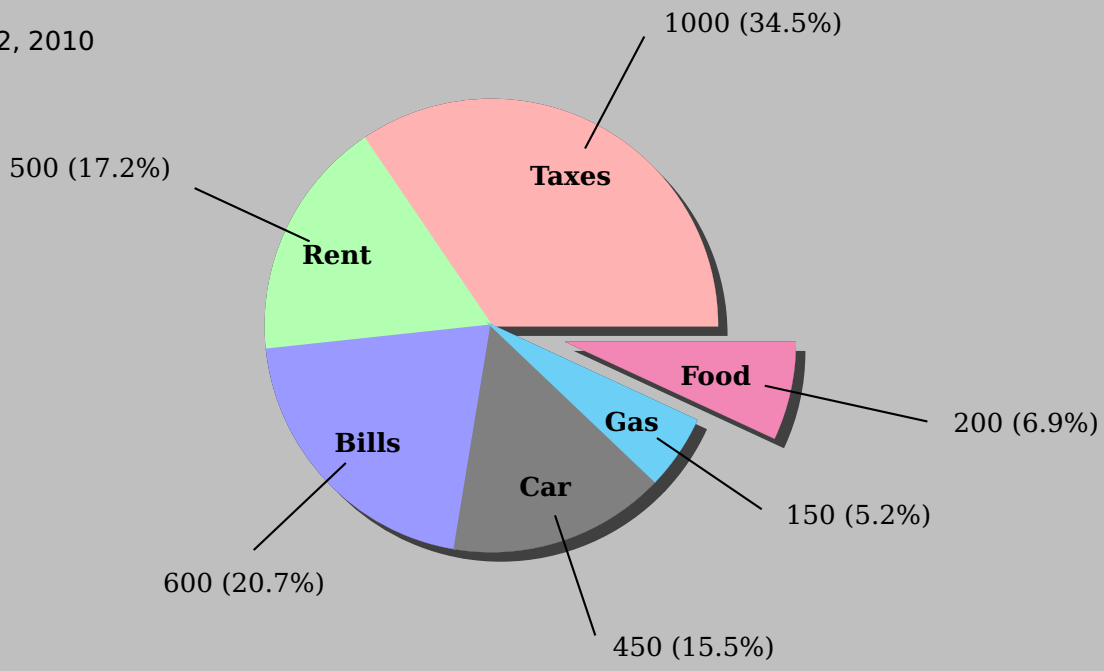
PSTricks

pstricks-add
additionals Macros for pstricks

v.3.39

March 12, 2010



Documentation by
Herbert Voß

Package author(s):
Dominique Rodriguez
Herbert Voß

This version of pstricks-add needs pstricks.tex version >1.04 from June 2004, otherwise the additional macros may not work as expected. The ellipsis material and the option asolid (renamed to eofill) are now part of the new pstricks.tex package, available at CTAN or at http://perce.de/LaTeX/. pstricks-add will for ever be an experimental and dynamical package, try it at your own risk.

- It is important to load pstricks-add as the **last** PSTricks related package, otherwise a lot of the macros won't work in the expected way.
- pstricks-add uses the extended version of the keyval package. So be sure that you have installed pst-xkey which is part of the xkeyval-package, and that all packages that use the old keyval interface are loaded **before** the xkeyval.[1]
- the option tickstyle from pst-plot is no longer supported; use ticksize instead.
- the option xyLabel is no longer supported; use the option labelFontSize instead.
- if pstricks-add is loaded together with the package pst-func then InsideArrow of the \psbezier macro doesn't work!

Thanks to: Hendri Adriaens; Stefano Baroni; Martin Chicoine; Gerry Coombes; Ulrich Dirr; Christophe Fourey; Hubert Gäßlein; Jürgen Gilg; Denis Girou; Peter Hutnick; Christophe Jorssen; Uwe Kern; Manuel Luque; Jens-Uwe Morawski; Tobias Nähring; Rolf Niepraschk; Alan Ristow; Christine Römer; Arnaud Schmittbuhl; Timothy Van Zandt

Contents

1. \psGetSlope and \psGetDistance . . . 5
2. "'Handmade"' lines :-) . . . 6
3. \rmultiput: a multiple \rput . . . 7
4. \psrotate: Rotating objects . . . 8
5. \psComment: comments to a graphic . . . 10
6. \psChart: a pie chart . . . 11
7. \psHomothetie: central dilatation . . . 14
8. \psbrace . . . 15
9. Random dots . . . 20
10. \psDice . . . 22
11. \psFormatInt . . . 23
12. \psRelNode and \psDefPSPNodes . . . 24
13. \psRelLine . . . 25
14. \psParallelLine . . . 28
15. \psIntersectionPoint . . . 29
16. psCancel environment . . . 31
17. \psStep . . . 33
18. Tangent lines . . . 36
    - 18.1. \psTangentLine and option Tnormal . . . 36
    - 18.2. \psplotTangent and option Tnormal . . . 37
19. Successive derivatives of a function . . . 42
20. Variable step for plotting a curve . . . 44
    - 20.1. Theory . . . 44
    - 20.2. The cosine . . . 44
    - 20.3. The Napierian Logarithm . . . 45
    - 20.4. Sine of the inverse of x . . . 46
    - 20.5. A really complecated function . . . 47
    - 20.6. A hyperbola . . . 48
    - 20.7. Using \parametricplot . . . 49
21. New math functions and their derivatives . . . 50
    - 21.1. The inverse sine and its derivative . . . 50
    - 21.2. The inverse cosine and its derivative . . . 51
    - 21.3. The inverse tangent and its derivative . . . 52
    - 21.4. Hyperbolic functions . . . 53
22. \psplotDiffEqn – solving diffential equations . . . 57
    - 22.1. Variable step for differential equations . . . 58
    - 22.2. Equation of second order . . . 62
    - 22.3. Save final state of a equation . . . 76
23. \psMatrixPlot . . . 77
24. Dashed Lines . . . 83
25. Arrows . . . 85
    - 25.1. Definition . . . 85
    - 25.2. Multiple arrows . . . 85

25.3. hookarrow . . . 86
25.4. hookrightarrow and hookleftarrow . . . 87
25.5. ArrowInside Option . . . 87
25.6. ArrowFill Option . . . 88
25.7. Examples . . . 89
25.8. Special arrows v-V,t-T, and f-F . . . 96
25.9. Special arrow option arrowLW . . . 97
26. Transparent colors . . . 97
27. „Manipulating transparent colors” . . . 97
28. Calculated colors . . . 98
29. Gouraud shading . . . 100
A. \resetOptions . . . 103
B. PostScript . . . 103
C. List of all optional arguments for pstricks-add . . . 104
References . . . 105

1. \psGetSlope and \psGetDistance

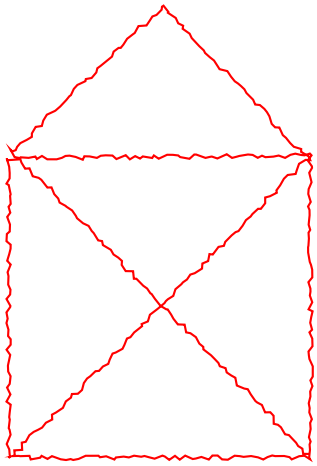
\psGetSlope(x_1,y_1)(x_2,y_2)\⟨*macro*⟩
\psGetDistance(x_1,y_1)(x_2,y_2)\⟨*macro*⟩

0.0 5.00146
2.0 2.23656
-0.2 5.09982
0.00615

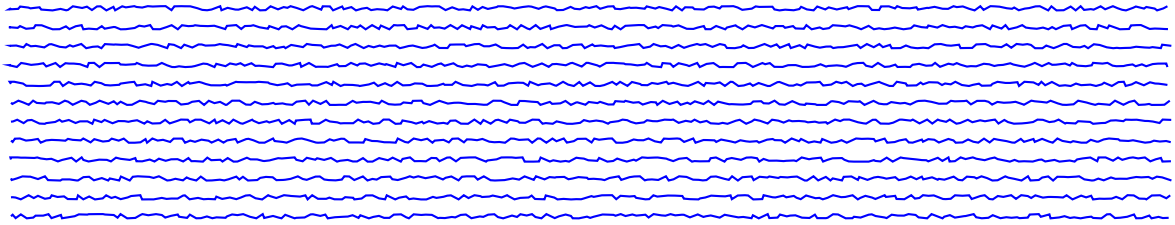
```
\psGetSlope(-2,1)(3,1)\SlopeVal \SlopeVal \quad
\psGetDistance(-2,1)(3,1)\DVal \DVal\\
\psGetSlope(-2,1)(-3,-1)\SlopeVal \SlopeVal\quad
\psGetDistance(-2,1)(-3,-1)\DVal \DVal\\
\psGetSlope(-2,0)(3,-1)\SlopeVal \SlopeVal\quad
\psGetDistance(-2,0)(3,-1)\DVal \DVal\\
\psGetSlope(-2111,-12)(3,1)\SlopeVal \SlopeVal\quad
%\psGetDistance(-2111,-12)(3,1)\DVal ==> Overflow!
```

2. "'Handmade"' lines :-)

\pslineByHand [Options] $(x_1,y_1)(x_2,y_2)(x_3,y_3)$ ...

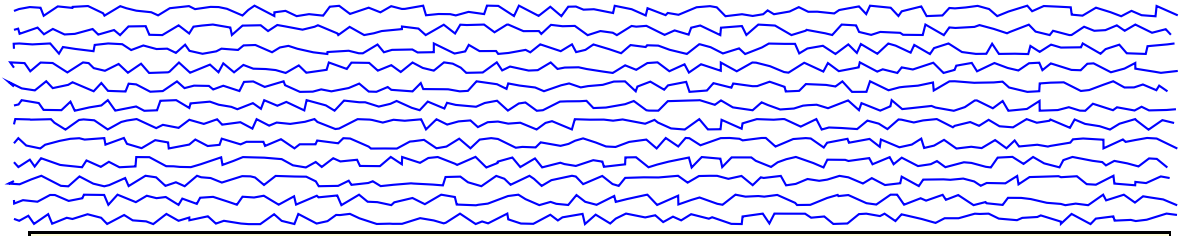


```
\begin{pspicture}(4,6)
\psset{unit=2cm}
  \pslineByHand[linecolor=red](0,0)(0,2)
    (2,2)(2,0)(0,0)(2,2)(1,3)(0,2)(2,0)
\end{pspicture}
```



```
\begin{pspicture}(\linewidth,3)
\multido{\rA=0.00+0.25}{12}{\pslineByHand[linecolor=blue](0,\rA)(\linewidth,\
  rA)}
\end{pspicture}
```

The amplitude and the width can be changed by the optional arguments `varsteptol` and `VarStepEpsilon`. Both are preset to `VarStepEpsilon=2,varsteptol=0.8`.

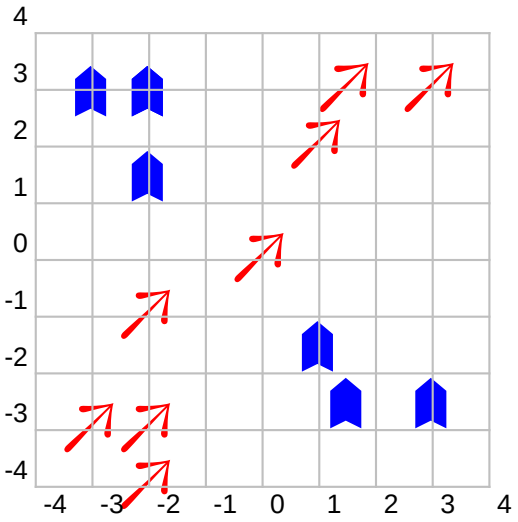


```
\begin{pspicture}(\linewidth,3)
\multido{\rA=0.00+0.25}{12}{%
  \pslineByHand[linecolor=blue,VarStepEpsilon=4,varsteptol=2](0,\rA)(\
    linewidth,\rA)}
\end{pspicture}
```

3. \rmultiput: a multiple \rput

PSTricks already has a \multirput, which puts a box n times with a difference of dx and dy relative to each other. It is not possible to put it with a different distance from one point to the next. This is possible with \rmultiput:

\rmultiput* [Options] {*any material*}$(x_1,y_1)(x_2,y_2)\ldots(x_n,y_n)$

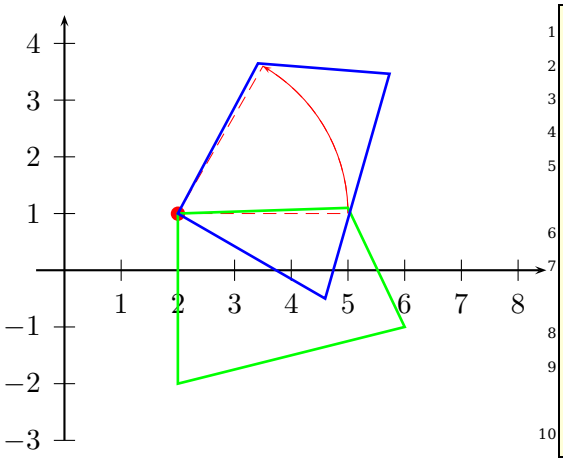



```
\psset{unit=0.75}
\begin{pspicture}(-4,-4)(4,4)
\rmultiput[rot=45]{\red\psscalebox{3}{\ding
  {250}}}%
   (-2,-4)(-2,-3)(-3,-3)(-2,-1)(0,0)(1,2)
     (1.5,3)(3,3)
\rmultiput[rot=90,ref=lC]{\blue\psscalebox
  {2}{\ding{253}}}%
   (-2,2.5)(-2,2.5)(-3,2.5)(-2,1)(1,-2)
     (1.5,-3)(3,-3)
\psgrid[subgriddiv=0,gridcolor=lightgray]
\end{pspicture}
```

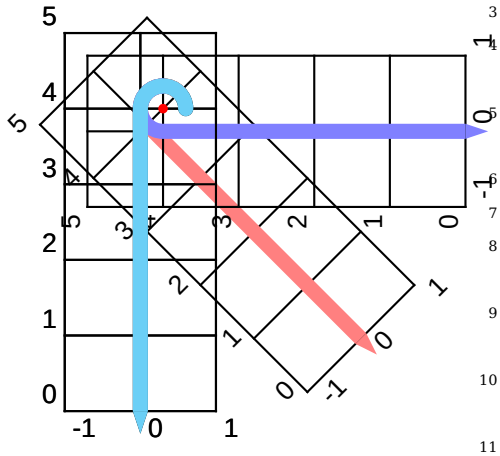
4. \psrotate: Rotating objects

\rput also has an optional argument for rotating objects, but it always depends on the \rput coordinates. With \psrotate the rotating center can be placed anywhere. The rotation is done with \pscustom, all optional arguments are only valid if they are part of the \pscustom macro.

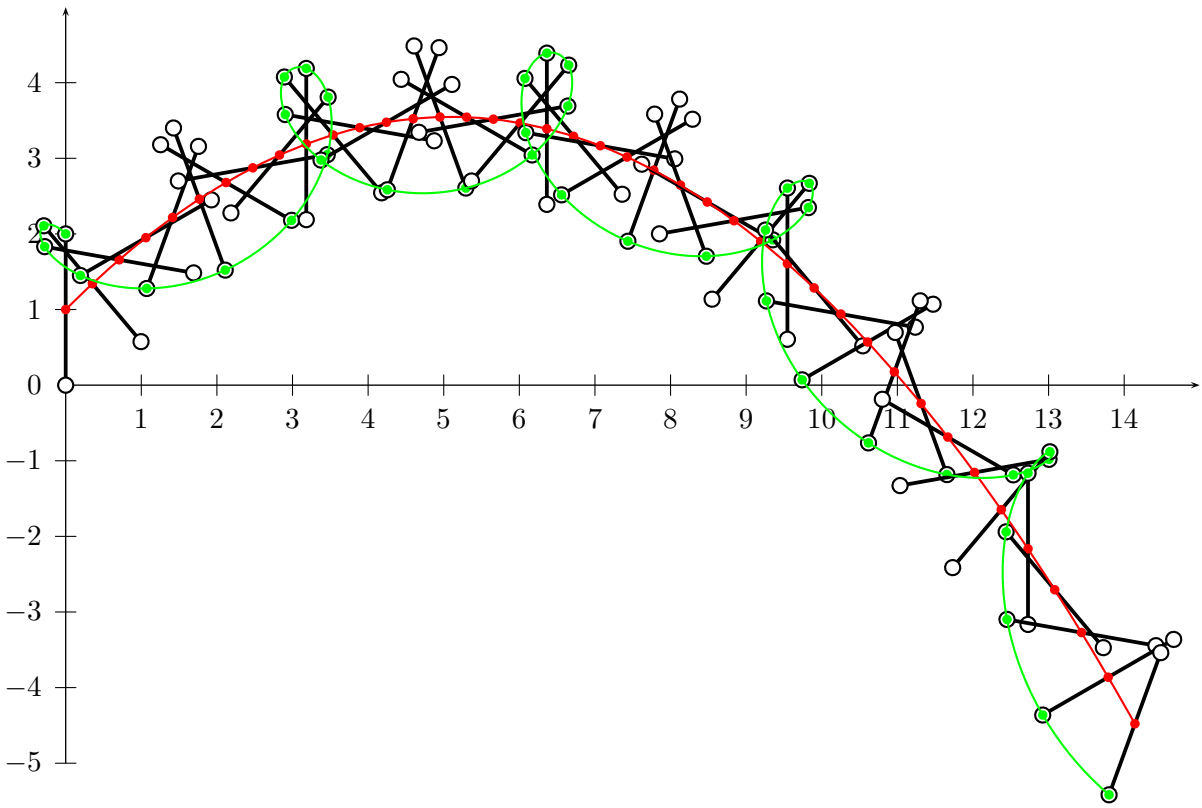
\psrotate [Options] (x, y) {*rot angle*} {*object*}



```
\psset{unit=0.75}
\begin{pspicture}(-0.5,-3.5)(8.5,4.5)
  \psaxes{->}(0,0)(-0.5,-3)(8.5,4.5)
  \psdots[linecolor=red,dotscale=1.5](2,1)
  \psarc[linecolor=red,linewidth=0.4pt,
    showpoints=true]
      {->}(2,1){3}{0}{60}
  \pspolygon[linecolor=green,linewidth=1pt
    ](2,1)(5,1.1)(6,-1)(2,-2)
  \psrotate(2,1){60}{%
    \pspolygon[linecolor=blue,linewidth=1pt
      ](2,1)(5,1.1)(6,-1)(2,-2)}
\end{pspicture}
```



```
\begin{pspicture}(-1,-1)(3,6)
\def\canne{% Idea by Manuel Luque
  \psgrid[subgriddiv=0](-1,0)(1,5)
  \pscustom[linewidth=2mm]{\psline(0,4)\
    psarcn(0.3,4){0.3}{180}{360}}%
  \pscircle*(0.6,4){0.1}\pstriangle*(0,0)
    (0.2,-0.3)}
\def\Object{}
  \canne
  \psrotate(0.3,4){45}{\psset{linecolor=red
    !50}\canne}
  \psrotate(0.3,4){90}{\psset{linecolor=blue
    !50}\canne}
  \psrotate(0.3,4){360}{\psset{linecolor=cyan
    !50}\canne}
  \psdot[linecolor=red](0.3,4)
\end{pspicture}
```

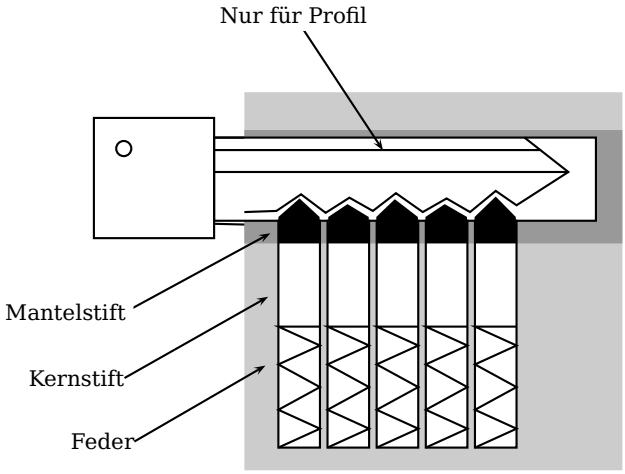



```
\begin{pspicture}(0,-6)(15,5)
\def\majorette{\psline[linewidth=0.5mm](0,2)% Idea by Manuel Luque
           \pscircle[fillstyle=solid]{0.1}
           \pscircle[fillstyle=solid](0,2){0.1}}
 \psaxes[linewidth=0.5pt]{->}(0,0)(0,-5)(15,5)
 \pstVerb{/V0 10 def /Alpha 45 def}% vitesse initiale, angle de lancement
 \multido{\nT=0.0+0.05,\iA=0+40}{41}{%
  \pstVerb{/nT \nT\space def}%
  \rput(!V0 Alpha cos mul nT mul -9.81 2 div nT dup mul mul V0 Alpha sin mul
    nT mul add){%
     \psrotate(0,1){\iA}{\majorette\psdot[linecolor=red](0,1)\psdot[linecolor
       =green](0,2)}}}
 \parametricplot[linecolor=red]{0}{2}{% trajectoire du milieu
   V0 Alpha cos mul t mul -9.81 2 div t dup mul mul V0 Alpha sin mul t mul
     add 1 add}
 \parametricplot[linecolor=green,plotpoints=360]{0}{2}{% d'une extremite
   V0 Alpha cos mul t mul 800 t mul sin sub % x(t)
   -9.81 2 div t dup mul mul V0 Alpha sin mul t mul add 1 add 800 t mul cos
     add }%y(t)
\end{pspicture}
```

5. \psComment: comments to a graphic

\psComment* [Options] {*arrows*} (x_0,y_0)(x_1,y_1){*Text*} [line macro]

By default the macro uses the \ncline macro to draw a line from the first to the second point. With the second additional argument one can use another macro for the line.




```
\SpecialCoor\newpsstyle{weiss}{fillstyle=solid,fillcolor=white}
\footnotesize\psset{unit=0.5cm,dimen=middle}
\begin{pspicture}(-12,-4)(6,10)
\psframe*[linecolor=black!20](-5,-3)(5,7) \psframe*[linecolor=black!40](-5,3)(5,6)
\pscircle(-8.19,5.51){0.2}
\psframe[fillcolor=white,fillstyle=solid](-5.8,3.6)(4.3,5.8)
\psframe(-8.98,3.14)(-5.8,6.32)
\multido{\rA=-4.1+1.3}{5}{\rput(\rA,-2.4){\psframe[style=weiss](1.1,6)
  \psline(0,0)(1.1,0.5)(0,1)(1.1,1.6)(0,2.2)(1.1,2.7)(0,3.2)(1.1,3.2)}}
\pspolygon*(-4.1,3.7)(-4.1,3)(-3,3)(-3.01,3.7)(-3.54,4.19)
\pspolygon*(1.09,3.7)(1.1,3)(2.2,3)(2.18,3.7)(1.65,4.24)
\pspolygon*(-2.78,3.7)(-2.8,3)(-1.7,3)(-1.71,3.7)(-2.27,4.04)
\pspolygon*(-1.51,3.7)(-1.5,3)(-0.4,3)(-0.41,3.7)(-1.02,4.17)
\pspolygon*(-0.21,3.7)(-0.2,3)(0.9,3)(0.89,3.7)(0.3,4.04)
\psline(-5,3.83)(-4.15,3.86)(-3.5,4.3)(-2.85,3.81)(-2.22,4.21)(-1.6,3.86)(-0.99,4.33)
     (-0.28,3.83)(0.35,4.19)(0.97,3.83)(1.65,4.39)(2.2,4.01)(3.57,4.89)(2.41,5.8)
  \psline(-5,5.8)(-5.78,5.8) \psline(-5.78,5.47)(2.85,5.47)
  \psline(-5.8,3.52)(-5,3.5) \psline(3.57,4.89)(-5.8,4.89)
  \psComment*[ref=r]{->}(-8.14,1.19)(-4.31,3.27){Mantelstift}
  \psComment*[ref=r]{->}(-8.17,-0.56)(-4.37,1.59){Kernstift}[\rput]
  \psComment*[ref=r]{->}(-7.91,-2.24)(-4.44,-0.23){Feder}[\rput]
  \psComment[npos=-0.1]{->}(-3.48,8.72)(-1.33,5.46){Nur f\"ur Profil}
\end{pspicture}
```

6. \psChart: a pie chart

\psChart [Options] {*comma separated value list*}{*comma separated value list*}{*radius*}

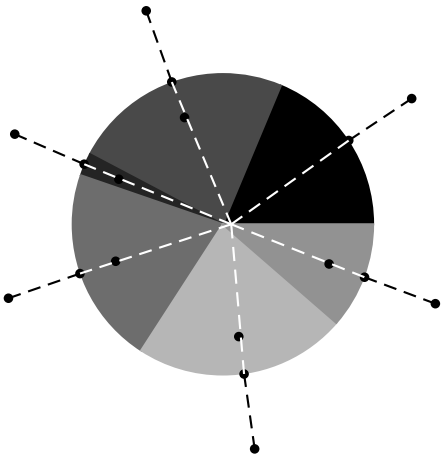
The special optional arguments for the \psChart macro are as follows:

name	*description*	*default*
chartSep	distance from the pie chart center to an outraged pie piece	10pt
chartColor	gray or colored pie (values are: gray or color)	gray
userColor	a comma separated list of user defined colors for the pie	{}

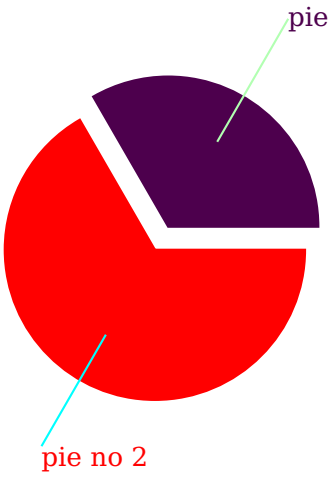
The first mandatory argument is the list of the values and may not be empty. The second one is a list of outraged pieces, numbered consecutively from 1 to up the total number of values. The list of user defined colors must be enclosed in braces!

