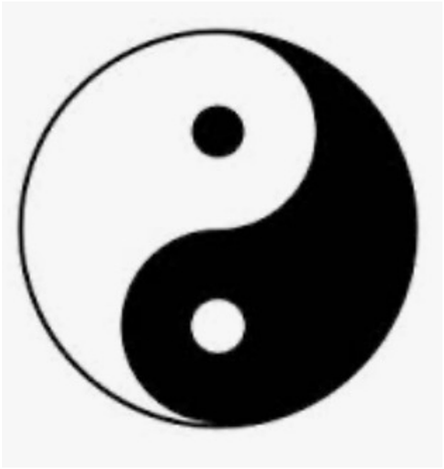
```
2120
```

Need Ideas to Try Out your New Skills ?

Inspirations

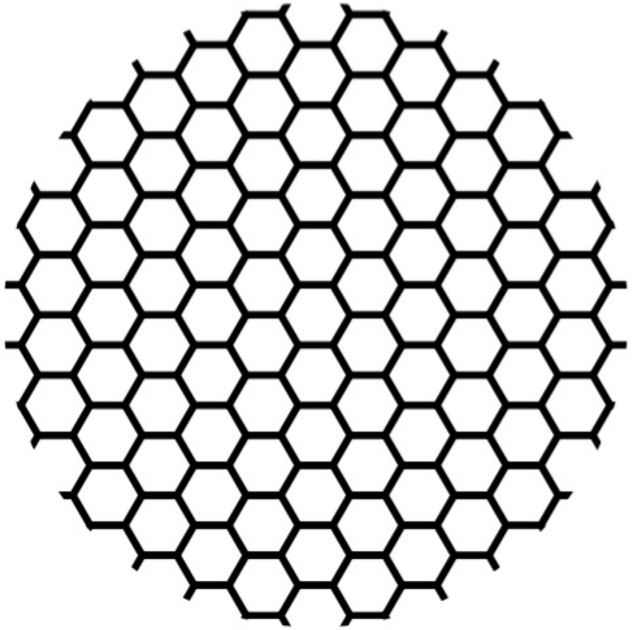


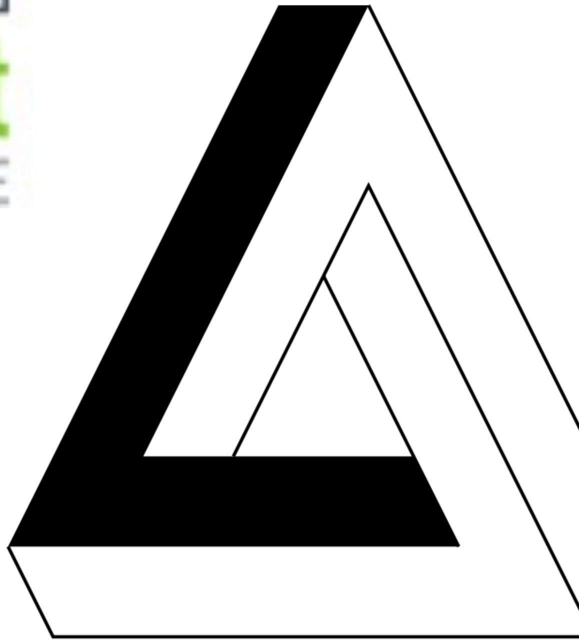




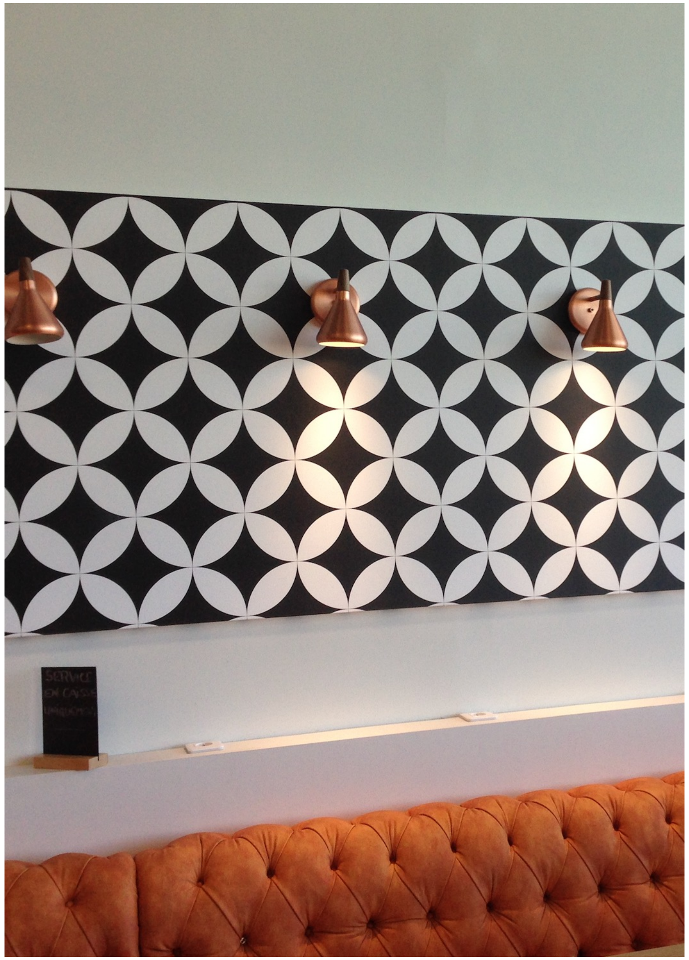
Inspirations

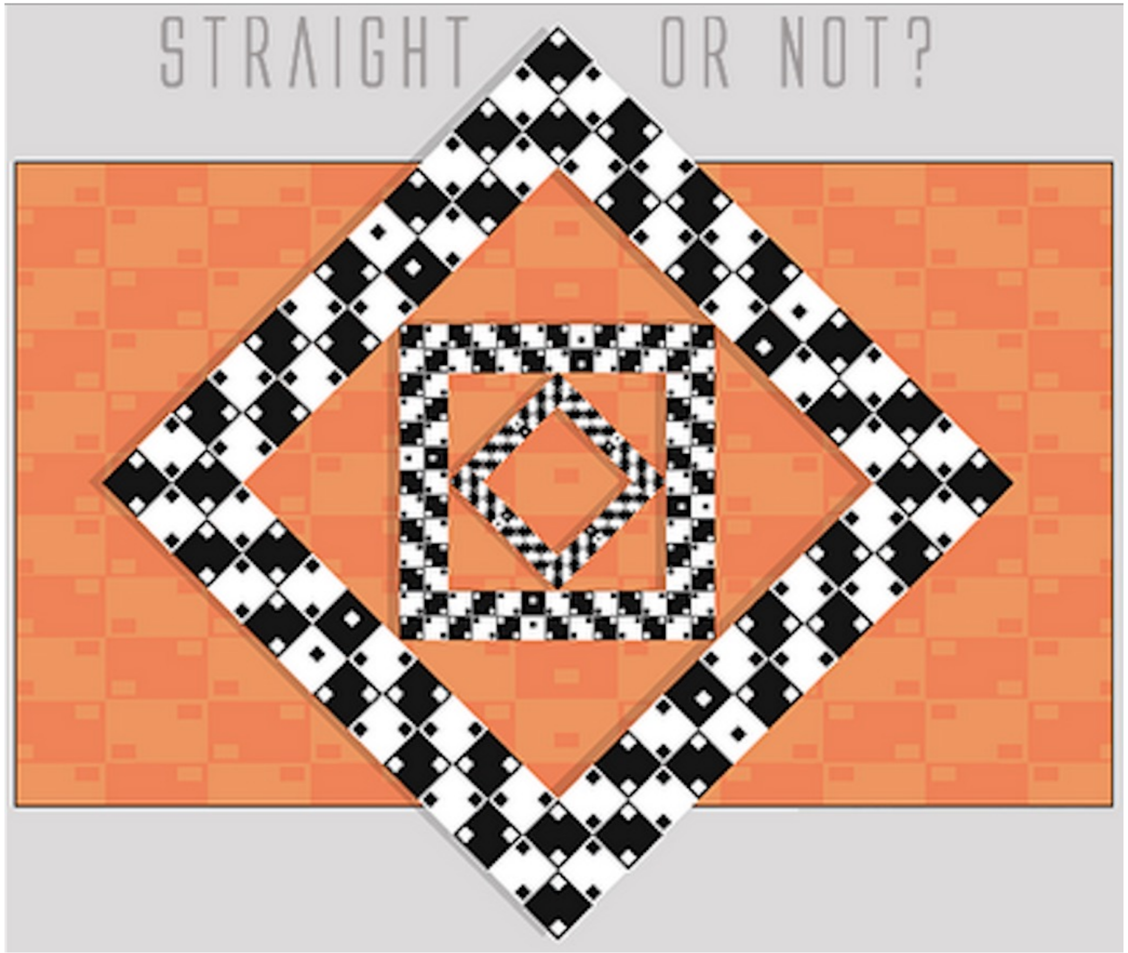
BioQuant
MODEL base of LIFE





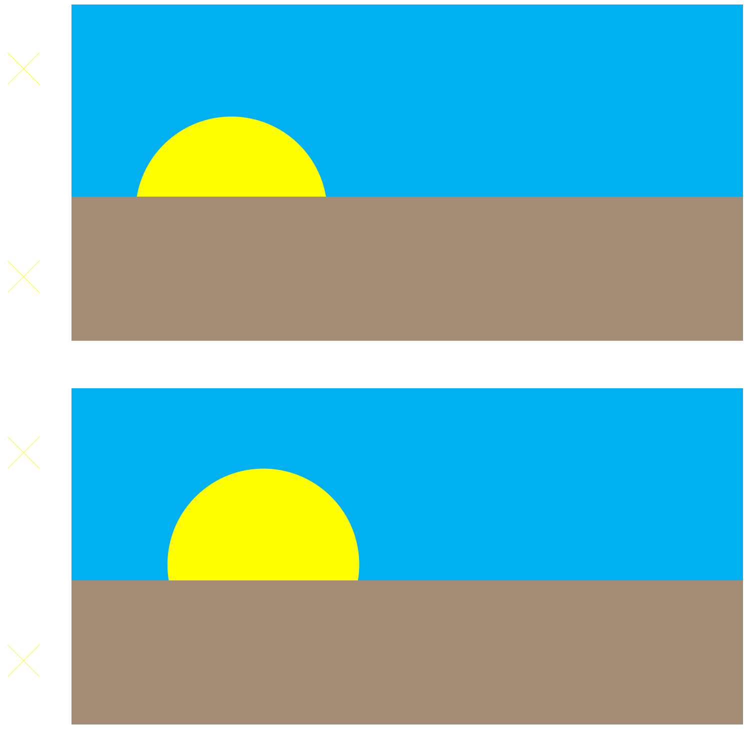