The macro \psChart defines for every value three nodes at the half angle and in distances from 0.75, 1, and 1.25 times of the radius from the origin. The nodes are named as psChartI?, psChart?, and psChartO?, where ? is the number of the pie. The letter I leads to the inner node and the letter O to the outer node. The distance can be changed with the optional arguments chartNodeI and chartNodeO in the usual way with \psset{chartNodeI=...,chartNodeO=...}.

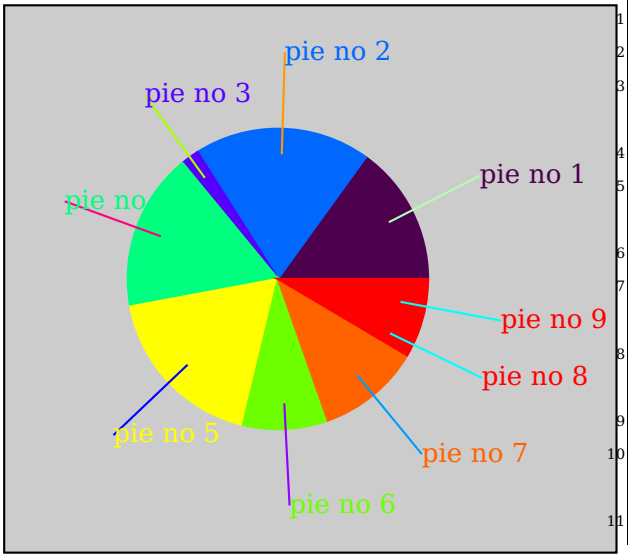
The other one is the node on the circle line. The origin is by default (0,0). Moving the pie to another position can be done as usual with the \rput-macro. The used colors are named internally as chartFillColor? and can be used by the user for coloring lines or text.



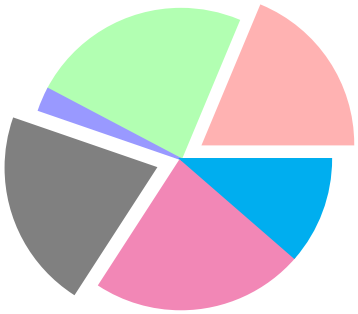
```
\begin{pspicture}(-3,-3)(3,3)
\psChart{ 23, 29, 3, 26, 28, 14 }{}{2}
\multido{\iA=1+1}{6}{%
  \psdot(psChart\iA)\psdot(psChartI\iA)\psdot
    (psChartO\iA)%
  \psline[linestyle=dashed,linecolor=white](
    psChart\iA)
  \psline[linestyle=dashed](psChart\iA)(
    psChartO\iA)}
\end{pspicture}
```



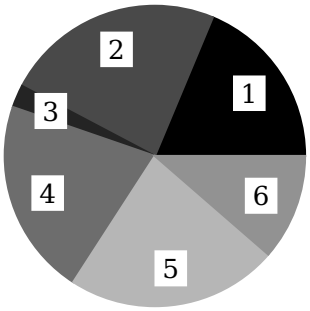

```
\begin{pspicture}(-3,-3)(3,3)
\psChart[chartColor=color]{45,90}{1}{2}
\ncline[linecolor=-chartFillColor1,
  nodesepB=-20pt]{psChartO1}{psChart1}
\rput[l](psChartO1){%
  \textcolor{chartFillColor1}{pie no 1}}
\ncline[linecolor=-chartFillColor2,
  nodesepB=-20pt]{psChartO2}{psChart2}
\rput[lt](psChartO2){%
  \textcolor{chartFillColor2}{pie no 2}}
\end{pspicture}
```



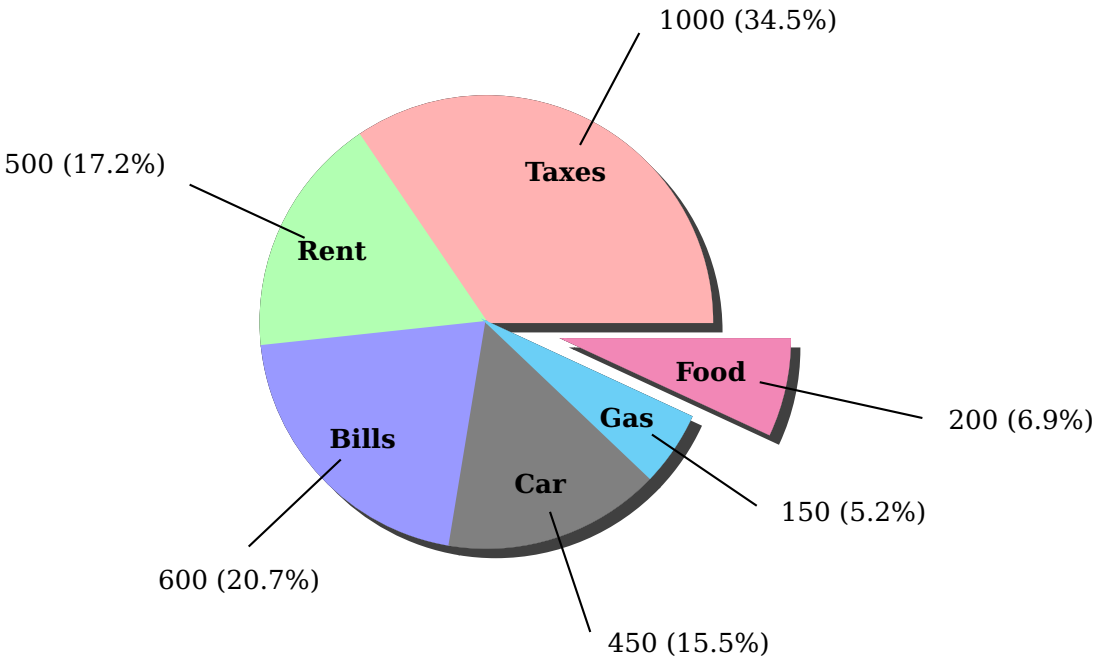

```
\psframebox[fillcolor=black!20,
  fillstyle=solid]{%
\begin{pspicture}(-3.5,-3.5)
  (4.25,3.5)
\psChart[chartColor=color]%
  {23, 29, 3, 26, 28, 14, 17, 4,
    9}{}{2}
\multido{\iA=1+1}{9}{%
  \ncline[linecolor=-chartFillColor\
    iA,
    nodesepB=-10pt]{psChartO\iA}{
      psChart\iA}
  \rput[l](psChartO\iA){%
    \textcolor{chartFillColor\iA}{pie
      no \iA}}}
\end{pspicture}}
```



```
\begin{pspicture}(-3,-3)(3,3)
\psChart[userColor={red!30,green!30,
   blue!40,gray,magenta!60,cyan}]%
    { 23, 29, 3, 26, 28, 14 }{1,4}{2}
\end{pspicture}
```



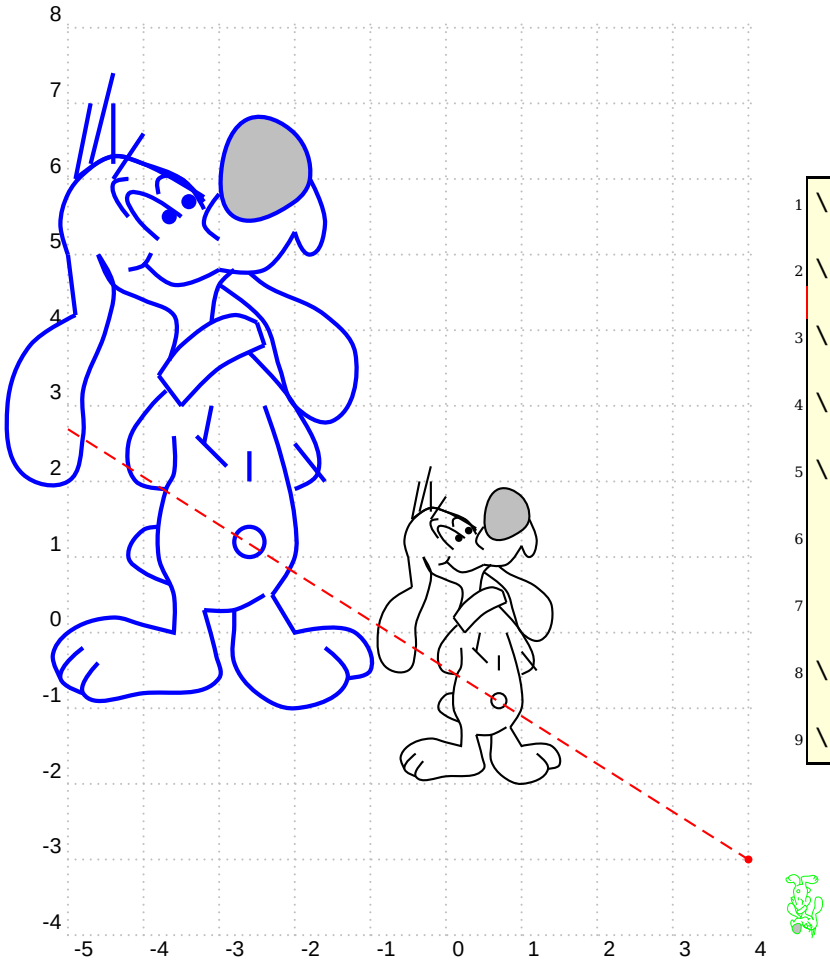

```
\begin{pspicture}(-3,-2.5)(3,2.5)
\psChart{ 23, 29, 3, 26, 28, 14 }{}{2}
\multido{\iA=1+1}{6}{\rput*(psChartI\iA){\iA
  }}
\end{pspicture}
```




```
\psset{unit=1.5}
\begin{pspicture}(-3,-3)(3,3)
\psChart[userColor={red!30,green!30,blue!40,gray,cyan!50,
   magenta!60,cyan},chartSep=30pt,shadow=true,shadowsize=5pt
     ]{34.5,17.2,20.7,15.5,5.2,6.9}{6}{2}
\psset{nodesepA=5pt,nodesepB=-10pt}
\ncline{psChartO1}{psChart1}\nput{0}{psChartO1}{1000 (34.5\%)}
\ncline{psChartO2}{psChart2}\nput{150}{psChartO2}{500 (17.2\%)}
\ncline{psChartO3}{psChart3}\nput{-90}{psChartO3}{600 (20.7\%)}
\ncline{psChartO4}{psChart4}\nput{0}{psChartO4}{450 (15.5\%)}
\ncline{psChartO5}{psChart5}\nput{0}{psChartO5}{150 (5.2\%)}
\ncline{psChartO6}{psChart6}\nput{0}{psChartO6}{200 (6.9\%)}
\bfseries%
\rput(psChartI1){Taxes}\rput(psChartI2){Rent}\rput(psChartI3){Bills}
\rput(psChartI4){Car}\rput(psChartI5){Gas}\rput(psChartI6){Food}
\end{pspicture}
```

7. \psHomothetie: central dilatation

\psHomothetie [Options] (*center*){*factor*}{*object*}

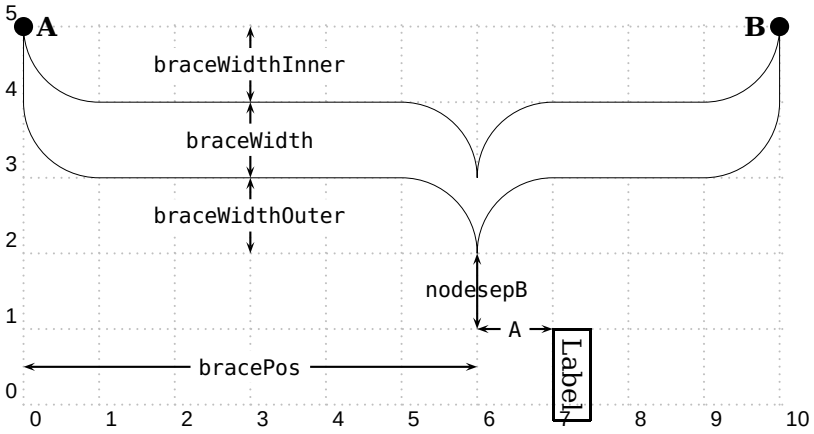



```
\begin{pspicture}[showgrid=
  true](-5,-4)(4,8)
\psBill% needs package pst-
  fun
\psHomothetie[linecolor=blue
  ](4,-3){2}{\psBill}
\psdots[dotsize=3pt,
  linecolor=red](4,-3)
\psplot[linestyle=dashed,
  linecolor=red]{-5}{4}%
  [ /m -3 -0.85 sub 4 0.6 sub
     div def ]
  { m x mul m 4 mul sub 3 sub
     }%
\psHomothetie[linecolor=
  green](4,-3){-0.2}{\psBill}
\end{pspicture}
```

8. \psbrace

\psbrace* [Options] (A)(B){text}

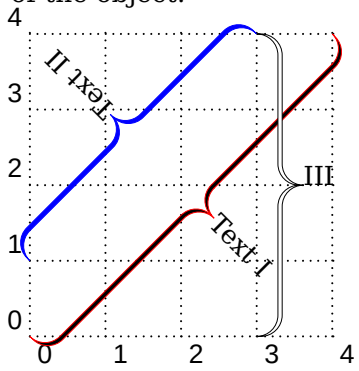
Additional to all other available options from pstricks or the other related packages, there are two new option, named braceWidth and bracePos. All important ones are shown in the following graphics and table.



A positive value for nodesepA and nodesepB shifts the label to the upper right and a negative value to the lower left. This does not depends on the value for the rotating of the label!

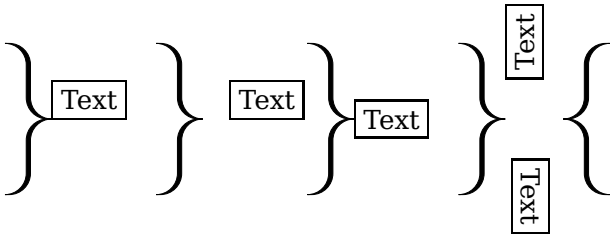
name	meaning
braceWidth	default is \pslinewidth
braceWidthInner	default is 10\pslinewidth
braceWidthOuter	default is 10\pslinewidth
bracePos	relative position (default is 0.5)
nodesepA	x-separation (default is $0pt$)
nodesepB	y-separation (default is $0pt$)
rot	additional rotating for the text (default is 0)
ref	reference point for the text (default is c)
fillcolor	default is black

By default the text is written perpendicular to the brace line and can be changed with the pstricks option rot=... The text parameter can take any object and may also be empty. The reference point can be any value of the combination of l (left) or r (right) and b (bottom) or B (Baseline) or C (center) or t (top), where the default is c, the center of the object.

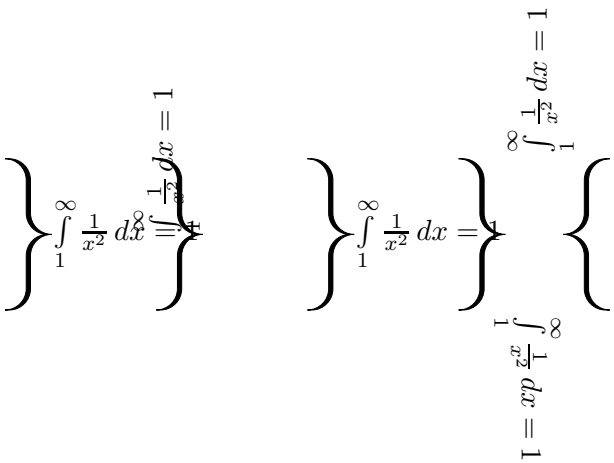



```
\begin{pspicture}(4,4)
\psgrid[subgriddiv=0,griddots=10]
\pnode(0,0){A}
\pnode(4,4){B}
\psbrace[linecolor=red,ref=lC](A)(B){Text I}
\psbrace*[linecolor=blue,ref=lC](3,4)(0,1){Text II}
\psbrace[fillcolor=white](3,0)(3,4){III}
\end{pspicture}
```

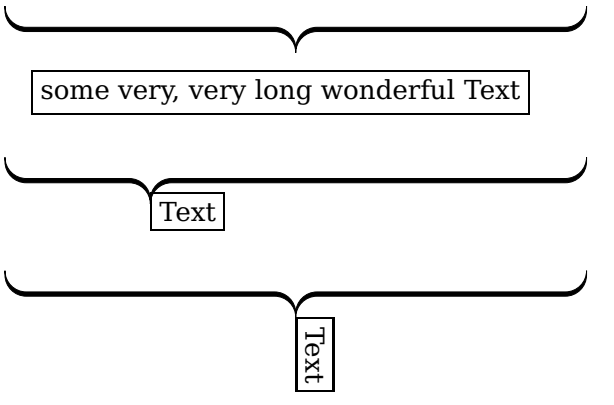
The option \specialCoor is enabled, so that all types of coordinates are possible, (nodename), (x, y), $(nodeA|nodeB)$, ... The star version fills the inner of the brace with the current linecolor. With the fillcolor white or any other background color the brace can be "'unfilled"'.



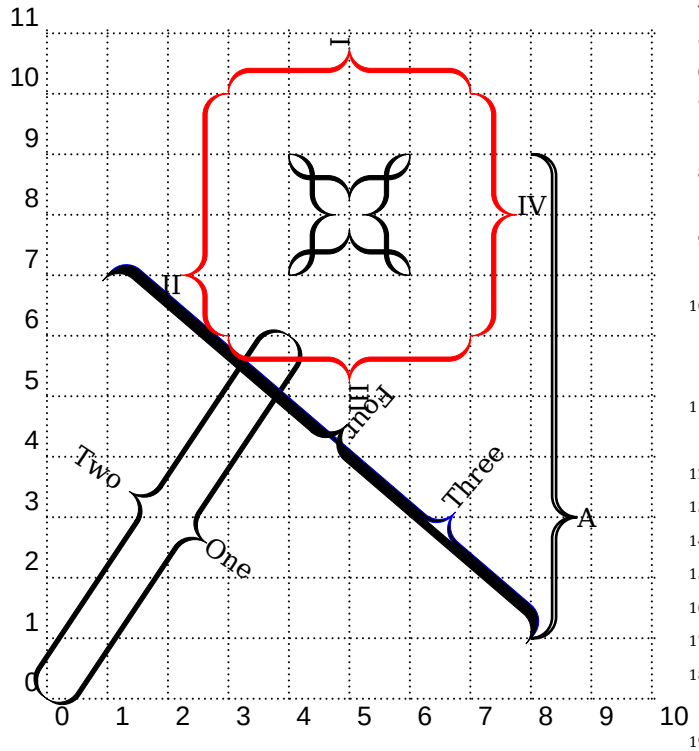

```
\begin{pspicture}(8,2.5)
\psbrace(0,0)(0,2){\fbox{Text}}%
\psbrace[nodesepA=10pt](2,0)(2,2){\
  fbox{Text}}
\psbrace[ref=lC](4,0)(4,2){\fbox{
  Text}}
\psbrace[ref=lt,rot=90,nodesepB=-15
  pt](6,0)(6,2){\fbox{Text}}
\psbrace[ref=lt,rot=90,nodesepA=-5
  pt,nodesepB=15pt](8,2)(8,0){\fbox
  {Text}}
\end{pspicture}
```



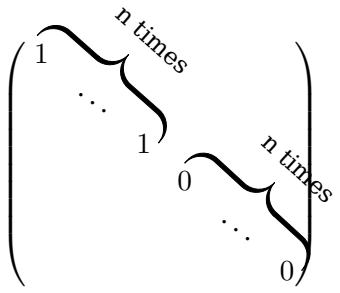

```
\def\someMath{$\int\limits_1^{\
  infty}\frac{1}{x^2}\,dx=1$}
\begin{pspicture}(8,2.5)
\psbrace[ref=lC](0,0)(0,2){\
  someMath}%
\psbrace[rot=90](2,0)(2,2){\
  someMath}
\psbrace[ref=lC](4,0)(4,2){\
  someMath}
\psbrace[ref=lt,rot=90,nodesepB=-30
  pt](6,0)(6,2){\someMath}
\psbrace[ref=lt,rot=90,nodesepB=30
  pt](8,2)(8,0){\someMath}
\end{pspicture}
```




```
\begin{pspicture}(\linewidth,5)
\psbrace(0,0.5)(\linewidth,0.5){\
  fbox{Text}}%
\psbrace[bracePos=0.25,nodesepB=10
  pt,rot=90](0,2)(\linewidth,2){\
  fbox{Text}}
\psbrace[ref=lC,nodesepA=-3.5cm,
  nodesepB=15pt,rot=90](0,4)(\
  linewidth,4){%
   \fbox{some very, very long
     wonderful Text}}
\end{pspicture}
```




```
\psset{unit=0.8}
\begin{pspicture}(10,11)
\psgrid[subgriddiv=0,griddots=10]
\pnode(0,0){A}
\pnode(4,6){B}
\psbrace[ref=lC](A)(B){One}
\psbrace[rot=180,nodesepA=-5pt,ref
  =rb](B)(A){Two}
\psbrace[linecolor=blue,bracePos
  =0.25,ref=lB](8,1)(1,7){Three}
\psbrace[braceWidth=-1mm,rot=180,
  ref=rB](8,1)(1,7){Four}
\psbrace*[linearc=0.5,fillstyle=
  none,linewidth=1pt,braceWidth
  =1.5pt,
  bracePos=0.25,ref=lC](8,1)(8,9){
    A}
\psbrace(4,9)(6,9){}
\psbrace(6,9)(6,7){}
\psbrace(6,7)(4,7){}
\psbrace(4,7)(4,9){}
\psset{linecolor=red}
\psbrace*[ref=lb](7,10)(3,10){I}
\psbrace*[ref=lb,bracePos
  =0.75](3,10)(3,6){II}
\psbrace*[ref=lb](3,6)(7,6){III}
\psbrace*[ref=lb](7,6)(7,10){IV}
\end{pspicture}
```




```
\[
\begin{pmatrix}
   \Rnode[vref=2ex]{A}{~1} \\
   & \ddots \\
   && \Rnode[href=2]{B}{1} \\
   &&& \Rnode[vref=2ex]{C}{0} \\
   &&&& \ddots \\
   &&&&& \Rnode[href=2]{D}{0}~ \\
\end{pmatrix}
\]
\psbrace[rot=-90,nodesepB=-0.5,nodesepA=-0.2](B)(
  A){\small n times}
\psbrace[rot=-90,nodesepB=-0.5,nodesepA=-0.2](D)(
  C){\small n times}
```

It is also possible to put a vertical brace around a default paragraph. This works by setting two invisible nodes at the beginning and the end of the paragraph. Indentation is possible with a minipage.

Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense.

Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense.

Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense.

Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense. Some nonsense text, which is nothing more than nonsense.

```
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.

\noindent\rnode{A}{}

\vspace*{-1ex}
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.

\vspace*{-2ex}\noindent\rnode{B}{}\psbrace[linecolor=red](A)(B){}

Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.

\medskip\hfill\begin{minipage}{0.95\linewidth}
\noindent\rnode{A}{}

\vspace*{-1ex}
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
Some nonsense text, which is nothing more than nonsense.
```

```
Some nonsense text, which is nothing more than nonsense.

\vspace*{-2ex}\noindent\rnode{B}{}\psbrace[linecolor=red](A)(B){}
\end{minipage}
```

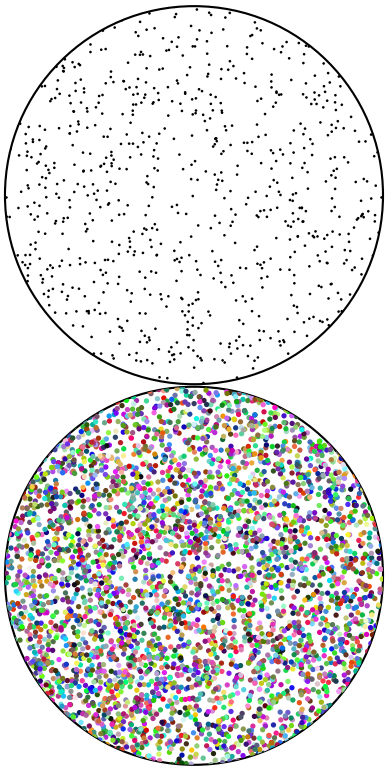
9. Random dots

The syntax of the new macro \psRandom is:

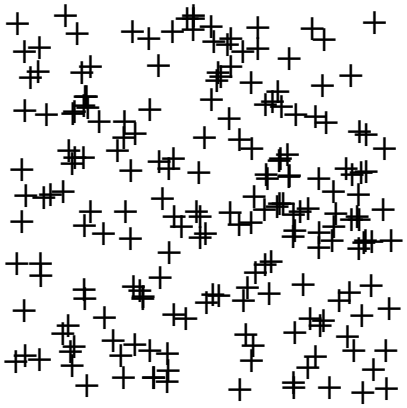
```
\psRandom [Options] {}
\psRandom [Options] (x_Min, y_Min) (x_Max, y_Max) {clip path}
```

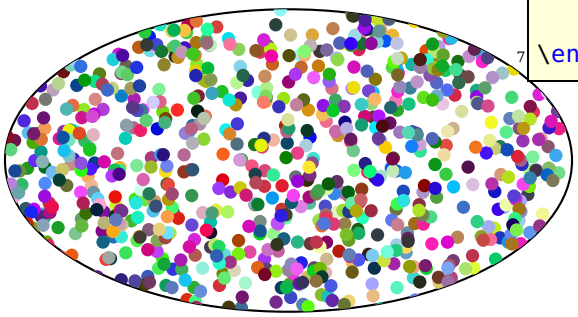
If there is no area for the dots defined, then (0,0)(1,1) in the current scale setting is used for placing the dots. If there is only one (x_{Max}, y_{Max}) defined, then (0,0) is used for the other point. This area should be greater than the clipping path to be sure that the dots are placed over the full area. The clipping path can be everything. If no clipping path is given, then the frame (0,0)(1,1) in user coordinates is used. The new options are:

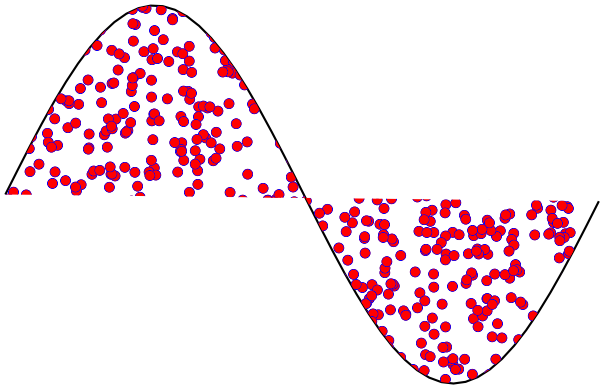
name	default	
randomPoints	1000	number of random dots
color	false	random color



```
\psset{unit=5cm}
\begin{pspicture}(1,1)
  \psRandom[dotsize=1pt,fillstyle=solid](1,1){\
    pscircle(0.5,0.5){0.5}}
\end{pspicture}
\begin{pspicture}(1,1)
  \psRandom[dotsize=2pt,randomPoints=5000,color,%
     fillstyle=solid](1,1){\pscircle(0.5,0.5){0.5}}
\end{pspicture}
```





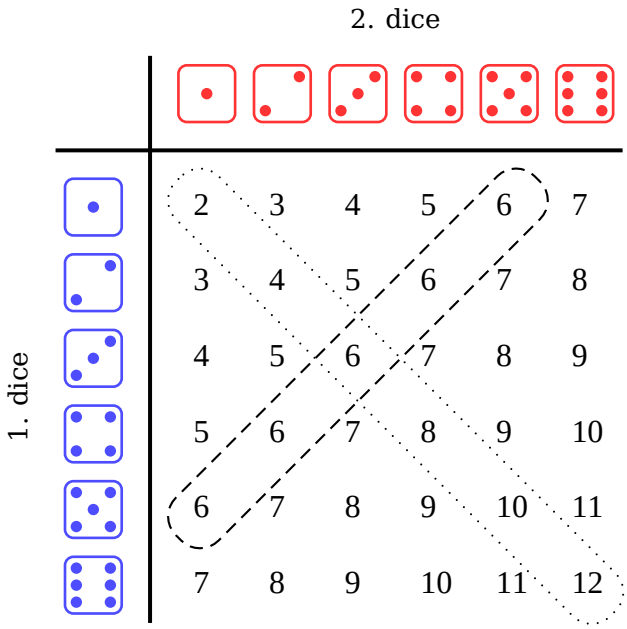


```
\psset{unit=5cm}
\begin{pspicture}(1,1)
  \psRandom[randomPoints=200,dotsize=8pt,
    dotstyle=+]{}
\end{pspicture}
\begin{pspicture}(1.5,1)
  \psRandom[dotsize=5pt,color](0,0)(1.5,0.8)
    {\psellipse(0.75,0.4)(0.75,0.4)}
\end{pspicture}
```

```
\psset{unit=2.5cm}
\begin{pspicture}(0,-1)(3,1)
  \psRandom[dotsize=4pt,dotstyle=o,
    linecolor=blue,fillcolor=red,%
    fillstyle=solid,randomPoints
      =1000]%
    (0,-1)(3,1){\psplot{0}{3.14}{ x
       114 mul sin }}
\end{pspicture}
```

10. \psDice

\psdice creates the view of a dice. The number on the dice is the only parameter. The optional parameters, like the color can be used as usual. The macro is a box of dimension zero and is placed at the current point. Use the \rput macro to place it anywhere. The optional argument unit can be used to scale the dice. the default size of the dice $1\text{cm} \times 1\text{cm}$.




```
\begin{pspicture}(-1,-1)(8,8)
\multido{\iA=1+1}{6}{%
  \rput(\iA,7.5){\Huge\psdice[unit=0.75,linecolor=red!80]{\iA}}
  \rput(! -0.5 7 \iA\space sub){\Huge\psdice[unit=0.75,linecolor=blue!70]{\iA
    }}%
  \multido{\iB=1+1}{6}{%
    \rput(! \iA\space 7 \iB\space sub){%
      \rnode[c]{p\iA\iB}{\makebox[1em][l]{\strut\psPrintValue[fontscale=12]{\iA
        \space \iB\space add}}}%
}}}
\ncbox[linearc=0.35,nodesep=0.2,linestyle=dotted]{p11}{p66}
\ncbox[linearc=0.35,nodesep=0.2,linestyle=dashed]{p15}{p51}
\rput{90}(-1.5,3.5){1. dice}
\rput{0}(3.5,8.5){2. dice}
\psline[linewidth=1.5pt](0.25,0.5)(0.25,8)
\psline[linewidth=1.5pt](-1,6.75)(6.5,6.75)
\end{pspicture}
```

11. \psFormatInt

There exist some packages and a lot of code to format an integer like $1\,000\,000$ or $1,234,567$ (in Europe $1.234.567$). But all packages expect a real number as argument and cannot handle macros as an argument. For this case `pstricks-add` has a macro `\psFormatInt` which can handle both:

1,234,567
1,234,567
1.234.567
1·234·567
965,432

```
\psFormatInt{1234567}\\
\psFormatInt[intSeparator={,}]{1234567}\\
\psFormatInt[intSeparator=.]{1234567}\\
\psFormatInt[intSeparator=$\cdot$]{1234567}\\
\def\temp{965432}
\psFormatInt{\temp}
```

With the option `intSeparator` the symbol can be changed to any any non-number character.

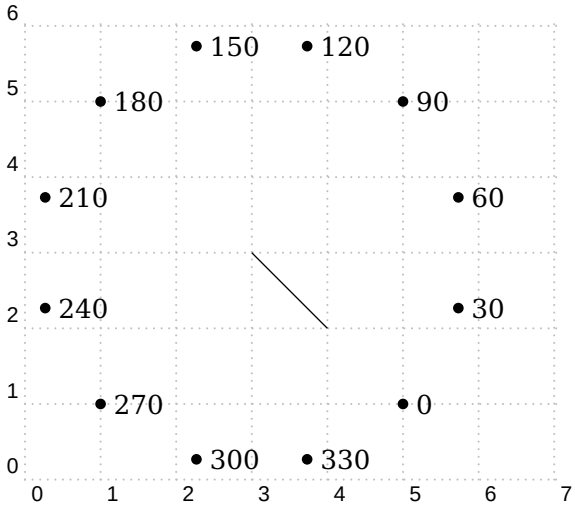
12. \psRelNode and \psDefPSPNodes

With these macros it is possible to put a node relative to a given line or given pspicture-environment. In the frist case the parameters are the angle and the length factor:

```
\psRelNode[P0][P1]{length factor}{end node name}
\psDefPSPNodes
```

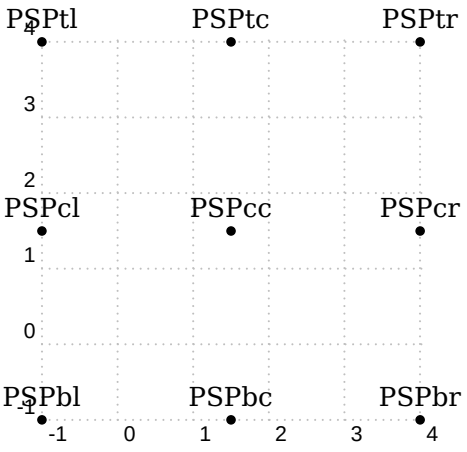
The length factor relates to the distance $\overline{P_0P_1}$ and the end node name must be a valid nodename and shouldn't contain any of the special PostScript characters. There are two valid options:

name	default	meaning
angle	0	angle between the given line $\overline{P_0P_1}$ and the new one $\overline{P_0P_{endNode}}$
trueAngle	false	defines whether the angle refers to the seen line or to the mathematical one, which respect the scaling factors xunit and yunit.




```
\begin{pspicture}[showgrid](7,6)
  \pnode(3,3){A}\pnode(4,2){B}
  \psline[nodesep=-3,linewidth=0.5pt](A
    )(B)
  \multido{\iA=0+30}{12}{%
    \psRelNode[angle=\iA](A)(B){2}{C}%
    \qdisk(C){2pt}
    \uput[0](C){\iA}}
\end{pspicture}
```

In the second case the new macro \psDefPSPNodes defines nine nodes that corresponds to nine particular points (namely bottom left, bottom center, bottom right, center left, center center, center right, top left, top center, top right) of the pspicture box.




```
\begin{pspicture}[showgrid=true](-1,-1)(4,4)
  \psDefPSPNodes
  \psdots(PSPbl)(PSPbc)(PSPbr)
     (PSPcl)(PSPcc)(PSPcr)(PSPtl)(PSPtc)(
       PSPtr)
  \uput[90](PSPbl){PSPbl} \uput[90](PSPbc){
    PSPbc}
  \uput[90](PSPbr){PSPbr} \uput[90](PSPcl){
    PSPcl}
  \uput[90](PSPcc){PSPcc} \uput[90](PSPcr){
    PSPcr}
  \uput[90](PSPtl){PSPtl} \uput[90](PSPtc){
    PSPtc}
  \uput[90](PSPtr){PSPtr}
\end{pspicture}
```

The name of the nodes are predefined as:

```
\psset[pst-PSPNodes]{blName=PSPbl,bcName=PSPbc,brName=PSPbr,
  clName=PSPcl,ccName=PSPcc,crName=PSPcr,tlName=PSPtl,tcName=PSPtc,trName=PSPtr}
```

and can be modified in the same way.

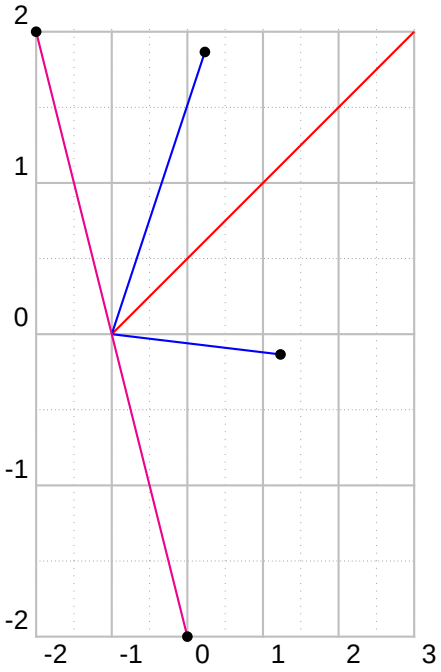
13. \psRelLine

With this macro it is possible to plot lines relative to a given one. Parameter are the angle and the length factor:

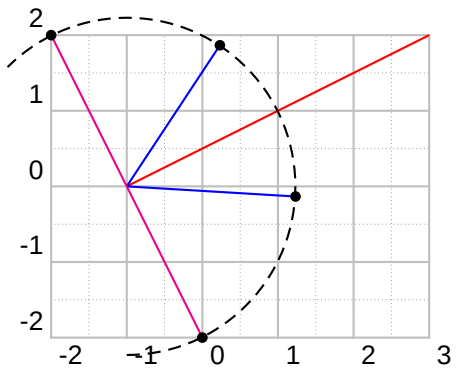
```
\psRelLine(P0)(P1){length factor}{<end node name>}
\psRelLine[{arrows}](P0)(P1){length factor}{end node name}
\psRelLine[Options](P0)(P1){length factor}{end node name}
\psRelLine[Options][{arrows}](P0)(P1){length factor}{end node name}
```

The length factor relates to the distance $\overline{P_0P_1}$ and the end node name must be a valid nodename and shouldn't contain any of the special PostScript characters. There are two valid options which are described in the foregoing section for \psRelNode.

The following two figures show the same, the first one with a scaling different to $1:1$, this is the reason why the end points are on an ellipse and not on a circle like in the second figure.

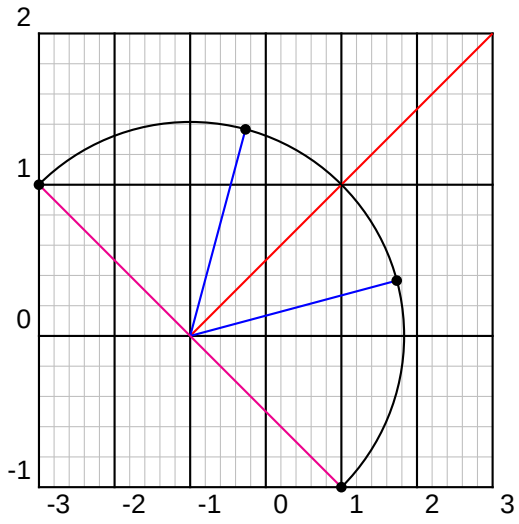



```
\psset{yunit=2,xunit=1}
\begin{pspicture}(-2,-2)(3,2)
\psgrid[subgriddiv=2,subgriddots=10,gridcolor=
  lightgray]
\pnode(-1,0){A}\pnode(3,2){B}
\psline[linecolor=red](A)(B)
\psRelLine[linecolor=blue,angle=30](-1,0)(B)
  {0.5}{EndNode}
\qdisk(EndNode){2pt}
\psRelLine[linecolor=blue,angle=-30](A)(B){0.5}{
  EndNode}
\qdisk(EndNode){2pt}
\psRelLine[linecolor=magenta,angle=90](-1,0)(3,2)
  {0.5}{EndNode}
\qdisk(EndNode){2pt}
\psRelLine[linecolor=magenta,angle=-90](A)(B)
  {0.5}{EndNode}
\qdisk(EndNode){2pt}
\end{pspicture}
```



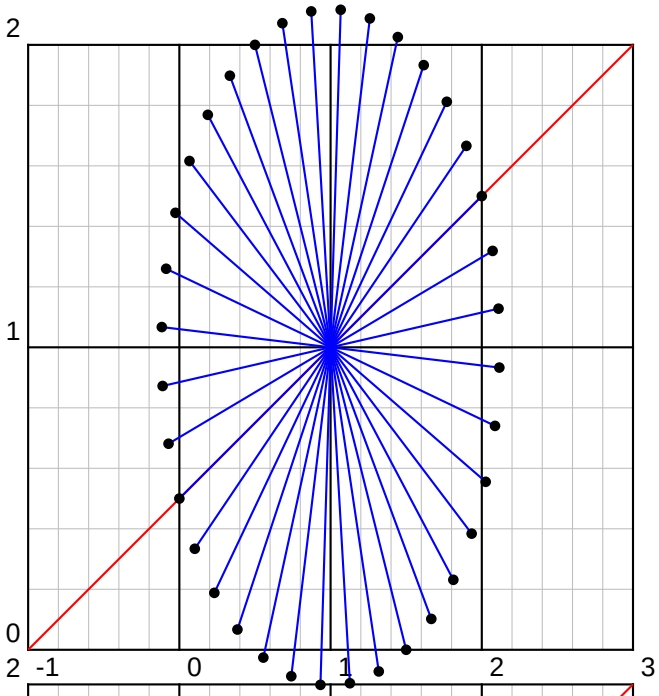

```
\begin{pspicture}(-2,-2)(3,2)
\psgrid[subgriddiv=2,subgriddots=10,gridcolor=
  lightgray]
\pnode(-1,0){A}\pnode(3,2){B}
\psline[linecolor=red](A)(B)
\psarc[linestyle=dashed](A){2.23}{-90}{135}
\psRelLine[linecolor=blue,angle=30](-1,0)(B)
  {0.5}{EndNode}
\qdisk(EndNode){2pt}
\psRelLine[linecolor=blue,angle=-30](A)(B){0.5}{
  EndNode}
\qdisk(EndNode){2pt}
\psRelLine[linecolor=magenta,angle=90](-1,0)(3,2)
  {0.5}{EndNode}
\qdisk(EndNode){2pt}
\psRelLine[linecolor=magenta,angle=-90](A)(B)
  {0.5}{EndNode}
\qdisk(EndNode){2pt}
\end{pspicture}
```

The following figure has also a different scaling, but has set the option `trueAngle`, all angles refer to "what you see".

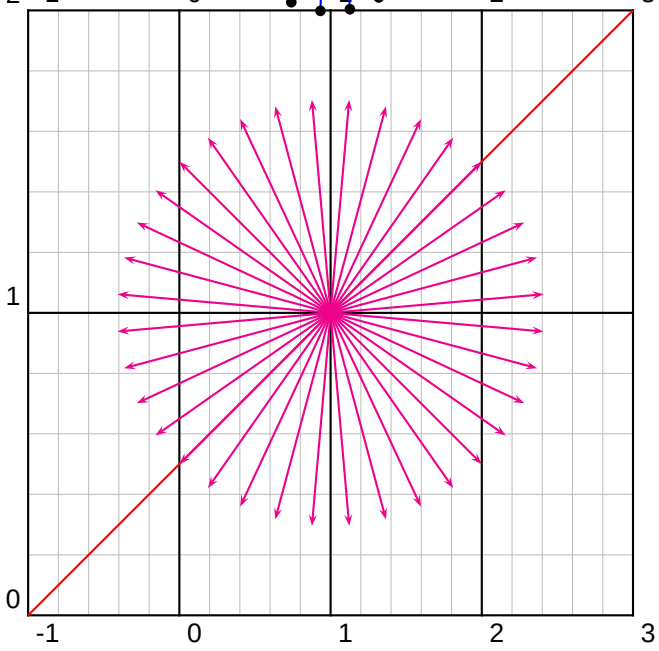



```
\psset{yunit=2,xunit=1}
\begin{pspicture}(-3,-1)(3,2)\psgrid[
  subgridcolor=lightgray]
\pnode(-1,0){A}\pnode(3,2){B}
\psline[linecolor=red](A)(B)
\psarc(A){2.83}{-45}{135}
\psRelLine[linecolor=blue,angle=30,
  trueAngle](A)(B){0.5}{EndNode}
\qdisk(EndNode){2pt}
\psRelLine[linecolor=blue,angle=-30,
  trueAngle](A)(B){0.5}{EndNode}
\qdisk(EndNode){2pt}
\psRelLine[linecolor=magenta,angle=90,
  trueAngle](A)(B){0.5}{EndNode}
\qdisk(EndNode){2pt}
\psRelLine[linecolor=magenta,angle=-90,
  trueAngle](A)(B){0.5}{EndNode}
\qdisk(EndNode){2pt}
\end{pspicture}
```

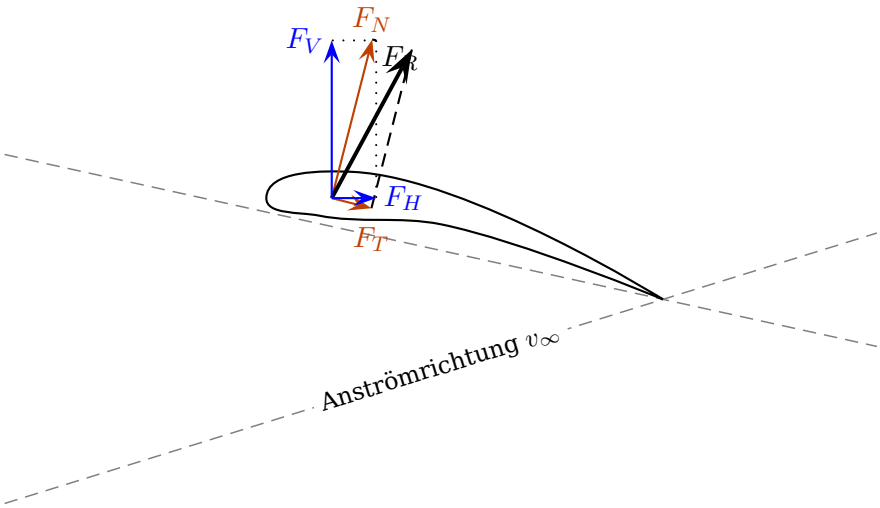
Two examples using `\multido` to show the behaviour of the options `trueAngle` and `angle`.




```
\psset{yunit=4,xunit=2}
\begin{pspicture}(-1,0)(3,2)\
  psgrid[subgridcolor=lightgray]
\pnode(-1,0){A}\pnode(1,1){B}
\psline[linecolor=red](A)(3,2)
\multido{\iA=0+10}{36}{%
  \psRelLine[linecolor=blue,angle
    =\iA](B)(A){-0.5}{EndNode}
  \qdisk(EndNode){2pt}
}
\end{pspicture}
```




```
\psset{yunit=4,xunit=2}
\begin{pspicture}(-1,0)(3,2)\
  psgrid[subgridcolor=lightgray]
\pnode(-1,0){A}\pnode(1,1){B}
\psline[linecolor=red](A)(3,2)
\multido{\iA=0+10}{36}{%
  \psRelLine[linecolor=magenta,
    angle=\iA,trueAngle]{->}(B)(A)
    {-0.5}{EndNode}
}
\end{pspicture}
```



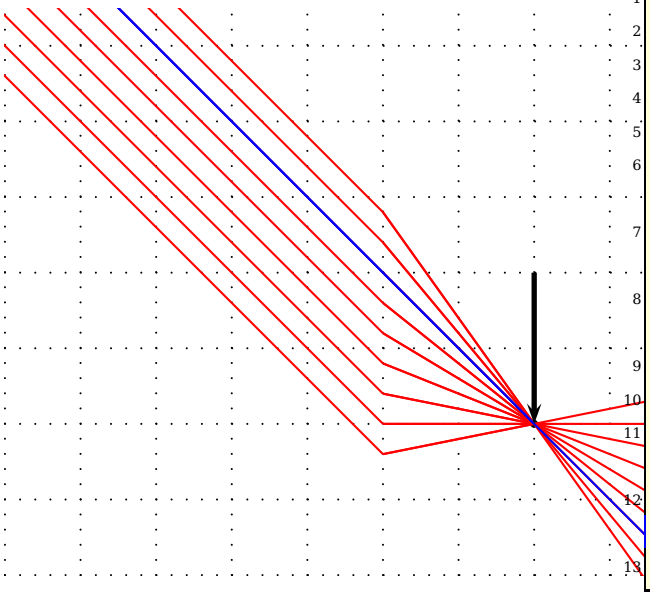

```
\psset{xunit=0.75\linewidth,yunit=0.75\linewidth,trueAngle}%
\end{center}
\begin{pspicture}(1,0.6)%\psgrid
 \pnode(.3,.35){Vk} \pnode(.375,.35){D} \pnode(0,.4){DST1} \pnode(1,.18){DST
   2}
 \pnode(0,.1){A1} \pnode(1,.31){A1}
 { \psset{linewidth=.02,linestyle=dashed,linecolor=gray}%
  \pcline(DST1)(DST2) % <- Druckseitentangente
  \pcline(A2)(A1) % <- Anstr"omrichtung
  \lput*{:U}{\small Anstr"omrichtung $v_{\infty}$} }%
 \psIntersectionPoint(A1)(A2)(DST1)(DST2){Hk}
 \pscurve(Hk)(.4,.38)(Vk)(.36,.33)(.5,.32)(Hk)
 \psParallelLine[linecolor=red!75!green,arrows=->,arrowscale=2](Vk)(Hk)(D)
   {.1}{FtE}
 \psRelLine[linecolor=red!75!green,arrows=->,arrowscale=2,angle=90](D)(FtE)
   {4}{Fn}% why "4"?
 \psParallelLine[linestyle=dashed](D)(FtE)(Fn){.1}{Fnr1}
 \psRelLine[linestyle=dashed,angle=90](FtE)(D){-4}{Fnr2} % why "-4"?
 \psline[linewidth=1.5pt,arrows=->,arrowscale=2](D)(Fnr2)
 \psIntersectionPoint(D)([nodesep=2]D)(Fnr1)([offset=-4]Fnr1){Fh}
 \psIntersectionPoint(D)([offset=2]D)(Fnr1)([nodesep=4]Fnr1){Fv}
 \psline[linecolor=blue,arrows=->,arrowscale=2](D)(Fh)
 \psline[linecolor=blue,arrows=->,arrowscale=2](D)(Fv)
 \psline[linestyle=dotted](Fh)(Fnr1) \psline[linestyle=dotted](Fv)(Fnr1)
 \uput{.1}[0](Fh){\blue $F_{H}$} \uput{.1}[180](Fv){\blue $F_{V}$}
 \uput{.1}[-45](Fnr1){$F_{R}$} \uput{.1}[90](Fn){\color{red!75!green}$F_{N}$}
 \uput{.25}[-90](FtE){\color{red!75!green}$F_{T}$}
\end{pspicture}
```

14. \psParallelLine

With this macro it is possible to plot lines relative to a given one, which is parallel. There is no special parameter here.

```
\psParallelLine(<P0>)(<P1>)(<P2>){<length>}{<end node name>}
\psParallelLine{<arrows>}(<P0>)(<P1>)(<P2>){<length>}{<end node name>}
\psParallelLine[<options>](<P0>)(<P1>)(<P2>){<length>}{<end node name>}
\psParallelLine[<options>]{<arrows>}(<P0>)(<P1>)(<P2>){<length>}{<end node name
  >}
```

The line starts at P_2, is parallel to $\overline{P_0P_1}$ and the length of this parallel line depends on the length factor. The end node name must be a valid nodename and shouldn't contain any of the special PostScript characters.