More Inspirations

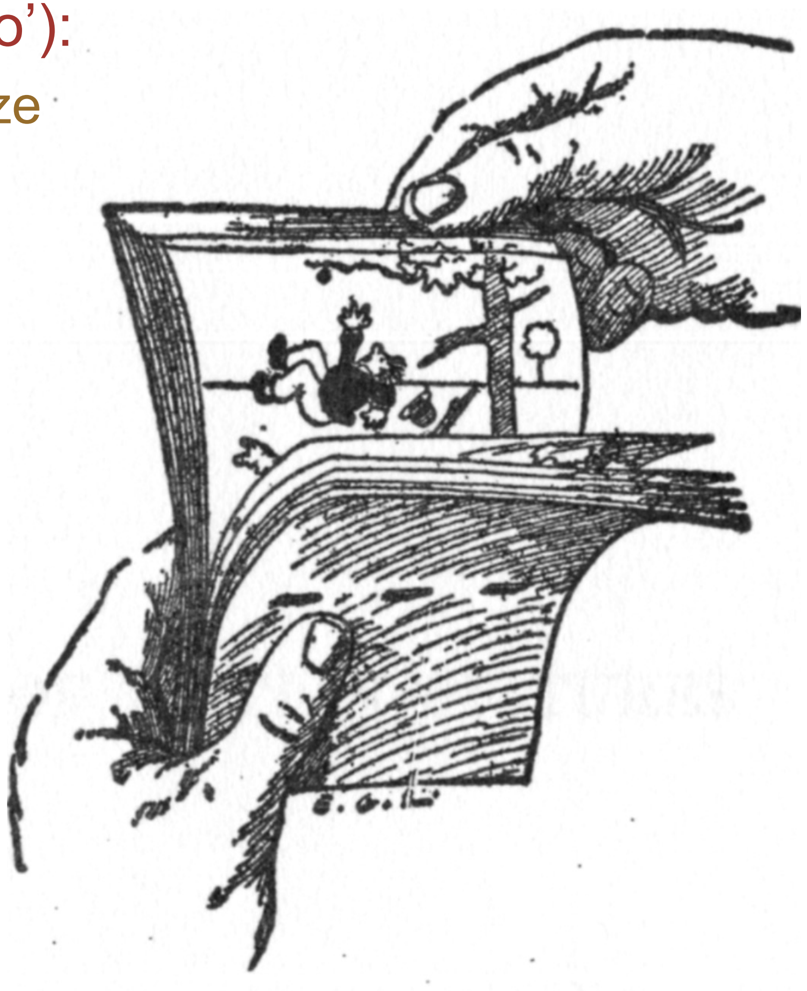




More Inspiration

- Make a Flipbook (‘Daumenkino’):
  - Define a (small) sheet of unit size
  - Add alignment holes / pins / markers for later assembly
  - Add a scene drawing
  - Generate a series of sheets



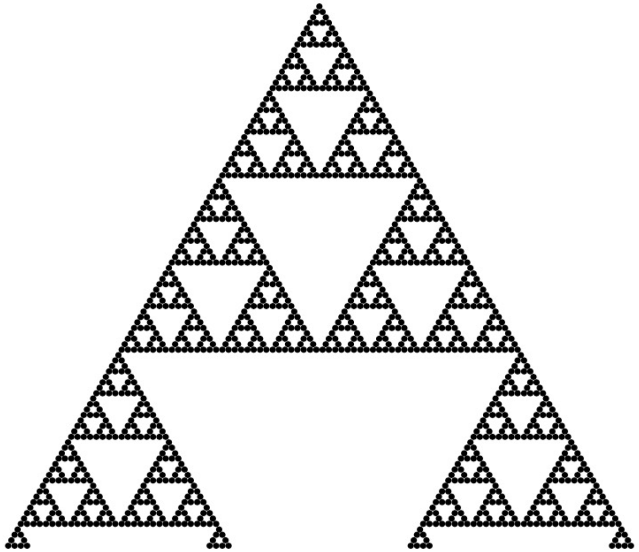


THE KINEOGRAPH.