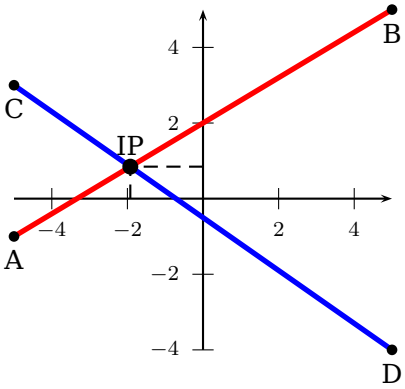


```
\begin{pspicture*}(-5,-4)(5,3.5)
  \psgrid[subgriddiv=0,griddots=5]
  \pnode(2,-2){FF}\qdisk(FF){1.5pt}
  \pnode(-5,5){A}\pnode(0,0){O}
  \multido{\nCountA=-2.4+0.4}{9}{%
    \psParallelLine[linecolor=red](O
      )(A)(0,\nCountA){9}{P1}
    \psline[linecolor=red](0,\
      nCountA)(FF)
    \psRelLine[linecolor=red](0,\
      nCountA)(FF){9}{P2}
  }
  \psline[linecolor=blue](A)(FF)
  \psRelLine[linecolor=blue](A)(FF)
    {5}{END1}
  \psline[linewidth=2pt,arrows
    =->](2,0)(FF)
\end{pspicture*}
```

15. \psIntersectionPoint

This macro calculates the intersection point of two lines, given by the four coordinates. There is no special parameter here.

```
\psIntersectionPoint(<P0>)(<P1>)(<P2>)(<P3>){<node name>}
```



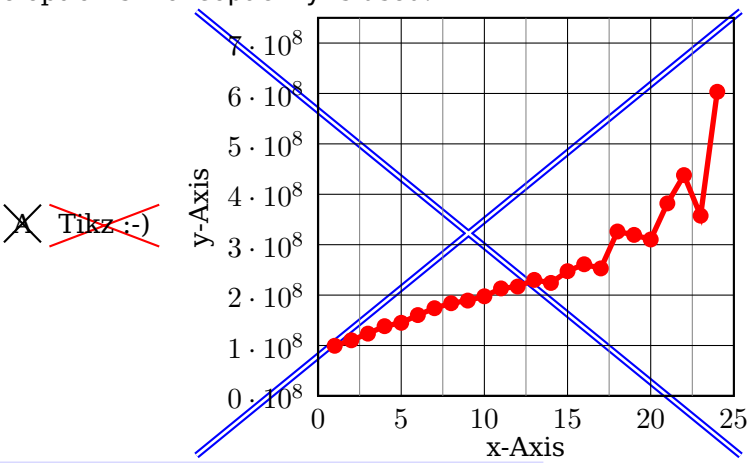

```
\psset{unit=0.5cm}
\begin{pspicture}(-5,-4)(5,5)
  \psaxes[labelFontSize=\scriptstyle,
    dx=2,Dx=2,dy=2,Dy=2]{->}(0,0)(-5,-4)(5,5)
  \psline[linecolor=red,linewidth=2pt](-5,-1)
    (5,5)
  \psline[linecolor=blue,linewidth=2pt](-5,3)
    (5,-4)
  \qdisk(-5,-1){2pt}\uput[-90](-5,-1){A}
  \qdisk(5,5){2pt}\uput[-90](5,5){B}
  \qdisk(-5,3){2pt}\uput[-90](-5,3){C}
  \qdisk(5,-4){2pt}\uput[-90](5,-4){D}
  \psIntersectionPoint(-5,-1)(5,5)(-5,3)(5,-4){
    IP}
  \qdisk(IP){3pt}\uput{0.3}[90](IP){IP}
  \psline[linestyle=dashed](IP|0,0)(IP)(0,0|IP)
\end{pspicture}
```

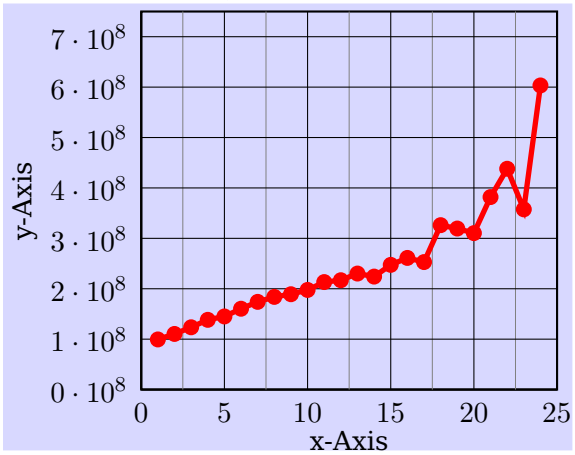
16. psCancel environment[1]

This macro works like the \cancel macro from the package of the same name but it allows as argument any contents, not only letters but also a complex graphic.

\psCancel * [Options] {*contents*}

All optional arguments for lines and boxes are valid and can be used in the usual way. The star option fills the underlying box rectangle with the linecolor. This can be transparent if opacity is set to a value less than 1. This can be used in presentation to strike out words, equations, and graphic objects. Lines can also be transparent when the option strokeopacity is used.





$$\begin{pmatrix} x_R \\ y_R \end{pmatrix} = \underbrace{r}_{\text{Scaling}} \cdot \underbrace{\begin{pmatrix} \sin\gamma & -\cos\gamma \\ \cos\gamma & \sin\gamma \end{pmatrix}}_{\text{Rotation}} \begin{pmatrix} x_K \\ y_K \end{pmatrix} + \underbrace{\begin{pmatrix} t_x \\ t_y \end{pmatrix}}_{\text{Translation}}$$

```
\psCancel{A} \psCancel[linecolor=red]{Tikz :-)} \quad
\psCancel[linecolor=blue,doubleline=true]{%
 \readdata{\data}{demo1.data}
 \psset{shift=*,xAxisLabel=x-Axis,yAxisLabel=y-Axis,llx=-13mm,lly=-7mm,
    xAxisLabelPos={c,-1},yAxisLabelPos={-7,c}}
 \pstScalePoints(1,0.00000001){}{}
 \begin{psgraph}[axesstyle=frame,xticksize=0 7.5,yticksize=0 25,subticksize
   =1,
```

1 Thanks to by Stefano Baroni

```
    ylabelFactor=\cdot 10^8,Dx=5,Dy=1,xsubticks=2](0,0)(25,7.5){5.5cm}{5cm}
  \listplot[linecolor=red, linewidth=2pt, showpoints=true]{\data}
  \end{psgraph}} \qquad% end of Cancel
\psCancel[linewidth=3pt,linecolor=red,
   strokeopacity=0.5]{\tabular[b]{c}first line\\second line\endtabular}\quad
\psCancel*[linecolor=red!50,opacity=0.5]{\tabular[b]{c}first line\\second line
  \endtabular}
\quad
\psCancel*[linecolor=blue!30,opacity=0.5]{%
  \readdata{\data}{demo1.data}
  \psset{shift=*,xAxisLabel=x-Axis,yAxisLabel=y-Axis,llx=-15mm,lly=-7mm,urx=1
    mm,
     xAxisLabelPos={c,-1},yAxisLabelPos={-7,c}}
  \pstScalePoints(1,0.00000001){}{}
  \begin{psgraph}[axesstyle=frame,xticksize=0 7.5,yticksize=0 25,subticksize
    =1,
    ylabelFactor=\cdot 10^8,Dx=5,Dy=1,xsubticks=2](0,0)(25,7.5){5.5cm}{5cm}
  \listplot[linecolor=red, linewidth=2pt, showpoints=true]{\data}
  \end{psgraph}} \quad% end of Cancel
\psCancel[linewidth=4pt,strokeopacity=0.5]{\parbox{8cm}{\[
  \binom{x_R}{y_R} = \underbrace{r\vphantom{\binom{A}{B}}}_{\text{Scaling}}\
    cdot
   \underbrace{\begin{pmatrix}
      \sin\gamma & -\cos\gamma \\
    \cos \gamma & \sin \gamma \\
    \end{pmatrix}}_{\text{Rotation}} \binom{x_K}{y_K} +
  \underbrace{\binom{t_x}{t_y}}_{\text{Translation}} \]} }% end of psCancel
```

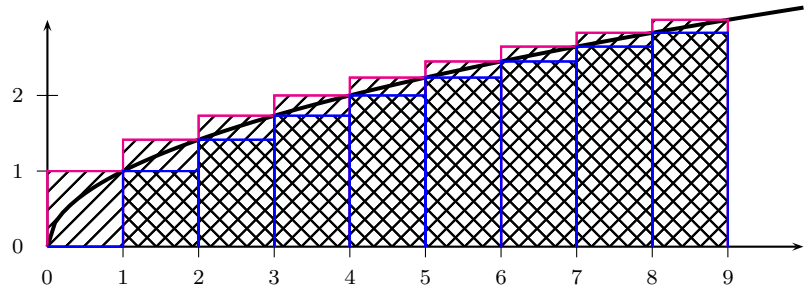
17. \psStep

\psStep calculates a step function for the upper or lower sum or the max/min of the Riemann integral definition of a given function. The available option is

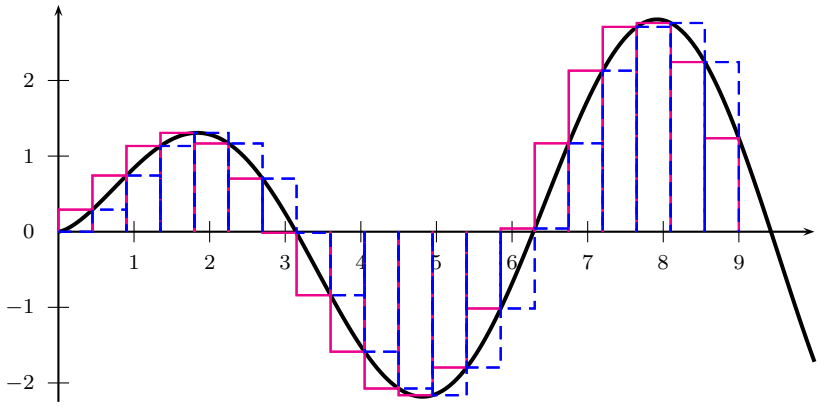
StepType=lower |upper|Riemann|infimum|supremum or alternative StepType=l |u|R|i|s with lower as the default setting. The syntax of the function is

\psStep [Options] (()x1,x2){*n*}{*function*}

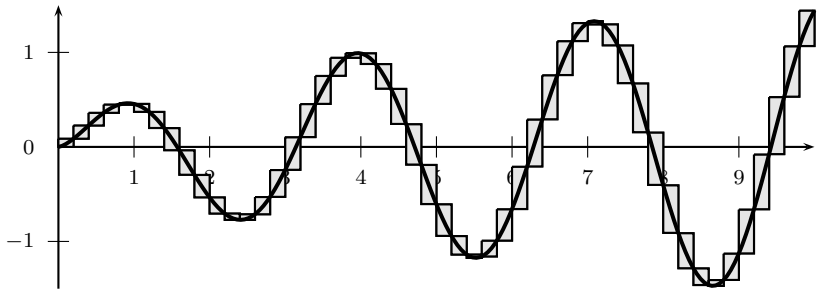
(x1,x2) is the given interval for the step wise calculated function, n is the number of the rectangles and *function* is the mathematical function in postfix or algebraic=true notation (with algebraic=true).



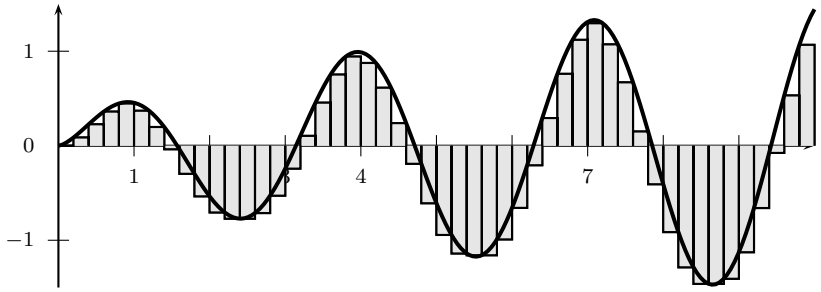

```
\begin{pspicture}(-0.5,-0.5)(10,3)
 \psaxes[labelFontSize=\scriptstyle]{->}(10,3)
 \psplot[plotpoints=100,linewidth=1.5pt,algebraic=true]{0}{10}{sqrt(x)}
 \psStep[linecolor=magenta,StepType=upper,fillstyle=hlines](0,9){9}{x sqrt}
 \psStep[linecolor=blue,fillstyle=vlines](0,9){9}{x sqrt }
\end{pspicture}
```



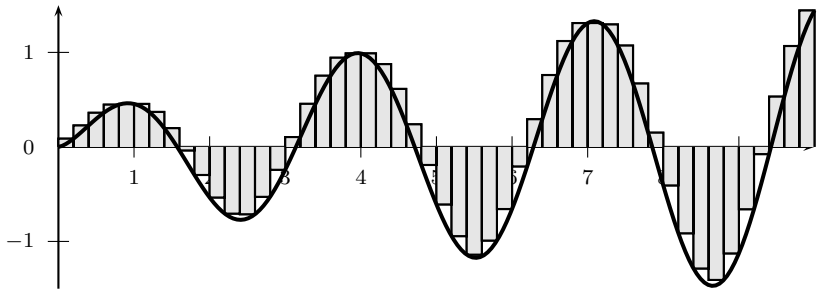

```
\psset{plotpoints=200}
\begin{pspicture}(-0.5,-2.25)(10,3)
 \psaxes[labelFontSize=\scriptstyle]{->}(0,0)(0,-2.25)(10,3)
 \psplot[linewidth=1.5pt,algebraic=true]{0}{10}{sqrt(x)*sin(x)}
 \psStep[algebraic=true,linecolor=magenta,StepType=upper](0,9){20}{sqrt(x)*sin
   (x)}
 \psStep[linecolor=blue,linestyle=dashed](0,9){20}{x sqrt x RadtoDeg sin mul}
\end{pspicture}
```



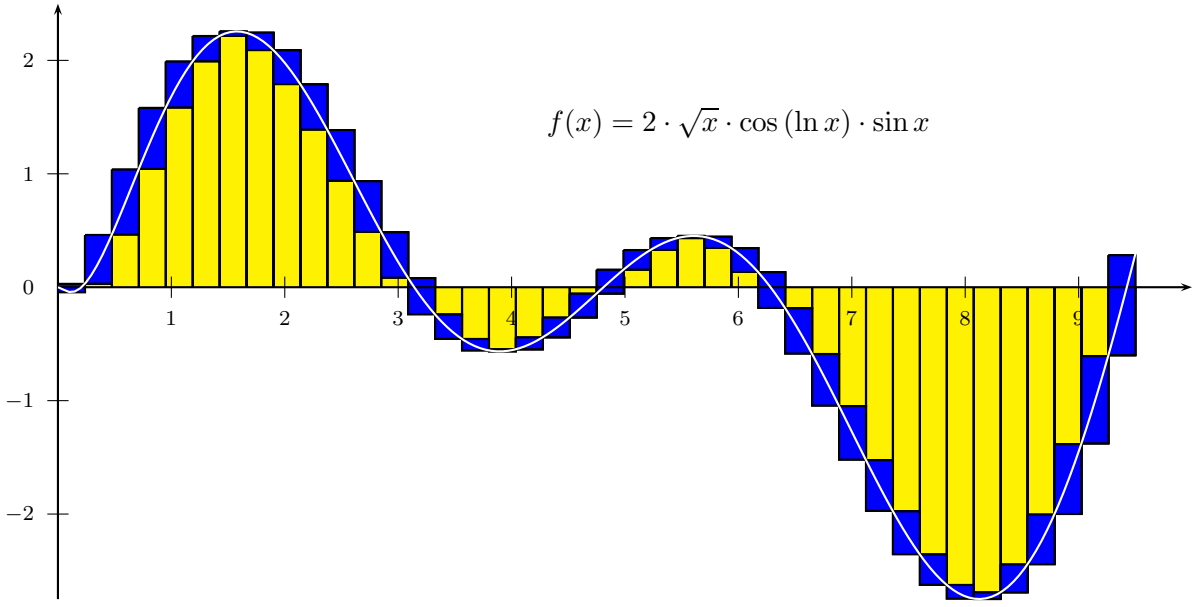

```
\psset{yunit=1.25cm,plotpoints=200}
\begin{pspicture}(-0.5,-1.5)(10,1.5)
 \psaxes[labelFontSize=\scriptstyle]{->}(0,0)(0,-1.5)(10,1.5)
 \psStep[algebraic=true,StepType=Riemann,fillstyle=solid,fillcolor=black
   !10](0,10){50}%
   {sqrt(x)*cos(x)*sin(x)}
 \psplot[linewidth=1.5pt,algebraic=true]{0}{10}{sqrt(x)*cos(x)*sin(x)}
\end{pspicture}
```




```
\psset{yunit=1.25cm,plotpoints=200}
\begin{pspicture}(-0.5,-1.5)(10,1.5)
 \psaxes[labelFontSize=\scriptstyle]{->}(0,0)(0,-1.5)(10,1.5)
 \psStep[algebraic=true,StepType=infimum,fillstyle=solid,fillcolor=black
   !10](0,10){50}%
   {sqrt(x)*cos(x)*sin(x)}
 \psplot[linewidth=1.5pt,algebraic=true]{0}{10}{sqrt(x)*cos(x)*sin(x)}
\end{pspicture}
```




```
\psset{yunit=1.25cm,plotpoints=200}
\begin{pspicture}(-0.5,-1.5)(10,1.5)
 \psaxes[labelFontSize=\scriptstyle]{->}(0,0)(0,-1.5)(10,1.5)
 \psStep[algebraic=true,StepType=supremum,fillstyle=solid,fillcolor=black
   !10](0,10){50}%
   {sqrt(x)*cos(x)*sin(x)}
 \psplot[linewidth=1.5pt,algebraic=true]{0}{10}{sqrt(x)*cos(x)*sin(x)}
\end{pspicture}
```



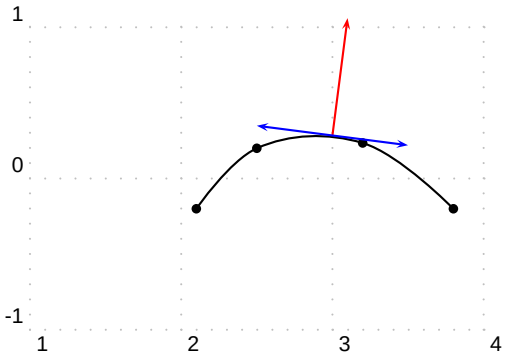

```
\psset{unit=1.5cm,plotpoints=200}
\begin{pspicture}[plotpoints=200](-0.5,-3)(10,2.5)
 \psStep[algebraic=true,fillstyle=solid,fillcolor=yellow](0.001,9.5){40}{2*
   sqrt(x)*cos(ln(x))*sin(x)}
 \psStep[algebraic=true,StepType=Riemann,fillstyle=solid,fillcolor=blue
   ](0.001,9.5){40}{2*sqrt(x)*cos(ln(x))*sin(x)}
 \psaxes[labelFontSize=\scriptstyle]{->}(0,0)(0,-2.75)(10,2.5)
 \psplot[algebraic=true,linecolor=white]{0.001}{9.75}{2*sqrt(x)*cos(ln(x))*
   sin(x)}
 \uput[90](6,1.2){$f(x)=2\cdot\sqrt{x}\cdot\cos{(\ln{x})}\cdot\sin{x}$}
\end{pspicture}
```

18. Tangent lines

There are two macros for plotting a tangent line or the tangent normal line. The first one is `\psTangentLine` which expects three pairs of coordinates, a x and a dx value. The second one is `\psplotTangent` which expects a function for the curve.

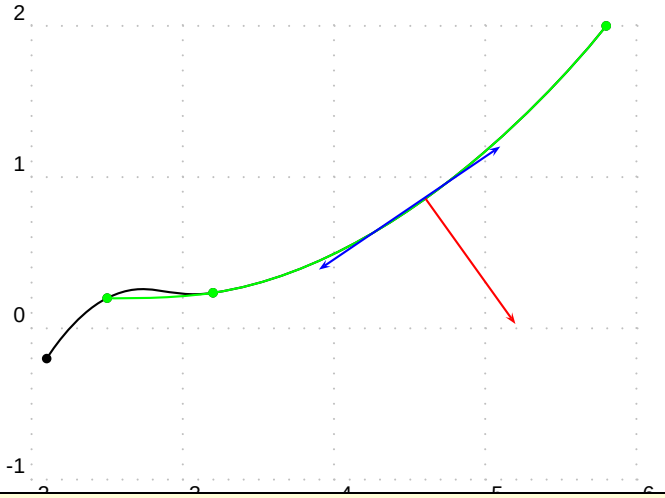
18.1. `\psTangentLine` and option `Tnormal`

`\psTangentLine[Options]`$((x_1,y_1))((x_2,y_2))((x_3,y_3))\{x\}\{dx\}$




```
\psset{unit=2}
\begin{pspicture}[showgrid=true](1,-1)(4,1)
  \pscurve[showpoints=true]
    (2.1,-0.2)(2.5,0.2)(3.2,0.235)(3.8,-0.2)
  \psTangentLine[Tnormal,arrows=->,
    linecolor=red](2.5,0.2)(3.2,0.235)%
      (3.8,-0.2){3}{0.1}
  \psTangentLine[arrows=<->,
    linecolor=blue](2.5,0.2)(3.2,0.235)%
      (3.8,-0.2){3}{0.5}
\end{pspicture}
```

In special cases one has to use `curvature=1 1 1` for the macro `\pscurve` to get the same equation for the curve as `\psplotTangentLine` does.




```
\psset{unit=2}
\begin{pspicture}[showgrid=true](2,-1)(6,2)
\pscurve[showpoints=true,
  curvature=1 1 1](2.1,-0.2)(2.5,0.2)(3.2,0.235)(5.8,2)
\pscurve[showpoints=true,linecolor=green,
  curvature=1 1 1](2.5,0.2)(3.2,0.235)(5.8,2)
\psTangentLine[Tnormal,arrows=->,linecolor=red](2.5,0.2)(3.2,0.235)(5.8,2){4.6}{0.6}
\psTangentLine[arrows=<->,linecolor=blue](2.5,0.2)(3.2,0.235)(5.8,2){4.5}{0.6}
\end{pspicture}
```

18.2. \psplotTangent and option Tnormal

There is an additional option, named Derive for an alternative function (see following example) to calculate the slope of the tangent. This will be in general the first derivative, but can also be any other function. If this option is different to to the default value Derive=default , then this function is taken to calculate the slope. For the other cases, pstricks-add builds a secant with -0.00005<x<0.00005, calculates the slope and takes this for the tangent. This may be problematic in some cases of special functions or x values, then it may be appropriate to use the Derive option.

```
\psplotTangent* [Options] {x}{dx}{function}
```

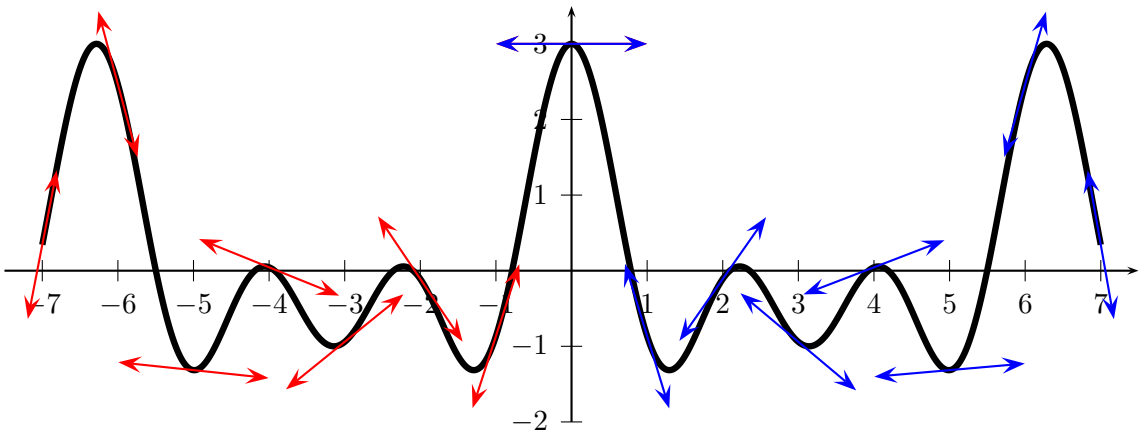
The macro expects three parameters:

x : the x value of the function for which the tangent should be calculated

dx : the dx to both sides of the x value

$f(x)$: the function in infix (with option algebraic) or the default postfix (PostScript) notation

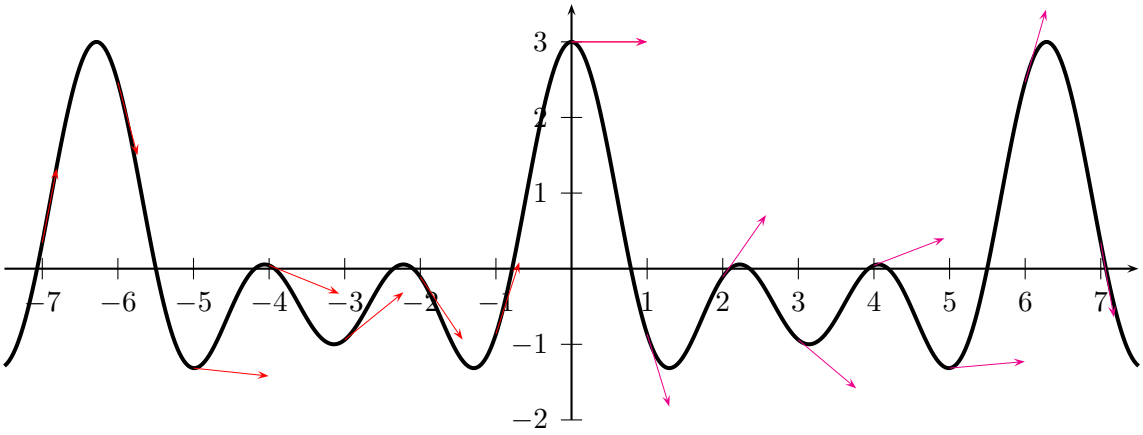
The following examples show the use of the algebraic=true option together with the Derive option. Remember that using the algebraic option implies that the angles have to be in the radian unit!




```
\def\F{x RadtoDeg dup dup cos exch 2 mul cos add exch 3 mul cos add}
\def\Fp{x RadtoDeg dup dup sin exch 2 mul sin 2 mul add exch 3 mul sin 3 mul
  add neg}
\psset{plotpoints=1001}
\begin{pspicture}(-7.5,-2.5)(7.5,4)%X\psgrid
  \psaxes{->}(0,0)(-7.5,-2)(7.5,3.5)
  \psplot[linewidth=3\pslinewidth]{-7}{7}{\F}
  \psset{linecolor=red, arrows=<->, arrowscale=2}
  \multido{\n=-7+1}{8}{\psplotTangent{\n}{1}{\F}}
  \psset{linecolor=magenta, arrows=<->, arrowscale=2}%
```

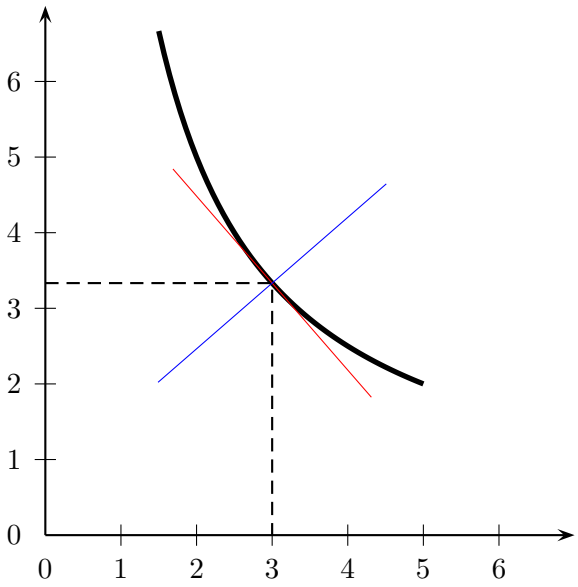
```
  \multido{\n=0+1}{8}{\psplotTangent[linecolor=blue, Derive=\Fp]{\n}{1}{\F}}
\end{pspicture}
```

The star version plots only the tangent line in the positive x-direction:



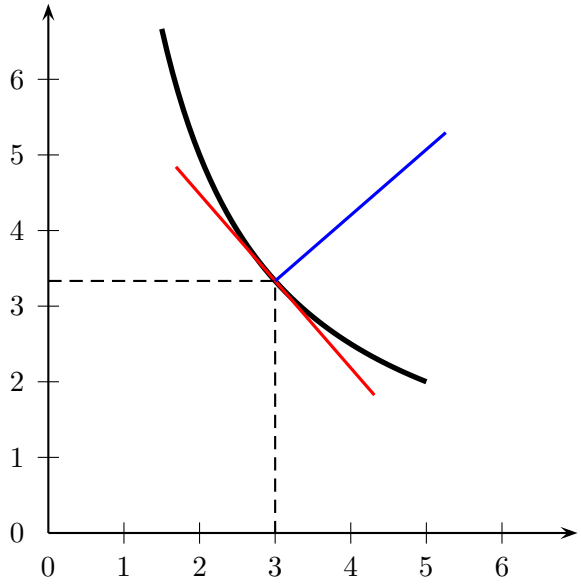

```
\def\Falg{cos(x)+cos(2*x)+cos(3*x)} \def\Fpalg{-sin(x)-2*sin(2*x)-3*sin(3*x)}
\begin{pspicture}(-7.5,-2.5)(7.5,4)%\psgrid
  \psaxes{->}(0,0)(-7.5,-2)(7.5,3.5)
  \psplot[linewidth=1.5pt,algebraic=true,plotpoints=500]{-7.5}{7.5}{\Falg}
  \multido{\n=-7+1}{8}{\psplotTangent*[linecolor=red,arrows=->,arrowscale=2,
    algebraic=true]{\n}{1}{\Falg}}
  \multido{\n=0+1}{8}{\psplotTangent*[linecolor=magenta,%
     arrows=->,arrowscale=2,algebraic=true,Derive={\Fpalg}]{\n}{1}{\Falg}}
\end{pspicture}
```

The next example shows the use of the `Derive` option to draw the perpendicular line to the tangent.




```
\begin{pspicture}(-0.5,-0.5)(7.25,7.25)
  \def\Func{10 x div}
  \psaxes[arrowscale=1.5]{->}(7,7)
  \psplot[linewidth=2pt,algebraic=true
    ]{1.5}{5}{10/x}
  \psplotTangent[linewidth=.5\pslinewidth,
    linecolor=red,algebraic=true]{3}{2}{10/x}
  \psplotTangent[linewidth=.5\pslinewidth,
    linecolor=blue,algebraic=true,Derive=(x*x
    )/10]{3}{2}{10/x}
  \psline[linestyle=dashed](!0 /x 3 def \Func
    )(!3 /x 3 def \Func)(3,0)
\end{pspicture}
```

By setting the optional argument `Tnormal` one can plot the normal of the tangent line. It always starts at the given point.

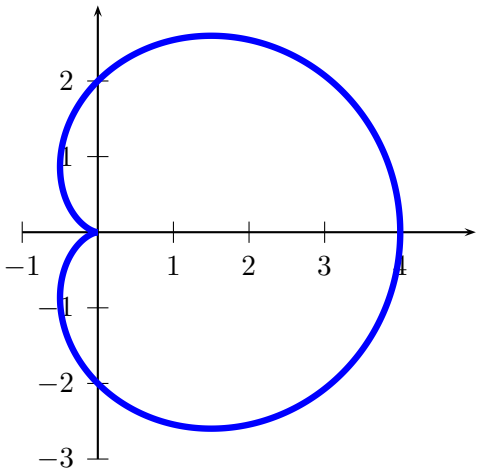



```
\begin{pspicture}(-0.5,-0.5)(7.25,7.25)
  \def\Func{10 x div}
  \psaxes[arrowscale=1.5]{->}(7,7)
  \psplot[linewidth=2pt]{1.5}{5}{\Func}
  \psplotTangent[linewidth=1.5\pslinewidth,
    linecolor=red]{3}{2}{\Func}
  \psplotTangent[linewidth=1.5\pslinewidth,
    linecolor=blue,Tnormal]{3}{2}{\Func}
  \psline[linestyle=dashed](!0 /x 3 def \Func
    )(!3 /x 3 def \Func)(3,0)
\end{pspicture}
```

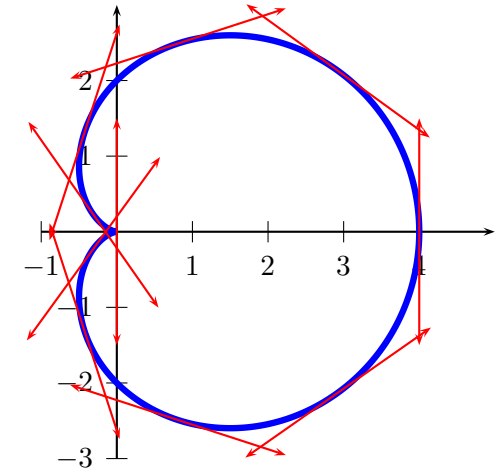
Let's work with the classical cardioid: $r = 2(1+\cos(\theta))$ and $\dfrac{dr}{d\theta} = -2\sin(\theta)$. The `Derive` option always expects the $\frac{dr}{d\theta}$ value and uses internally the equation for the derivative of implicitly defined functions:

$$\frac{dy}{dx} = \frac{r' \cdot \sin\theta + x}{r' \cdot \cos\theta - y}$$

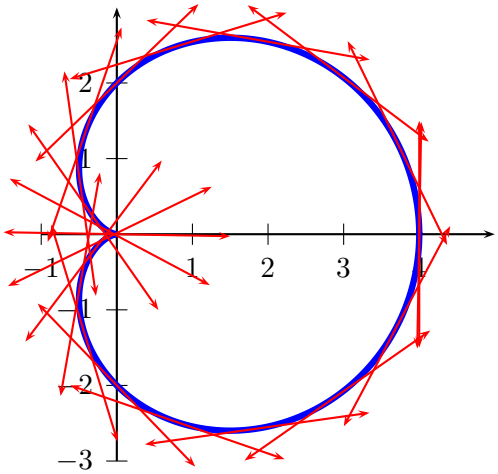
where $x = r \cdot \cos\theta$ and $y = r \cdot \sin\theta$




```
\begin{pspicture}(-1,-3)(5,3)%\psgrid[subgridcolor=
  lightgray]
  \psaxes{->}(0,0)(-1,-3)(5,3)
  \psplot[polarplot,linewidth=3\pslinewidth,linecolor=
    blue,%
    plotpoints=500]{0}{360}{1 x cos add 2 mul}
\end{pspicture}
```



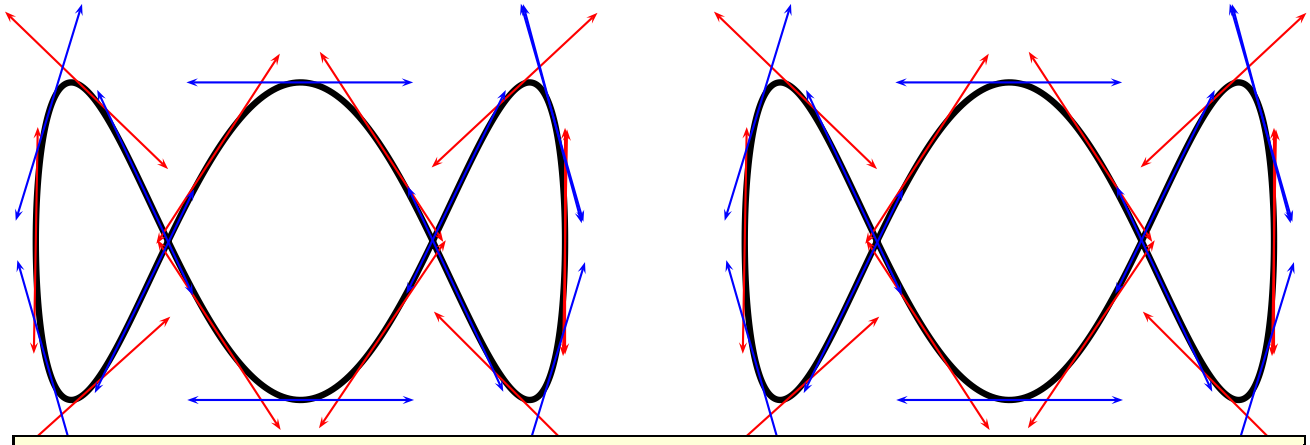

```
\begin{pspicture}(-1,-3)(5,3)%\psgrid[subgridcolor=
  lightgray]
  \psaxes{->}(0,0)(-1,-3)(5,3)
  \psplot[polarplot,linewidth=3\pslinewidth,linecolor=
    blue,plotpoints=500]{0}{360}{1 x cos add 2 mul}
  \multido{\n=0+36}{10}{%
    \psplotTangent[polarplot,linecolor=red,arrows
      =<->]{\n}{1.5}{1 x cos add 2 mul} }
\end{pspicture}
```




```
\begin{pspicture}(-1,-3)(5,3)%\psgrid[subgridcolor=
  lightgray]
  \psaxes{->}(0,0)(-1,-3)(5,3)
  \psplot[polarplot,linewidth=3\pslinewidth,linecolor=
    blue,algebraic=true,plotpoints=500]{0}{6.289}{2*(1+
    cos(x))}
  \multido{\r=0.000+0.314}{21}{%
    \psplotTangent[polarplot,Derive=-2*sin(x),algebraic
      =true,linecolor=red,arrows=<->]{\r}{1.5}{2*(1+cos
      (x))} }
\end{pspicture}
```

Let's work with a Lissajou curve: $\begin{cases} x = 3.5\cos(2t) \\ y = 3.5\sin(6t) \end{cases}$ whose derivative is : $\begin{cases} x = -7\sin(2t) \\ y = 21\cos(6t) \end{cases}$

The parameter must be the letter t instead of x and when using the `algebraic=true` option you must separate the two equations by a `|` (see example).



```
\def\Lissa{t dup 2 RadtoDeg mul cos 3.5 mul exch 6 mul RadtoDeg sin 3.5 mul}%
\psset{yunit=0.6}
\begin{pspicture}(-4,-4)(4,6)
  \parametricplot[plotpoints=500,linewidth=3\pslinewidth]{0}{3.141592}{\Lissa}
  \multido{\r=0.000+0.314}{11}{%
    \psplotTangent[linecolor=red,arrows=<->]{\r}{1.5}{\Lissa} }
  \multido{\r=0.157+0.314}{11}{%
    \psplotTangent[linecolor=blue,arrows=<->]{\r}{1.5}{\Lissa} }
\end{pspicture}\hfill%
\def\LissaAlg{3.5*cos(2*t)|3.5*sin(6*t)} \def\LissaAlgDer{-7*sin(2*t)|21*cos(6*t)}%
\begin{pspicture}(-4,-4)(4,6)
  \parametricplot[algebraic=true,plotpoints=500,linewidth=3\pslinewidth]{0}{3.141592}{\
    LissaAlg}
  \multido{\r=0.000+0.314}{11}{%
    \psplotTangent[algebraic=true,linecolor=red,arrows=<->]{\r}{1.5}{\LissaAlg} }
  \multido{\r=0.157+0.314}{11}{%
    \psplotTangent[algebraic=true,linecolor=blue,arrows=<->,%
      Derive=\LissaAlgDer]{\r}{1.5}{\LissaAlg} }
\end{pspicture}
```

19. Successive derivatives of a function

The new PostScript function `Derive` has been added for plotting successive derivatives of a function. It must be used with the `algebraic=true` option. This function has two arguments:

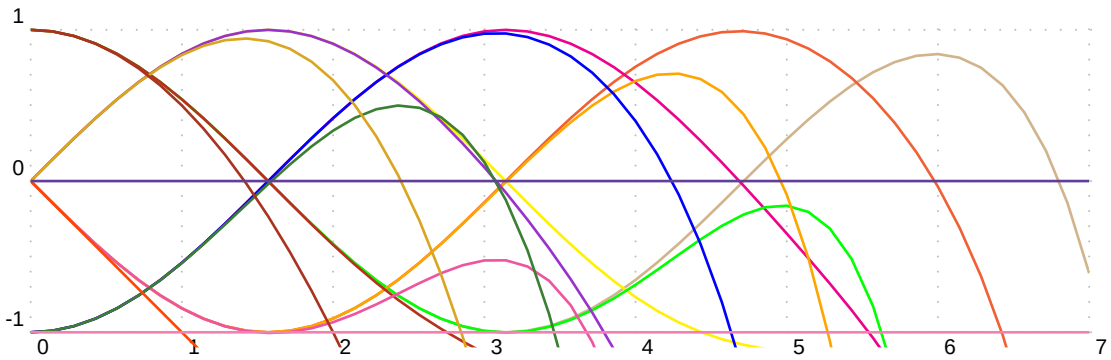
1. a positive integer which defines the order of the derivative; obviously 0 means the function itself!
2. a function of variable x which can be any function using common operators,

Do not think that the derivative is approximated, the internal PostScript engine will compute the real derivative using a formal derivative engine.

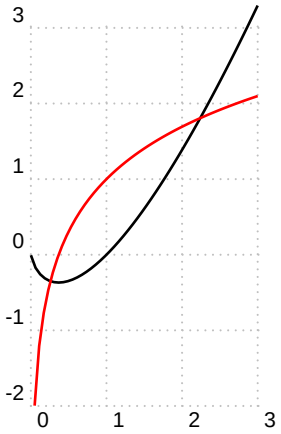
The following diagram contains the plot of the polynomial:

$$f(x)=\sum_{i=0}^{14}\frac{(-1)^i x^{2i}}{i!}=1-\frac{x^2}{2}+\frac{x^4}{4!}-\frac{x^6}{6!}+\frac{x^8}{8!}-\frac{x^{10}}{10!}+\frac{x^{12}}{12!}-\frac{x^{14}}{14!}$$

and of its first 15 derivatives. It is the sequence definition of the cosine.




```
\psset{unit=2}
\def\getColor#1{\ifcase#1 Tan\or RedOrange\or magenta\or yellow\or green\or Orange\or
  blue\or
 DarkOrchid\or BrickRed\or Rhodamine\or OliveGreen\or Goldenrod\or Mahogany\or
 OrangeRed\or CarnationPink\or RoyalPurple\or Lavender\fi}
\begin{pspicture}[showgrid=true](0,-1.2)(7,1.5)
 \psclip{\psframe[linestyle=none](0,-1.1)(7,1.1)}
 \multido{\in=0+1}{16}{%
   \psplot[linewidth=1pt,algebraic=true,linecolor=\getColor{\in}]{0}{7}
    {Derive(\in,1-x^2/2+x^4/24-x^6/720+x^8/40320-x^10/3628800+x^12/479001600-x
      ^14/87178291200)}}
 \endpsclip
\end{pspicture}
```




```
\begin{pspicture}[shift=-2.5,showgrid=true,linewidth=1pt
  ](0,-2)(3,3)
  \psplot[algebraic=true]{.001}{3}{x*ln(x)} % f(x)
  \psplot[algebraic=true,linecolor=red]{.05}{3}{Derive(1,x
    *ln(x))} % f'(x)=1+ln(x)
\end{pspicture}
```

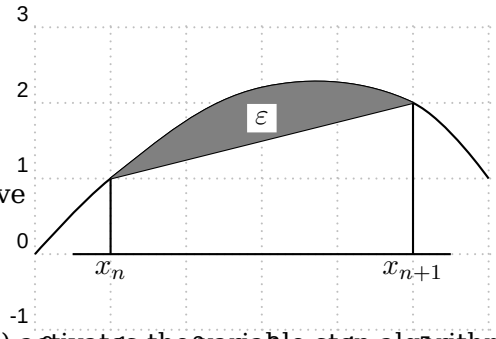
20. Variable step for plotting a curve

20.1. Theory

As you know with the `\psplot` macro, the curve is plotted using a piece-wise linear curve. The step is given by the parameter `plotpoints`. For each step between x_i and x_{i+1}, the area defined between the curve and its approximation (a segment) is majored by this formula :

$$|\varepsilon| \leq \frac{M_2(f)(x_{i+1} - x_i)^3}{12}$$

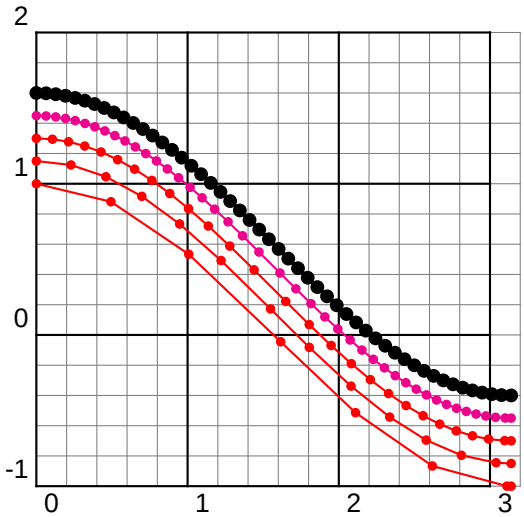
$M_2(f)$ is a majorant of the second derivative of f in the interval $[x_i; x_{i+1}]$.



The parameter `VarStep` (`false` by default) activates the variable step algorithm. It is set to a tolerance defined by the parameter `VarStepEpsilon` (`default` by default, accept real value). If this parameter is not set by the user, then it is automatically computed using the default first step given by the parameter `plotpoints`. Then, for each step, $f''(x_n)$ and $f''(x_{n+1})$ are computed and the smaller is used as $M_2(f)$, and then the step is approximated. This means that the step is constant for second order polynomials.

20.2. The cosine

Different value for the tolerance from 0.01 to $0.000\,1$, a factor 10 between each of them. In black, there is the classic `\psplot` behavior, and in magenta the default variable step behavior.