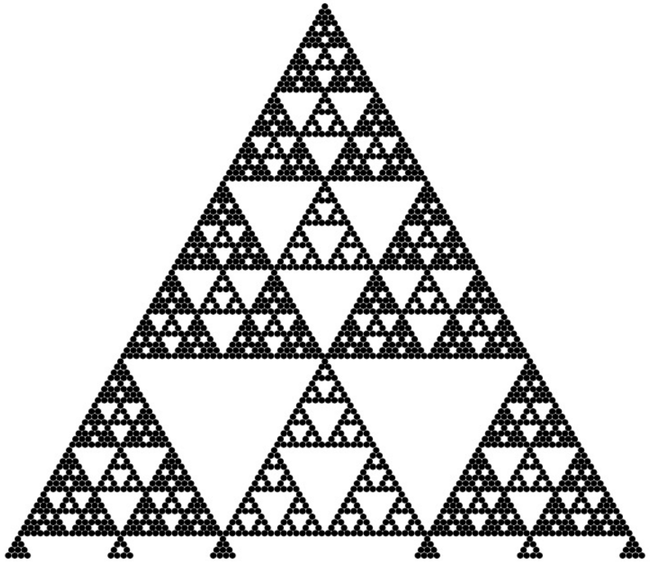
Wikipedia

More Inspirations

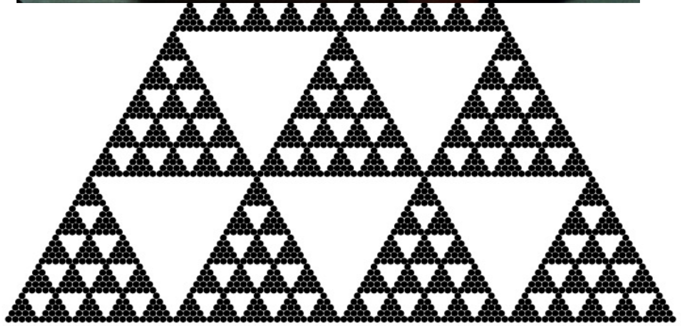
- Draw Pascal‘s Triangle (https://de.wikipedia.org/wiki/Pascalsches_Dreieck)
- Put a marker (circle, triangle,..) at the position of on all numbers which are multiples of some modulus K
- Examples:



K = 2



K = 4



K = 5

MISC

Document File Structure

- The life of viewers, print managers, etc. is simplified by adding **Document File Structure** commands, as described in the '*PostScript Language Document Structuring Conventions Specification*' document (on Adobe Web Page)
- Main Document blocks are

• Comments	at beginning of document	Prolog
• Prolog	Procedure definitions	
• Setup	General setup	Script
• Pages	Content (opt.: PageSetup...)	
• Trailer	Cleanup	

- Structuring by
  - %%BeginProlog
  - %%EndProlog
  - ...

Document File Structure: Example

```
%!PS-Adobe-3.0 EPSF-3.0
%%BoundingBox: 0 0 200 300
%%Creator: Peter Fischer
%%Title: SomeTitle
%%CreationDate: Adate
%%Pages: 1
%%DocumentMedia: … descibe
  paper sizes here…
%%EndComments
```

Must be **one** block, i.e. without blank lines!

Columns (:) are important

```
/somecommand … def
%%EndProlog
```

Command Definitions

```
%%BeginSetup
…
%%EndSetup
```

Setup before Drawing

```
%%Page: 1 1
…
```

Content of Page 1

```
%%Trailer
…
%%EOF
```

Trailer

Multiple Pages

- Only possible in .ps, not in .eps
- `%%Pages: N` gives total number of pages
- `%%Page: i i` starts page i. i must be increasing per page
- Pages *should* be protected by save…restore
  (in case content redefines system commands)
- Example:

```
%!PS-Adobe-3.0
%%Pages: 2
%%EndComments

%%Page: 1 1
save …commands … restore

%%Page: 2 2
save …commands … restore

%%EOF
```

Error Messages

- GhostScript produces Error messages
  - To Clear the Console, Start Viewer from Scratch!
  - Scroll up to **First** error