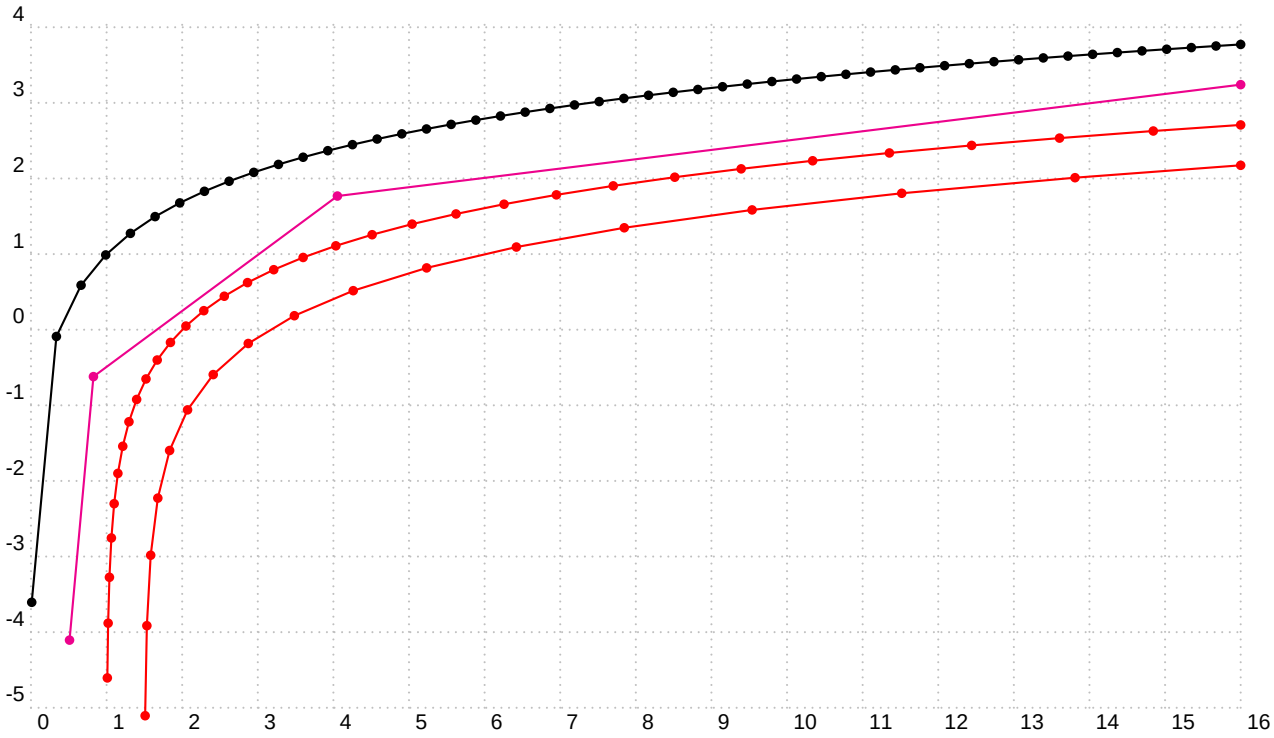



```
\psset{algebraic=true, VarStep=true, unit=2, showpoints=true, linecolor=red}
\begin{pspicture}[showgrid=true](-0,-1)(3.14,2)
  \psplot[VarStepEpsilon=.01]{0}{3.14}{cos(x)}
  \psplot[VarStepEpsilon=.001]{0}{3.14}{cos(x)+.15}
  \psplot[VarStepEpsilon=.0001]{0}{3.14}{cos(x)+.3}
```

```
  \psplot[linecolor=magenta]{0}{3.14}{cos(x)+.45}
  \psplot[VarStep=false,linewidth=1pt,linecolor=black]{-0}{3.14}{cos(x)+.6}
\end{pspicture}
```

20.3. The Napierian Logarithm

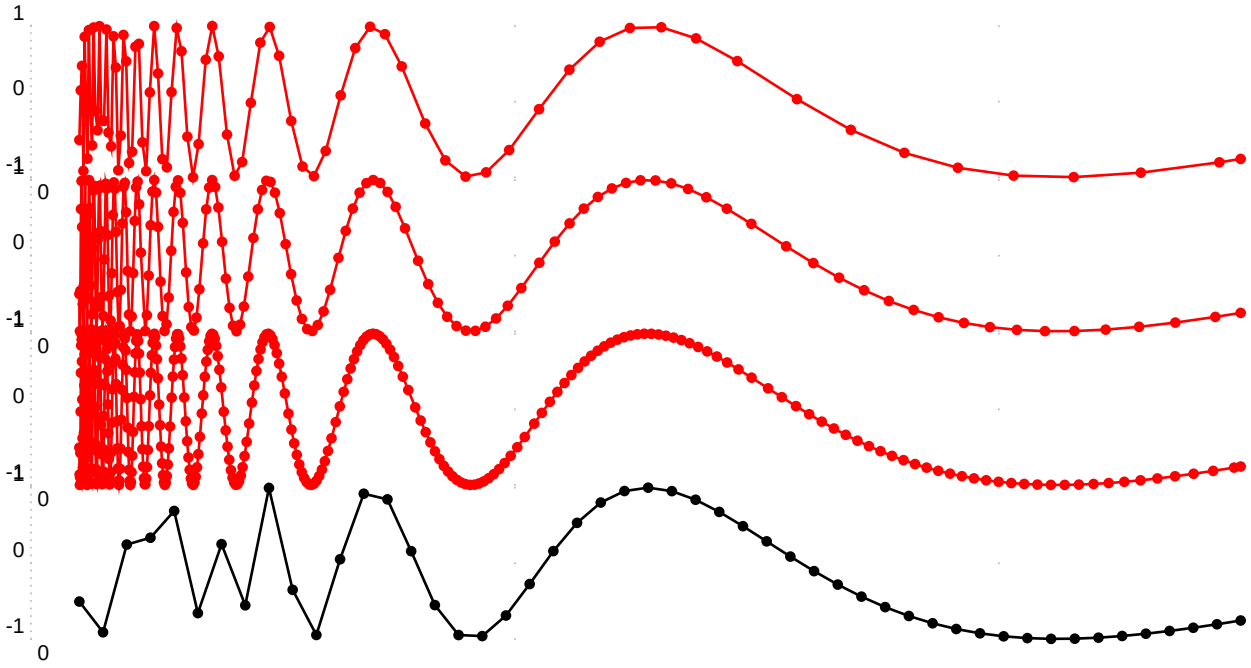
A really classic example which gives a bad beginning, the tolerance is set to 0.001.




```
\psset{algebraic=true, VarStep=true, linecolor=red, showpoints=true}
\begin{pspicture}[showgrid=true](0,-5)(16,4)
  \psplot[VarStep=false, linecolor=black]{.01}{16}{ln(x)+1}
  \psplot[linecolor=magenta]{.51}{16}{ln(x-1/2)+1/2}
  \psplot[VarStepEpsilon=.001]{1.01}{16}{ln(x-1)}
  \psplot[VarStepEpsilon=.01]{1.51}{16}{ln(x-1.5)-100/200}
\end{pspicture}
```

20.4. Sine of the inverse of x

Impossible to draw, but let's try!

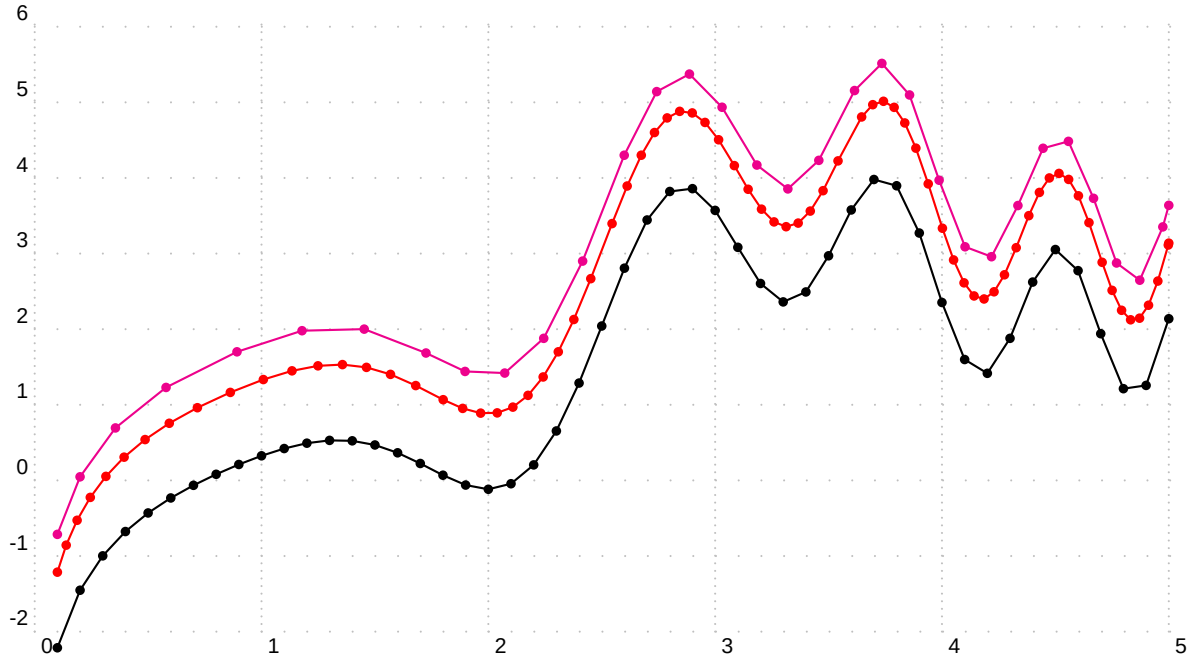



```
\psset{xunit=64,algebraic=true,VarStep,linecolor=red,showpoints=true,linewidth
  =1pt}
\begin{pspicture}[showgrid=true](0,-1)(.5,1)
  \psplot[VarStepEpsilon=.0001]{.01}{.25}{sin(1/x)}
\end{pspicture}\\
\begin{pspicture}[showgrid=true](0,-1)(.5,1)
  \psplot[VarStepEpsilon=.00001]{.01}{.25}{sin(1/x)}
\end{pspicture}\\
\begin{pspicture}[showgrid=true](0,-1)(.5,1)
  \psplot[VarStepEpsilon=.000001]{.01}{.25}{sin(1/x)}
\end{pspicture}\\
\begin{pspicture}[showgrid=true](0,-1)(.5,1)
  \psplot[VarStep=false, linecolor=black]{.01}{.25}{sin(1/x)}
\end{pspicture}
```

20.5. A really complecated function

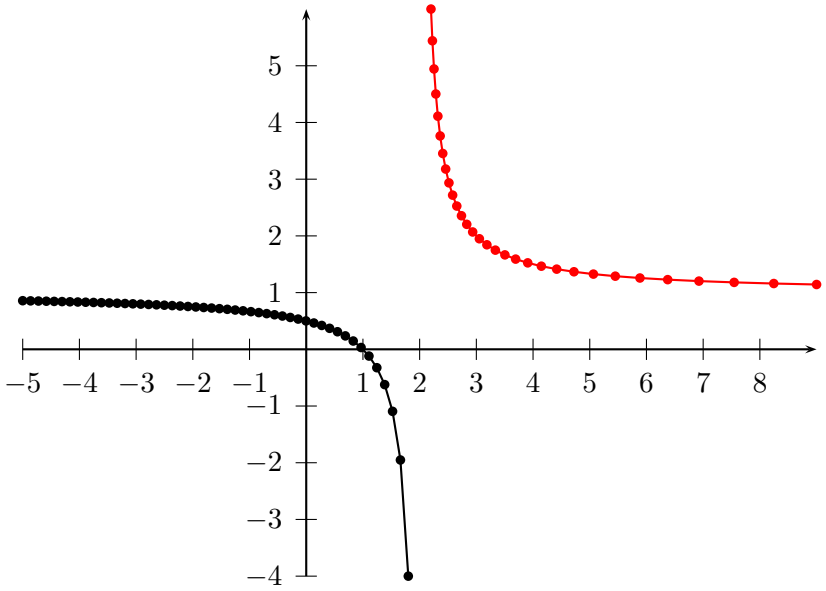
Just appreciate the difference between the normal behavior and the plotting with the `varStep` option. The function is:

$$f(x) = x - \frac{x^2}{10} + \ln(x) + \cos(2x) + \sin(x^2) - 1$$




```
\psset{xunit=3, algebraic=true, VarStep, showpoints=true}
\begin{pspicture}[showgrid=true](0,-2)(5,6)
  \psplot[VarStepEpsilon=.0005, linecolor=red]{.1}{5}{x-x^2/10+ln(x)+cos(2*x)+
    sin(x^2)}
  \psplot[linecolor=magenta]{.1}{5}{x-x^2/10+ln(x)+cos(2*x)+sin(x^2)+.5}
  \psplot[VarStep=false]{.1}{5}{x-x^2/10+ln(x)+cos(2*x)+sin(x^2)-1}
\end{pspicture}
```

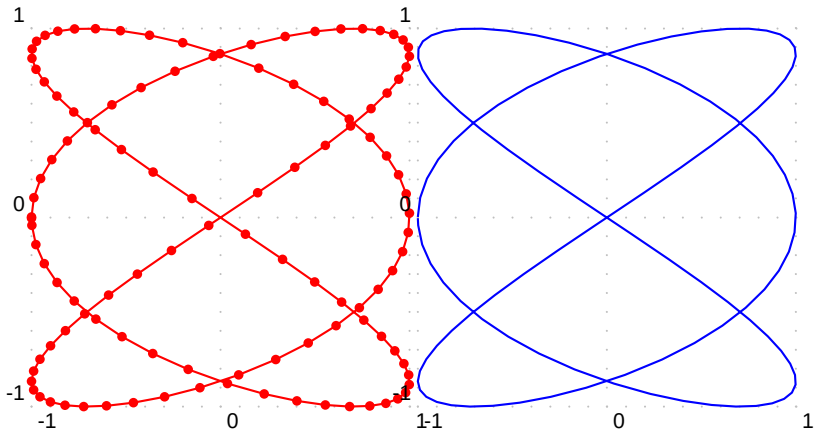
20.6. A hyperbola



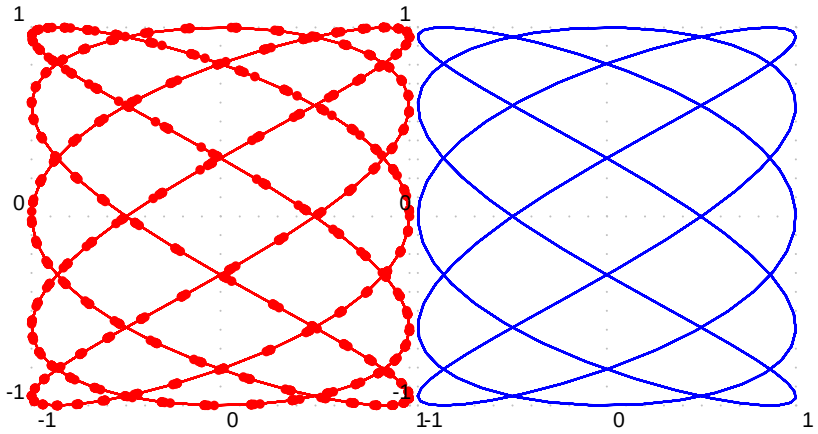

```
\psset{algebraic=true, showpoints=true, unit=0.75}
\begin{pspicture}(-5,-4)(9,6)
  \psplot[linecolor=black]{-5}{1.8}{(x-1)/(x-2)}
  \psplot[VarStep=true, VarStepEpsilon=.001, linecolor=red]{2.2}{9}{(x-1)/(x
    -2)}
  \psaxes{->}(0,0)(-5,-4)(9,6)
\end{pspicture}
```

20.7. Using \parametricplot

\parametricplot [Options] {*t0*}{*t1*} [PS commands] {*x(t) y(t)*}

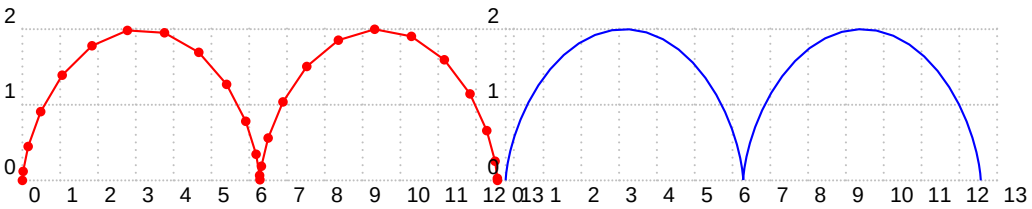



```
\psset{unit=3}
\begin{pspicture}[showgrid=true](-1,-1)(1,1)
\parametricplot[algebraic=true,linecolor=red,VarStep=true, showpoints=true,
            VarStepEpsilon=.0001]
            {-3.14}{3.14}{cos(3*t)|sin(2*t)}
\end{pspicture}
\begin{pspicture}[showgrid=true](-1,-1)(1,1)
\parametricplot[algebraic=true,linecolor=blue,VarStep=true, showpoints=false,
            VarStepEpsilon=.0001]
            {-3.14}{3.14}{cos(3*t)|sin(2*t)}
\end{pspicture}
```




```
\psset{unit=2.5}
\begin{pspicture}[showgrid=true](-1,-1)(1,1)
\parametricplot[algebraic=true,linecolor=red,VarStep=true, showpoints=true,
            VarStepEpsilon=.0001]
            {0}{47.115}{cos(5*t)|sin(3*t)}
\end{pspicture}
\begin{pspicture}[showgrid=true](-1,-1)(1,1)
\parametricplot[algebraic=true,linecolor=blue,VarStep=true, showpoints=false,
            VarStepEpsilon=.0001]
```

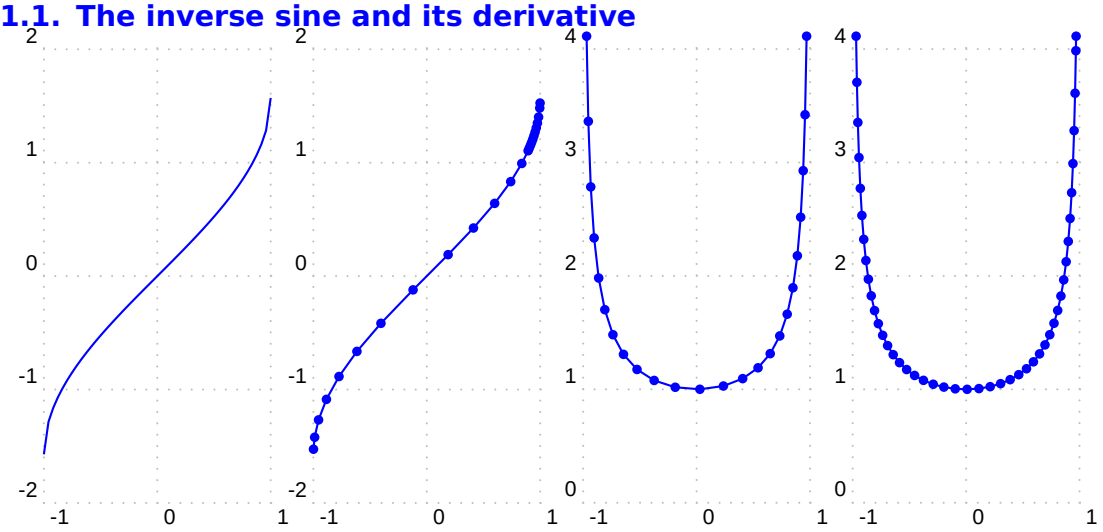
```
            {0}{47.115}{cos(5*t)|sin(3*t)}
\end{pspicture}
```




```
\psset{xunit=.5}
\begin{pspicture}[showgrid=true](0,0)(12.566,2)
\parametricplot[algebraic=true,linecolor=red,VarStep, showpoints=true,
      VarStepEpsilon=.01]{0}{12.566}{t+cos(-t-Pi/2)|1+sin(-t-Pi/2)}
\end{pspicture}
%
\begin{pspicture}[showgrid=true](0,0)(12.566,2)
\parametricplot[algebraic=true,linecolor=blue,VarStep, showpoints=false,
      VarStepEpsilon=.001]{0}{12.566}{t+cos(-t-Pi/2)|1+sin(-t-Pi/2)}
\end{pspicture}
```

21. New math functions and their derivatives

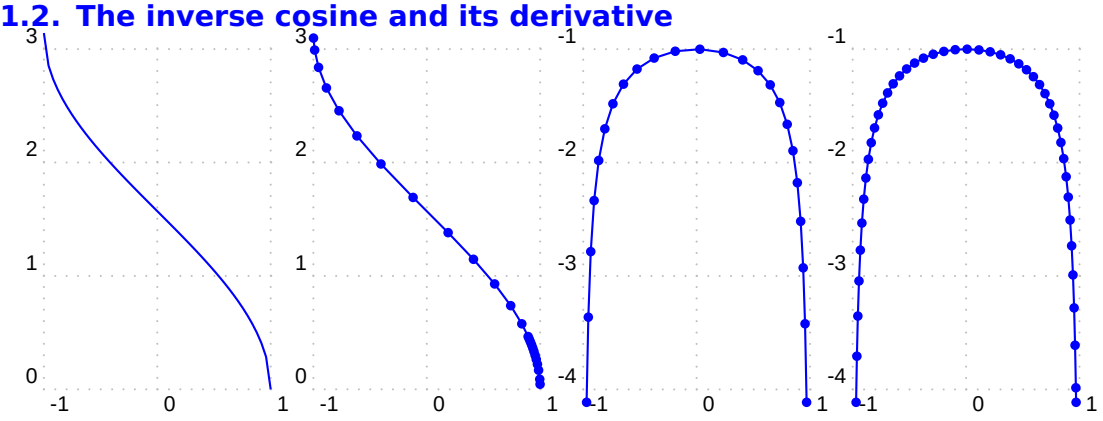
21.1. The inverse sine and its derivative




```
\psset{unit=1.5}
\begin{pspicture}[showgrid=true](-1,-2)(1,2)
  \psplot[linecolor=blue,algebraic=true]{-1}{1}{asin(x)}
\end{pspicture}
\hspace{1em}
\psset{algebraic=true, VarStep, VarStepEpsilon=.001, showpoints=true}
\begin{pspicture}[showgrid=true](-1,-2)(1,2)
  \psplot[linecolor=blue]{-.999}{.999}{asin(x)}
\end{pspicture}
\hspace{1em}
```

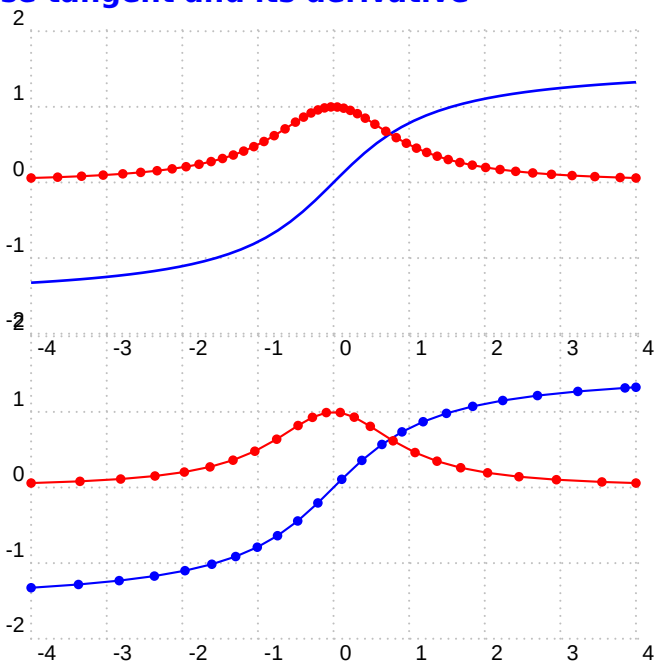
```
\begin{pspicture}[showgrid=true](-1,0)(1,4)
  \psplot[linecolor=red]{-.97}{.97}{Derive(1,asin(x))}
\end{pspicture}
\hspace{1em}
\psset{algebraic=true, VarStep, VarStepEpsilon=.0001, showpoints=true}
\begin{pspicture}[showgrid=true](-1,0)(1,4)
  \psplot[linecolor=red]{-.97}{.97}{Derive(1,asin(x))}
\end{pspicture}
```

21.2. The inverse cosine and its derivative



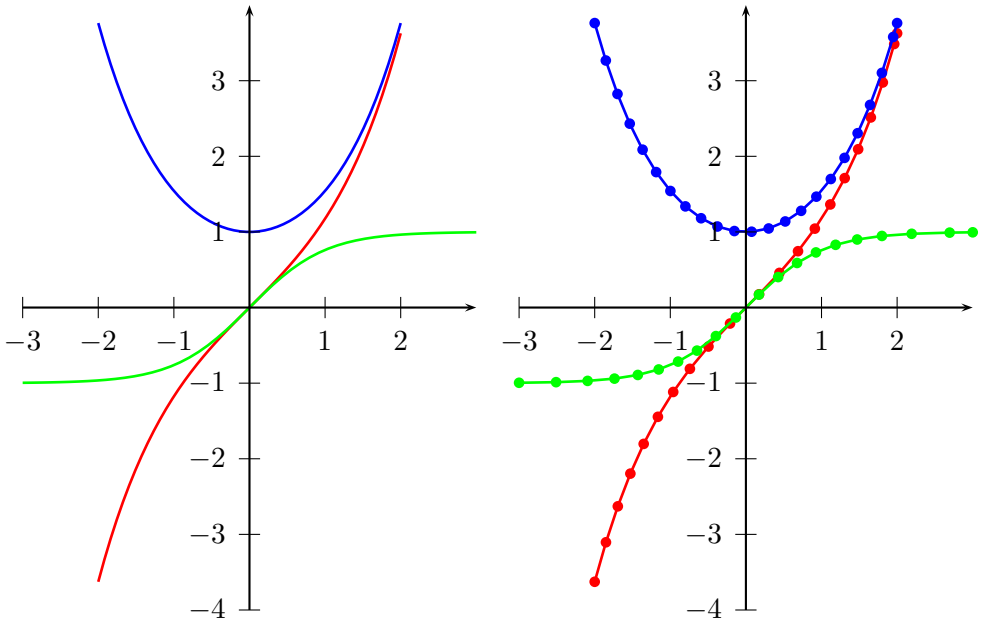

```
\psset{unit=1.5}
\begin{pspicture}[showgrid=true](-1,0)(1,3)
  \psplot[linecolor=blue,algebraic=true]{-1}{1}{acos(x)}
\end{pspicture}
\hspace{1em}
\psset{algebraic=true, VarStep, VarStepEpsilon=.001, showpoints=true}
\begin{pspicture}[showgrid=true](-1,0)(1,3)
  \psplot[linecolor=blue]{-.999}{.999}{acos(x)}
\end{pspicture}
\hspace{1em}
\begin{pspicture}[showgrid=true](-1,-4)(1,-1)
  \psplot[linecolor=red]{-.97}{.97}{Derive(1,acos(x))}
\end{pspicture}
\hspace{1em}
\psset{algebraic=true, VarStep, VarStepEpsilon=.0001, showpoints=true}
\begin{pspicture}[showgrid=true](-1,-4)(1,-1)
  \psplot[linecolor=red]{-.97}{.97}{Derive(1,acos(x))}
\end{pspicture}
```

21.3. The inverse tangent and its derivative

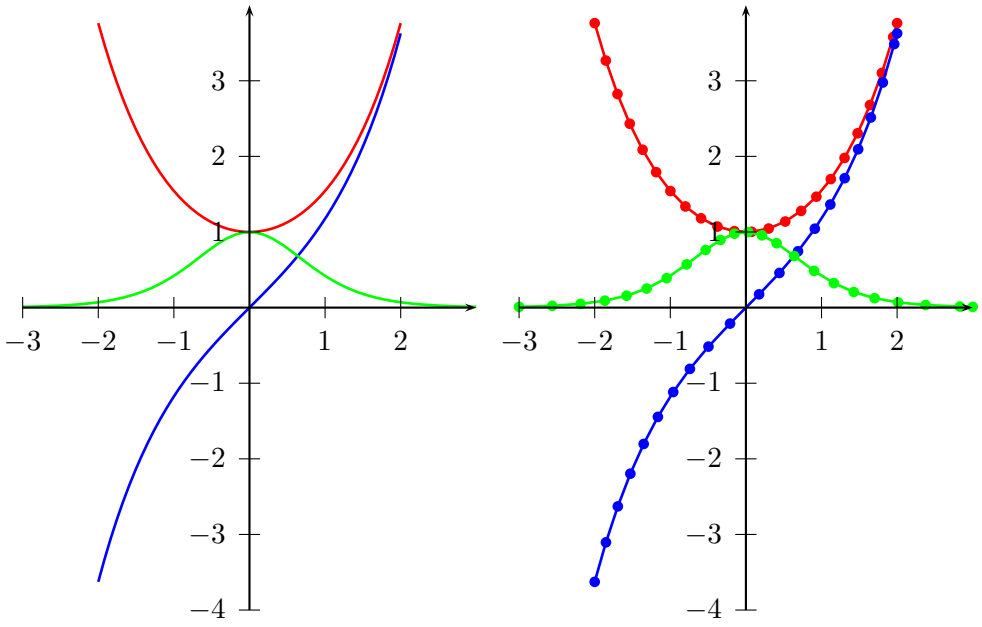



```
\begin{pspicture}[showgrid=true](-4,-2)(4,2)
\psset{algebraic=true}
  \psplot[linecolor=blue,linewidth=1pt]{-4}{4}{atg(x)}
  \psplot[linecolor=red,VarStep, VarStepEpsilon=.0001, showpoints=true
    ]{-4}{4}{Derive(1,atg(x))}
\end{pspicture}
\hspace{1em}
\begin{pspicture}[showgrid=true](-4,-2)(4,2)
\psset{algebraic=true, VarStep, VarStepEpsilon=.001, showpoints=true}
  \psplot[linecolor=blue]{-4}{4}{atg(x)}
  \psplot[linecolor=red]{-4}{4}{Derive(1,atg(x))}
\end{pspicture}
```

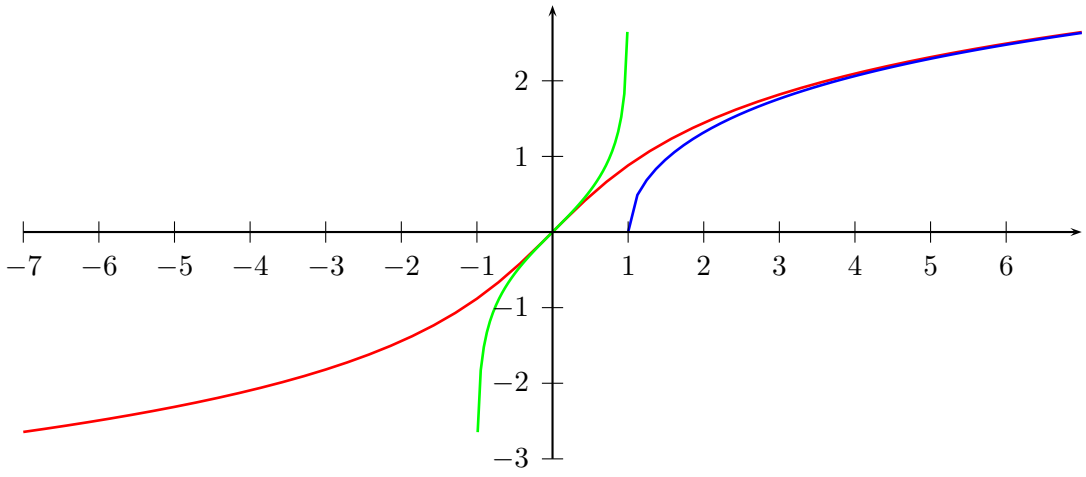
21.4. Hyperbolic functions

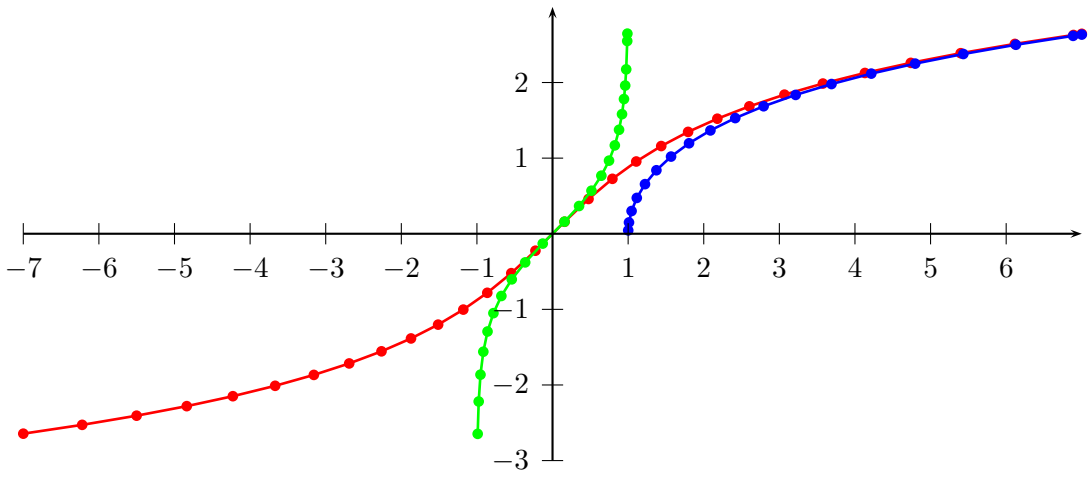



```
\begin{pspicture}(-3,-4)(3,4)
\psset{algebraic=true}
  \psplot[linecolor=red,linewidth=1pt]{-2}{2}{sh(x)}
  \psplot[linecolor=blue,linewidth=1pt]{-2}{2}{ch(x)}
  \psplot[linecolor=green,linewidth=1pt]{-3}{3}{th(x)}
  \psaxes{->}(0,0)(-3,-4)(3,4)
\end{pspicture}
\hspace{1em}
\begin{pspicture}(-3,-4)(3,4)
\psset{algebraic=true, VarStep=true, VarStepEpsilon=.001, showpoints=true}
  \psplot[linecolor=red,linewidth=1pt]{-2}{2}{sh(x)}
  \psplot[linecolor=blue,linewidth=1pt]{-2}{2}{ch(x)}
  \psplot[linecolor=green,linewidth=1pt]{-3}{3}{th(x)}
  \psaxes{->}(0,0)(-3,-4)(3,4)
\end{pspicture}
```

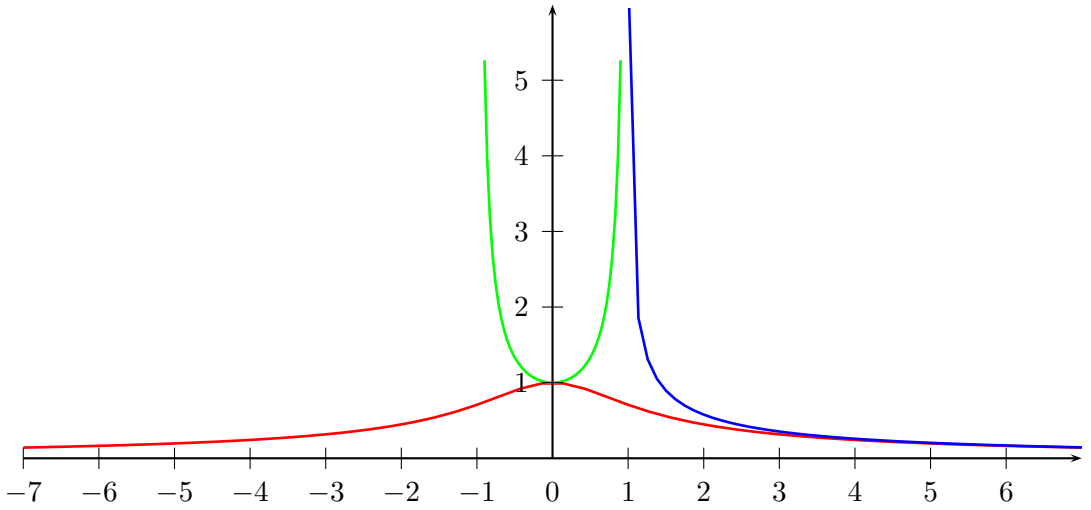


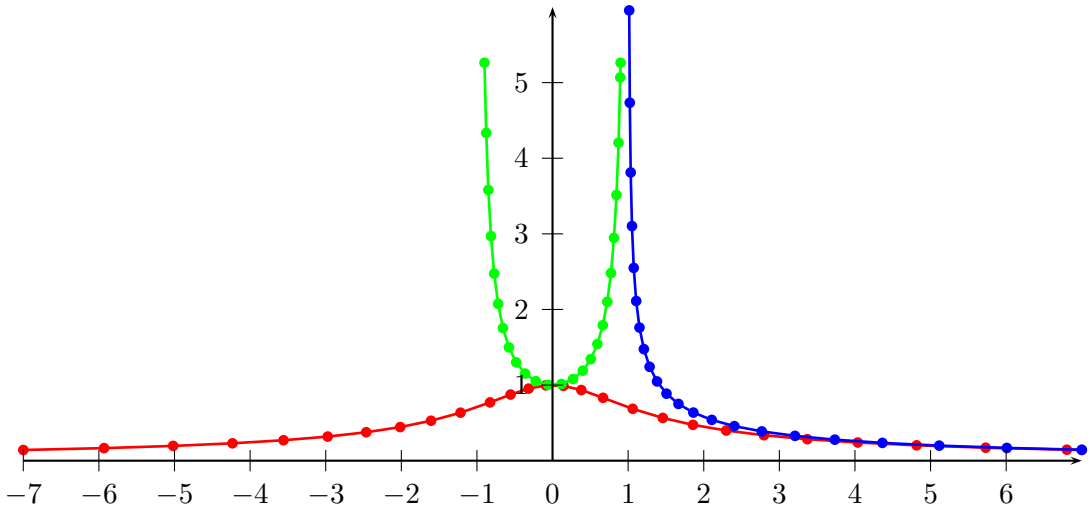

```
\begin{pspicture}(-3,-4)(3,4)
\psset{algebraic=true,linewidth=1pt}
  \psplot[linecolor=red,linewidth=1pt]{-2}{2}{Derive(1,sh(x))}
  \psplot[linecolor=blue,linewidth=1pt]{-2}{2}{Derive(1,ch(x))}
  \psplot[linecolor=green,linewidth=1pt]{-3}{3}{Derive(1,th(x))}
  \psaxes{->}(0,0)(-3,-4)(3,4)
\end{pspicture}
\hspace{1em}
\begin{pspicture}(-3,-4)(3,4)
\psset{algebraic=true, VarStep=true, VarStepEpsilon=.001, showpoints=true}
  \psplot[linecolor=red,linewidth=1pt]{-2}{2}{Derive(1,sh(x))}
  \psplot[linecolor=blue,linewidth=1pt]{-2}{2}{Derive(1,ch(x))}
  \psplot[linecolor=green,linewidth=1pt]{-3}{3}{Derive(1,th(x))}
  \psaxes{->}(0,0)(-3,-4)(3,4)
\end{pspicture}
```






```
\begin{pspicture}(-7,-3)(7,3)
\psset{algebraic=true}
  \psplot[linecolor=red,linewidth=1pt]{-7}{7}{Argsh(x)}
  \psplot[linecolor=blue,linewidth=1pt]{1}{7}{Argch(x)}
  \psplot[linecolor=green,linewidth=1pt]{-.99}{.99}{Argth(x)}
  \psaxes{->}(0,0)(-7,-3)(7,3)
\end{pspicture}\\[\baselineskip]
\begin{pspicture}(-7,-3)(7,3)
  \psset{algebraic=true, VarStep, VarStepEpsilon=.001, showpoints=true}
  \psplot[linecolor=red,linewidth=1pt]{-7}{7}{Argsh(x)}
  \psplot[linecolor=blue,linewidth=1pt]{1.001}{7}{Argch(x)}
  \psplot[linecolor=green,linewidth=1pt]{-.99}{.99}{Argth(x)}
  \psaxes{->}(0,0)(-7,-3)(7,3)
\end{pspicture}
```






```
\begin{pspicture}(-7,-0.5)(7,6)
\psset{algebraic=true}
  \psplot[linecolor=red,linewidth=1pt]{-7}{7}{Derive(1,Argsh(x))}
  \psplot[linecolor=blue,linewidth=1pt]{1.014}{7}{Derive(1,Argch(x))}
  \psplot[linecolor=green,linewidth=1pt]{-.9}{.9}{Derive(1,Argth(x))}
  \psaxes{->}(0,0)(-7,0)(7,6)
\end{pspicture}\\[\baselineskip]
\begin{pspicture}(-7,-0.5)(7,6)
\psset{algebraic=true}
  \psset{algebraic=true, VarStep=true, VarStepEpsilon=.001, showpoints=true}
  \psplot[linecolor=red,linewidth=1pt]{-7}{7}{Derive(1,Argsh(x))}
  \psplot[linecolor=blue,linewidth=1pt]{1.014}{7}{Derive(1,Argch(x))}
  \psplot[linecolor=green,linewidth=1pt]{-.9}{.9}{Derive(1,Argth(x))}
  \psaxes{->}(0,0)(-7,0)(7,6)
\end{pspicture}
```

22. \psplotDiffEqn – solving diffential equations

A differential equation of first order is like

$$y' = f(x, y, y') \tag{1}$$

where y is a function of x. We define some vectors $Y = [y, y', \cdots, y^{(n-1)}]$ and $Y' = [y', y'', \cdots, y^n]$, depending on the order n. The syntax of the macro is

```
\psplotDiffEqn [Options] {x0}{x1}{y0}{f(x,y,y',...)}
```

- `options`: the `\psplotDiffEqn` specific options and all other of PSTricks, which make sense;
- x_0: the start value;
- x_1: the end value of the definition interval;
- y_0: the initial values for $y(x_0)$ $y'(x_0)$ ...;
- $f(x, y, y', ...)$: the differential equation, depending to the number of initial values, e.g.: `{0 1}` for y_0 are two initial values, so that we have a differential equation of second order $f(x, y, y')$ and the macro leaves y y' on the stack.

The new options are:

- `method`: integration method (`euler` for order 1 euler method, `rk4` for 4^{th} order Runge-Kutta method);
- `whichabs`: select the abscissa for plotting the graph, by default it is x, but you can specify a number which represent a position in the vector y;
- `whichord`: same as precedent for the ordinate, by default $y(0)$;
- `plotfuncx`: describe a ps function for the abscissa, parameter `whichabs` becomes useless;
- `plotfuncy`: idem for the ordinate;
- `buildvector`: boolean parameter for specifying the input-output of the f description:

  `true` (default): y is put on the stack element by element, y' must be given in the same way;

  `false` : y is put on the stack as a vector, y' must be returned in the same way;

- `algebraic=true`: algebraic=true description for f, `buildvector` parameter is useless when activating this option.

22.1. Variable step for differential equations

A new algorithm has been added for adjusting the step according to the variations of the curve. The parameter `method` has a new possible value : `varrkiv` to activate the Runge-Kutta method with variable step, then the parameter `varsteptol` (real value; `.01` by default) can control the tolerance of the algortihm.

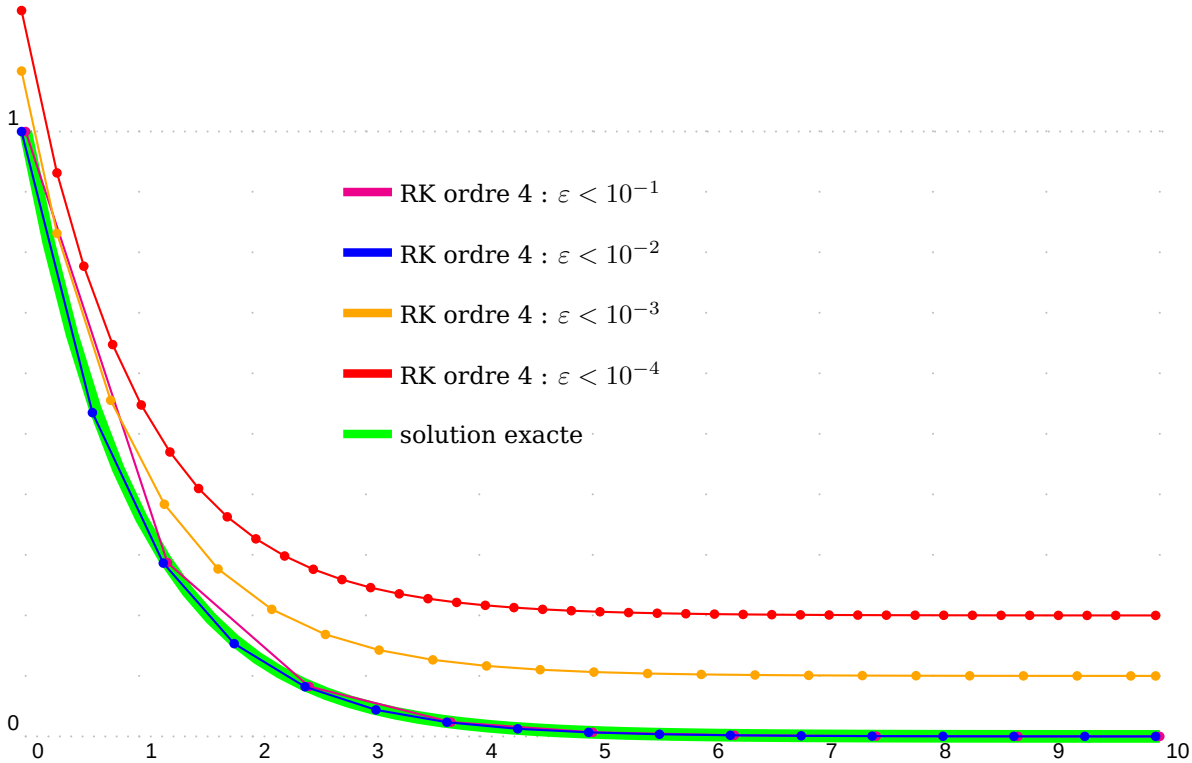


Figure 1: Equation $y' = -y$ with $y_0 = 1$.

```
\def\Funct{neg}\def\FunctAlg{-y[0]}
\psset{xunit=1.5, yunit=8, showpoints=true}
\begin{pspicture}[showgrid=true](0,0)(10,1.2)
 \psplot[linewidth=6\pslinewidth, linecolor=green, showpoints=false]{0}{10}{
   Euler x neg exp}
 \psplotDiffEqn[linecolor=magenta, method=varrkiv, varsteptol=.1, plotpoints
   =2]{0}{10}{1}{\Funct}
 \rput(0,.0){\psplotDiffEqn[linecolor=blue, method=varrkiv, varsteptol=.01,
   plotpoints=2]{0}{10}{1}{\Funct}}
 \rput(0,.1){\psplotDiffEqn[linecolor=Orange, method=varrkiv, varsteptol
   =.001, plotpoints=2]{0}{10}{1}{\Funct}}
 \rput(0,.2){\psplotDiffEqn[linecolor=red, method=varrkiv, varsteptol=.0001,
   plotpoints=2]{0}{10}{1}{\Funct}}
 \psset{linewidth=4\pslinewidth,showpoints=false}
 \rput*(3.3,.9){\psline[linecolor=magenta](-.75cm,0)}
 \rput*[l](3.3,.9){\small RK ordre 4 : $\varepsilon<10^{-1}$}
 \rput*(3.3,.8){\psline[linecolor=blue](-.75cm,0)}
 \rput*[l](3.3,.8){\small RK ordre 4 : $\varepsilon<10^{-2}$}
 \rput*(3.3,.7){\psline[linecolor=Orange](-.75cm,0)}
```

```
  \rput*[l](3.3,.7){\small RK ordre 4 : $\varepsilon<10^{-3}$}
  \rput*(3.3,.6){\psline[linecolor=red](-.75cm,0)}
  \rput*[l](3.3,.6){\small RK ordre 4 : $\varepsilon<10^{-4}$}
  \rput*(3.3,.5){\psline[linecolor=green](-.75cm,0)}
  \rput*[l](3.3,.5){\small solution exacte}
\end{pspicture}
```