- Some typical Errors

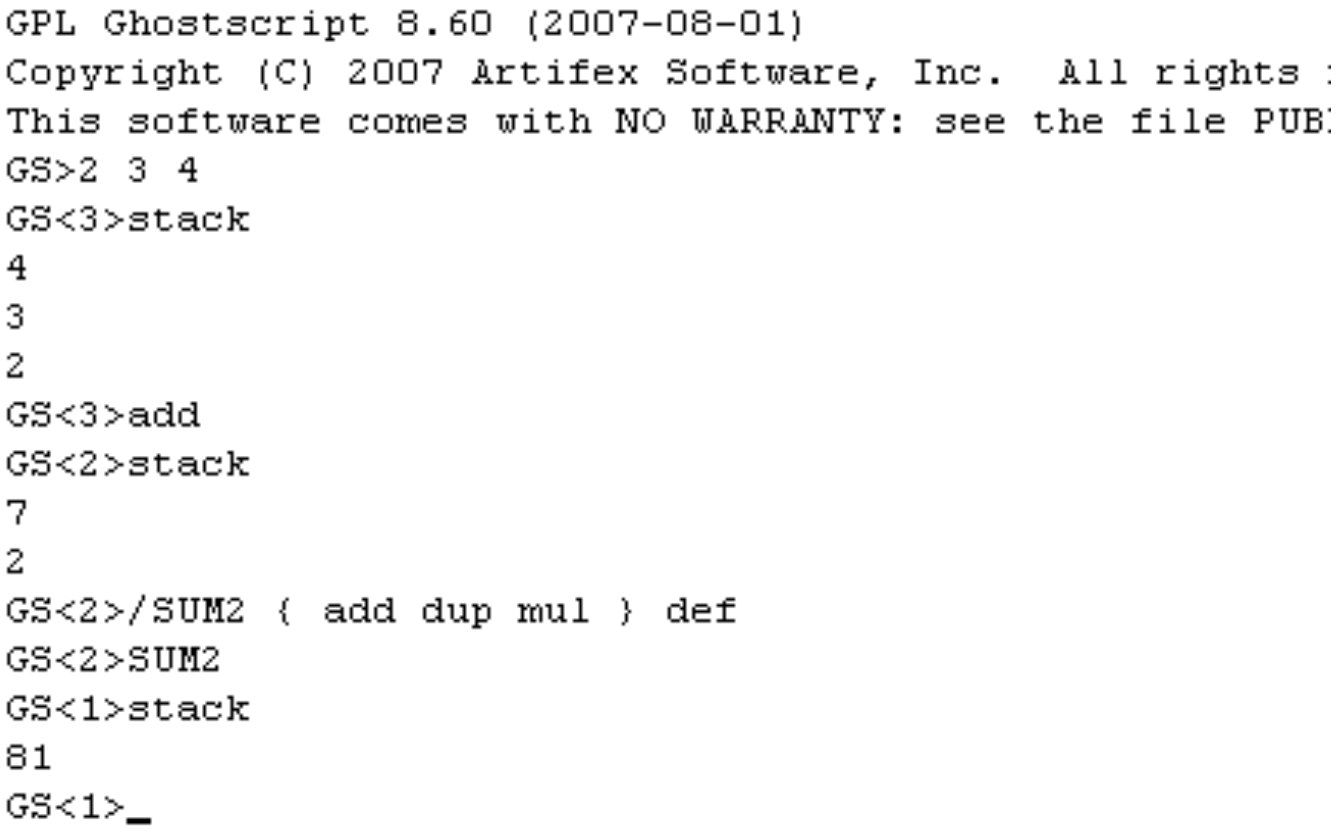
• Stack underflow	command has too few arguments
• No current point	`show` or `stroke` without point data
• Variable not known	…
• …	

Converting to Other Formats

- Linux:
  - ps2eps
  - ps2pdf
  - epstopdf
- Convert
  - http://www.imagemagick.org/script/convert.php

Interactive Mode

- GhostScript can be run interactively
  - List stack using **`stack`** command
  - Not further covered here…



```
GPL Ghostscript 8.60 (2007-08-01)
Copyright (C) 2007 Artifex Software, Inc.  All rights :
This software comes with NO WARRANTY: see the file PUB:
GS>2 3 4
GS<3>stack
4
3
2
GS<3>add
GS<2>stack
7
2
GS<2>/SUM2 { add dup mul } def
GS<2>SUM2
GS<1>stack
81
GS<1>_
```

History

- PostScript has been developed by Adobe

Level1	1984
(Display PostScript)	1988
Level 2	1991
PostScript 3	1997/98

- Info at http://www.adobe.com/devnet/postscript.html

- pdf is an ‚extension' of PostScript
  - All graphics possibilities are preserved
  - transparency
  - Better page structure (can scroll to pages without code analysis)
  - Interactive elements
  - …
  - But: No programming language!

Source: wikipedia

(atend)

- Some %%-Parameters can be deferred to the trailer section with (atend) instead of parameter
  - quite useful if page size or #pages not know at the beginning
- Example:

```
%!PS-Adobe-3.0
%%Pages: (atend)
%%EndComments

%%Page: 1 1
save …commands … restore

%%Page: 2 2
save …commands … restore

%%Trailer
%%Pages: 2

%%EOF
```

What Else ?

- Other PostScript features are
  - Control structures: loop, forall, …
  - Access to external files
  - Arrays
  - Dictionaries
  - …
- Crazy Stuff (from the web)
  - Raytracer
  - Cellular Automaton
  - Henon Attractor
  - …