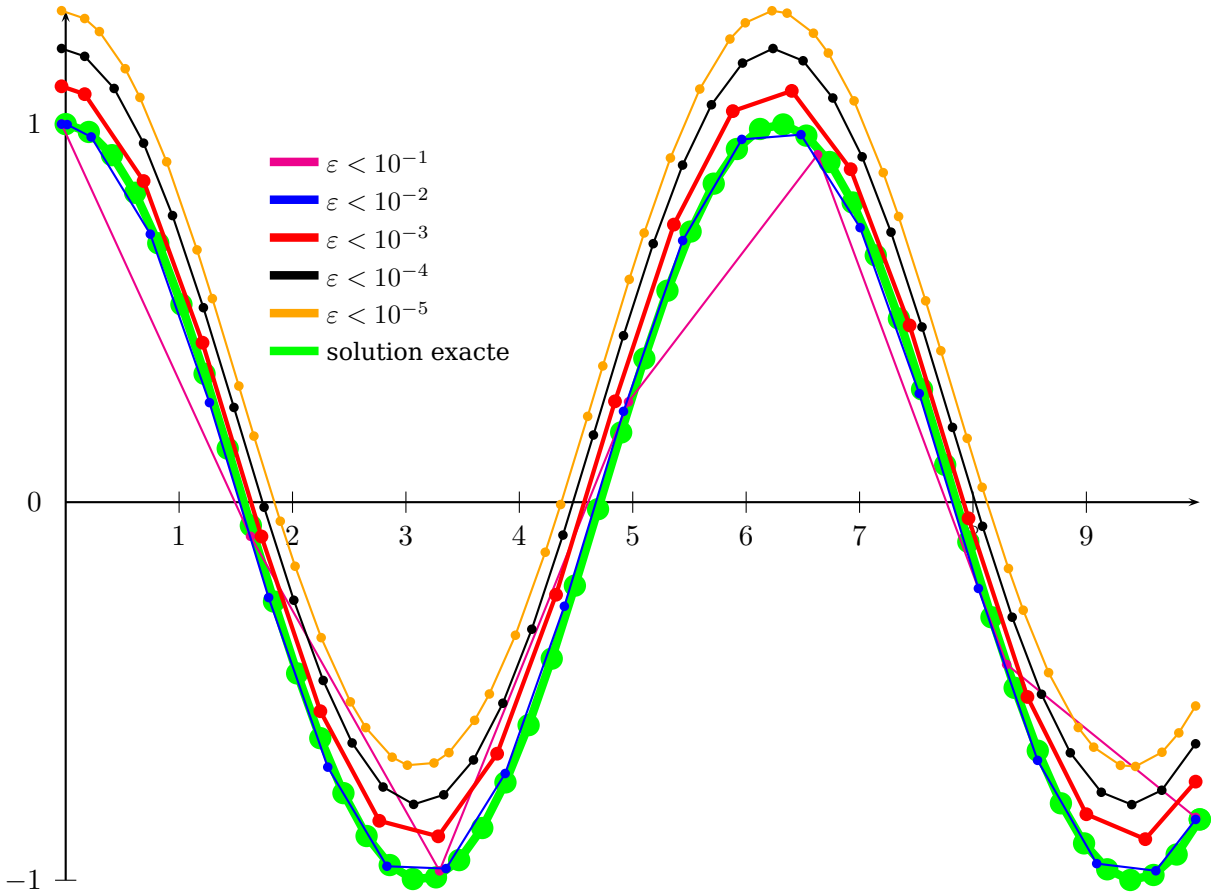


Figure 2: Equation $y'' = -y$

```
\def\Funct{exch neg}
\psset{xunit=1.5, yunit=5, method=varrkiv, showpoints=true}%%
\def\quatrepi{12.5663706144}
\begin{pspicture}(0,-1)(10,1.3)
  \psaxes{->}(0,0)(0,-1)(10,1.3)
  \psplot[linewidth=4\pslinewidth, linecolor=green, algebraic=true]{0}{10}{cos
    (x)}
  \rput(0,.0){\psplotDiffEqn[linecolor=magenta, plotpoints=7, varsteptol
    =.1]{0}{10}{1 0}{\Funct}}
  \rput(0,.0){\psplotDiffEqn[linecolor=blue, plotpoints=201, varsteptol
    =.01]{0}{10}{1 0}{\Funct}}
  \rput(0,.1){\psplotDiffEqn[linewidth=2\pslinewidth, linecolor=red,
    varsteptol=.001]{0}{10}{1 0}{\Funct}}
  \rput(0,.2){\psplotDiffEqn[linecolor=black, varsteptol=.0001]{0}{10}{1 0}{\
    Funct}}
```

```
  \rput(0,.3){\psplotDiffEqn[linecolor=Orange, varsteptol=.00001]{0}{10}{1
    0}{\Funct}}
  \psset{linewidth=4\pslinewidth,showpoints=false}
  \rput*(2.3,.9){\psline[linecolor=magenta](-.75cm,0)}
  \rput*[l](2.3,.9){\small $\varepsilon<10^{-1}$}
  \rput*(2.3,.8){\psline[linecolor=blue](-.75cm,0)}
  \rput*[l](2.3,.8){\small $\varepsilon<10^{-2}$}
  \rput*(2.3,.7){\psline[linecolor=red](-.75cm,0)}
  \rput*[l](2.3,.7){\small $\varepsilon<10^{-3}$}
  \rput*(2.3,.6){\psline[linecolor=black](-.75cm,0)}
  \rput*[l](2.3,.6){\small $\varepsilon<10^{-4}$}
  \rput*(2.3,.5){\psline[linecolor=Orange](-.75cm,0)}
  \rput*[l](2.3,.5){\small $\varepsilon<10^{-5}$}
  \rput*(2.3,.4){\psline[linecolor=green](-.75cm,0)}
  \rput*[l](2.3,.4){\small solution exacte}
\end{pspicture}
```

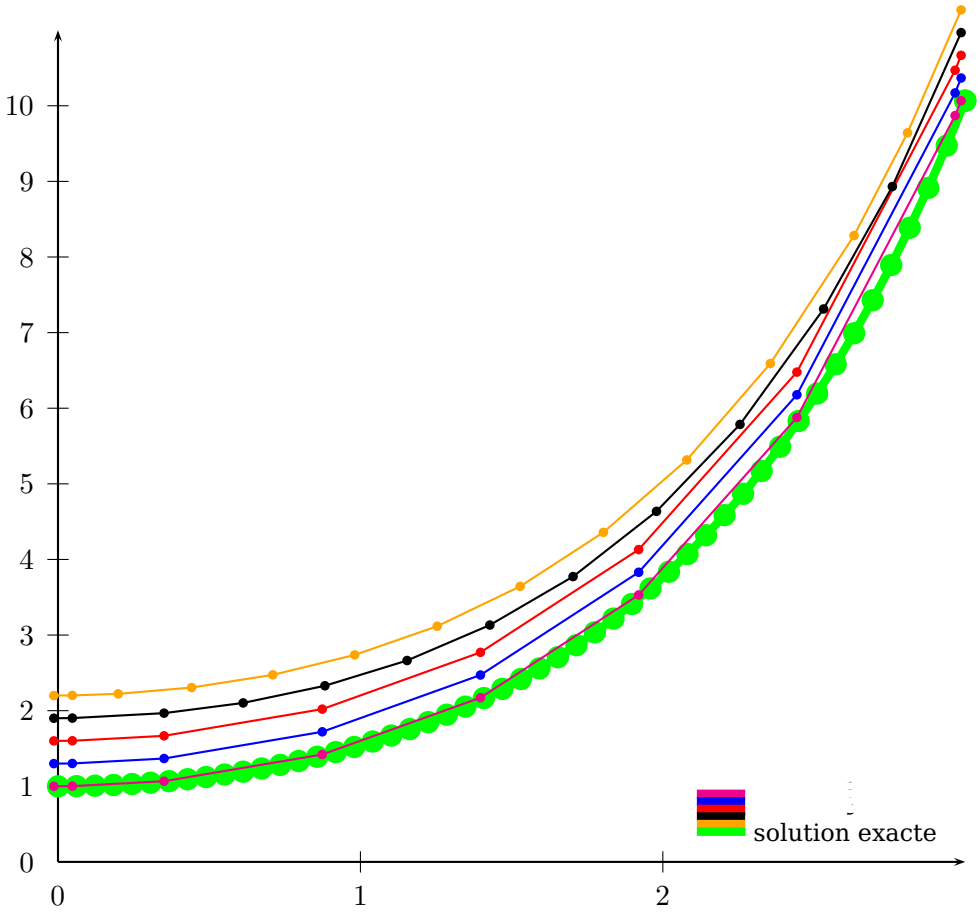


Figure 3: Equation $y'' = y$

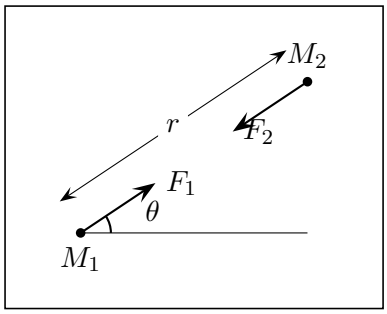
```
\def\Funct{exch}
\psset{xunit=4, yunit=1, method=varrkiv, showpoints=true}%%
\def\quatrepi{12.5663706144}
\begin{pspicture}(0,-0.5)(3,11)
```

```
  \psaxes{->}(0,0)(3,11)
  \psplot[linewidth=4\pslinewidth, linecolor=green, algebraic=true]{0}{3}{ch(x
    )}
  \rput(0,.0){\psplotDiffEqn[linecolor=magenta, varsteptol=.1]{0}{3}{1 0}{\
    Funct}}
  \rput(0,.3){\psplotDiffEqn[linecolor=blue, varsteptol=.01]{0}{3}{1 0}{\Funct
    }}
  \rput(0,.6){\psplotDiffEqn[linecolor=red, varsteptol=.001]{0}{3}{1 0}{\Funct
    }}
  \rput(0,.9){\psplotDiffEqn[linecolor=black, varsteptol=.0001]{0}{3}{1 0}{\
    Funct}}
  \rput(0,1.2){\psplotDiffEqn[linecolor=Orange, varsteptol=.00001]{0}{3}{1
    0}{\Funct}}
  \psset{linewidth=4\pslinewidth,showpoints=false}
  \rput*(2.3,.9){\psline[linecolor=magenta](-.75cm,0)}
  \rput*[l](2.3,.9){\small $\varepsilon<10^{-1}$}
  \rput*(2.3,.8){\psline[linecolor=blue](-.75cm,0)}
  \rput*[l](2.3,.8){\small $\varepsilon<10^{-2}$}
  \rput*(2.3,.7){\psline[linecolor=red](-.75cm,0)}
  \rput*[l](2.3,.7){\small $\varepsilon<10^{-3}$}
  \rput*(2.3,.6){\psline[linecolor=black](-.75cm,0)}
  \rput*[l](2.3,.6){\small $\varepsilon<10^{-4}$}
  \rput*(2.3,.5){\psline[linecolor=Orange](-.75cm,0)}
  \rput*[l](2.3,.5){\small $\varepsilon<10^{-5}$}
  \rput*(2.3,.4){\psline[linecolor=green](-.75cm,0)}
  \rput*[l](2.3,.4){\small solution exacte}
\end{pspicture}
```

22.2. Equation of second order

Here is the traditional simulation of two stars attracting each other according to the classical gravitation law in $\frac{1}{r^2}$. In 2-Dimensions, the system to be solved is composed of four second order differential equations. In order to be described, each of them gives two first order equations, then we obtain a 8 sized vectorial equation. In the following example the masses of the stars are 1 and 20.

$$\begin{cases} x_1'' = \dfrac{M_2}{r^2}\cos(\theta) \\ y_1'' = \dfrac{M_2}{r^2}\sin(\theta) \\ x_2'' = \dfrac{M_1}{r^2}\cos(\theta) \\ y_2'' = \dfrac{M_1}{r^2}\sin(\theta) \end{cases} \text{ avec } \begin{cases} r^2 = (x_1 - x_2)^2 + (y_1 - y_2)^2 \\ \cos(\theta) = \dfrac{(x_1 - x_2)}{r} \\ \sin(\theta) = \dfrac{(y_1 - y_2)}{r} \end{cases}$$

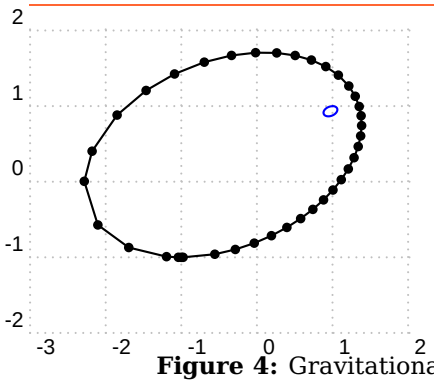



```
                                                    %% x1 y1 x'1 y'1 x2 y2 x'2 y'2
/yp2 exch def /xp2 exch def /ay2 exch def /ax2 exch def %% mise en variables
/yp1 exch def /xp1 exch def /ay1 exch def /ax1 exch def %% mise en variables
/ro2 ax2 ax1 sub dup mul ay2 ay1 sub dup mul add def    %% calcul de r*r
xp1 yp1                                                 %%
ax2 ax1 sub ro2 sqrt div ro2 div                        %% calcul de x"1
ay2 ay1 sub ro2 sqrt div ro2 div                        %% calcul de y"1
xp2 yp2                                                 %%
3 index -20 mul                                         %% calcul de x"2=-20x"1
3 index -20 mul                                         %% calcul de y"2=-20y"1
```

Table 1: `PostScript` source code for the gravitational interaction

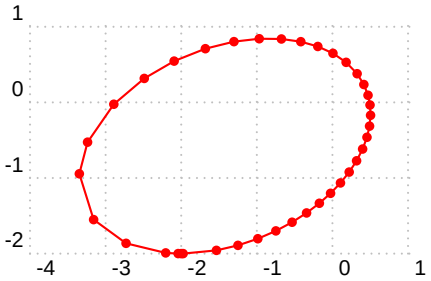
```
y[2]|                                                    %% y'[0]
y[3]|                                                    %% y'[1]
(y[4]-y[0])/((y[4]-y[0])^2+(y[5]-y[1])^2)^1.5|           %% y'[2]=y"[0]
(y[5]-y[1])/((y[4]-y[0])^2+(y[5]-y[1])^2)^1.5|           %% y'[3]=y"[1]
y[6]|                                                    %% y'[4]
y[7]|                                                    %% y'[5]
20*(y[0]-y[4])/((y[4]-y[0])^2+(y[5]-y[1])^2)^1.5|        %% y'[6]=y"[4]
20*(y[1]-y[5])/((y[4]-y[0])^2+(y[5]-y[1])^2)^1.5         %% y'[7]=y"[5]
```

Table 2: Algebraic description for the gravitational interaction




```
\def\InitCond{ 1 1 .1 0 -1 -1 -2 0}
\begin{pspicture}[shift=-2,showgrid=true](-3,-1.75)(2,1.5)
 \psplotDiffEqn[whichabs=0, whichord=1, linecolor=blue,
   method=rk4, plotpoints=100]{0}{3.95}{\InitCond}{\Grav}
 \psset{showpoints=true,whichabs=4, whichord=5}
 \psplotDiffEqn[linecolor=black, method=varrkiv, varsteptol
   =.0001, plotpoints=200]{0}{3.9}{\InitCond}{\Grav}
\end{pspicture}
```

Figure 4: Gravitational interaction: fixed landmark, trajectory of the stars




```
\def\InitCond{ 1 1 .1 0 -1 -1 -2 0}
\begin{pspicture}[shift=-1.5,showgrid=true](-4,-1.75)(1,1)
 \psplotDiffEqn[linecolor=red, plotpoints=200,method=
   varrkiv, varsteptol=.0001, showpoints=true,
    plotfuncx=y dup 4 get exch 0 get sub,
    plotfuncy=dup 5 get exch 1 get sub ]{0}{3.9}{\InitCond
     }{\Grav}
\end{pspicture}
```

Figure 5: Gravitational interaction : landmark defined by one star

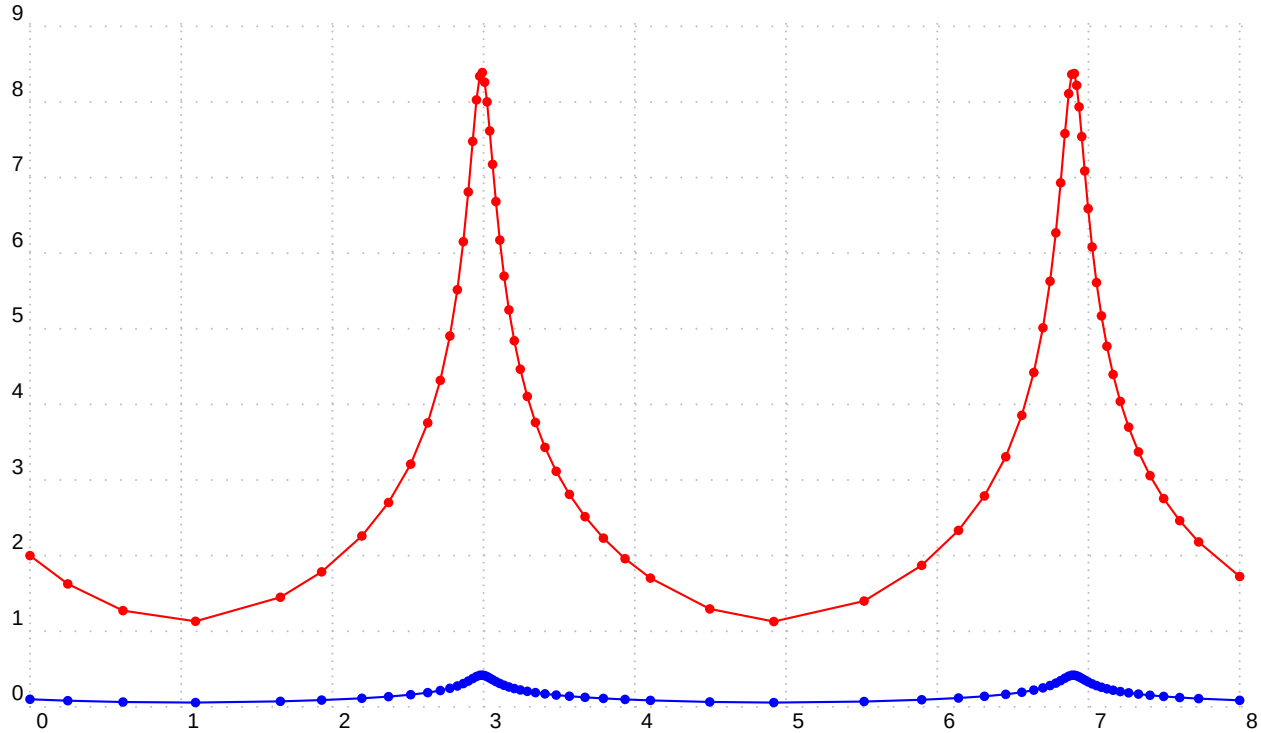


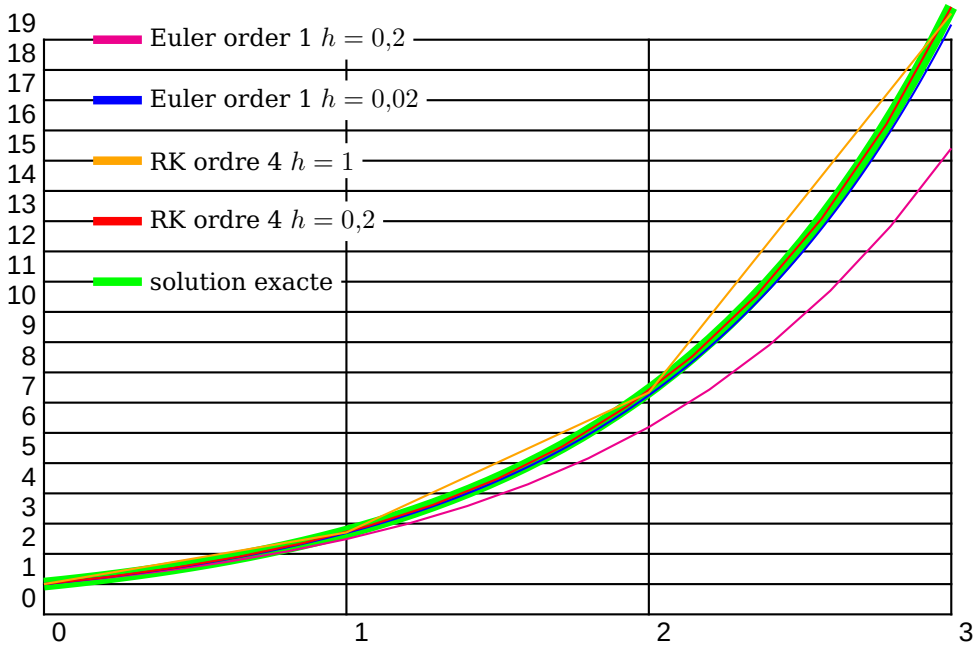
Figure 6: Gravitational interaction : speeds of the stars

```
\psset{xunit=2}
\begin{pspicture}[showgrid=true](0,0)(8,9)
 \psset{showpoints=true}
```

```
4  \psplotDiffEqn[linecolor=red, method=varrkiv, plotpoints=2, varsteptol
     =.0001,
5      plotfuncy=dup 6 get dup mul exch 7 get dup mul add sqrt]{0}{8}{\InitCond
       }{\Grav}
6  \psplotDiffEqn[linecolor=blue, method=varrkiv, plotpoints=2, varsteptol
     =.0001,
7      plotfuncy=dup 2 get dup mul exch 3 get dup mul add sqrt]{0}{8}{\InitCond
       }{\Grav}
8  \end{pspicture}
```

Simple equation of first order $y' = y$

For the initial value $y(0) = 1$ we have the solution $y(x) = e^x$. y is always on the stack, so we have to do nothing. Using the `algebraic=true` option, we write it as `y[0]`. The following example shows different solutions depending to the number of plotpoints with $y_0 = 1$:




```
\psset{xunit=4, yunit=.4}
\begin{pspicture}(3,19)\psgrid[subgriddiv=1]
  \psplot[linewidth=6\pslinewidth, linecolor=green]{0}{3}{Euler x exp}
  \psplotDiffEqn[linecolor=magenta,plotpoints=16,algebraic=true]{0}{3}{1}{y
    [0]}
  \psplotDiffEqn[linecolor=blue,plotpoints=151]{0}{3}{1}{}
  \psplotDiffEqn[linecolor=red,method=rk4,plotpoints=15]{0}{3}{1}{}
  \psplotDiffEqn[linecolor=Orange,method=rk4,plotpoints=4]{0}{3}{1}{}
  \psset{linewidth=4\pslinewidth}
  \rput*(0.35,19){\psline[linecolor=magenta](-.75cm,0)}
  \rput*[l](0.35,19){\small Euler order 1 $h=0{,}2$}
  \rput*(0.35,17){\psline[linecolor=blue](-.75cm,0)}
  \rput*[l](0.35,17){\small Euler order 1 $h=0{,}02$}
  \rput*(0.35,15){\psline[linecolor=Orange](-.75cm,0)}
  \rput*[l](0.35,15){\small RK ordre 4 $h=1$}
  \rput*(0.35,13){\psline[linecolor=red](-.75cm,0)}
  \rput*[l](0.35,13){\small RK ordre 4 $h=0{,}2$}
  \rput*(0.35,11){\psline[linecolor=green](-.75cm,0)}
  \rput*[l](0.35,11){\small solution exacte}
\end{pspicture}
```

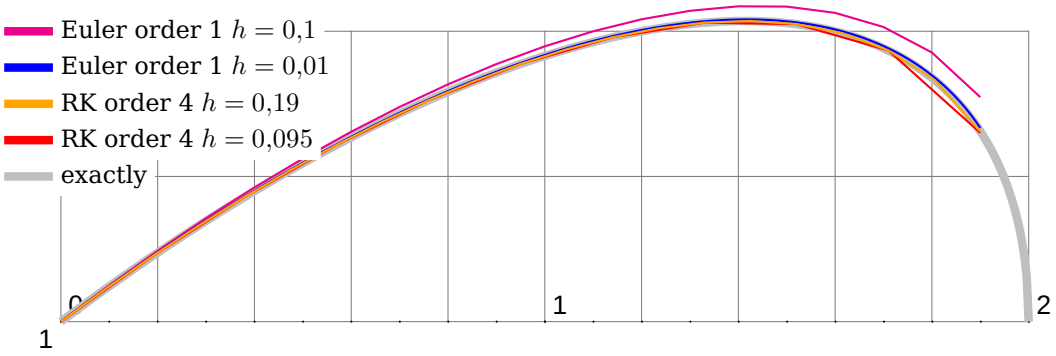
$$y' = \frac{2 - ty}{4 - t^2}$$

For the initial value $y(0) = 1$ the exact solution is $y(x) = \frac{t + \sqrt{4 - t^2}}{2}$. The function f described in PostScript code is like (y is still on the stack):

```
x           %% y x
mul         %% x*y
2 exch sub  %% 2-x*y
4 x dup mul %% 2-x*y 4 x^2
sub         %% 2-x*y 4-x^2
div         %% (2-x*y)/(4-x^2)
```

The following example uses $y_0 = 1$.

```
\newcommand{\InitCond}{1}
\newcommand{\Func}{x mul 2 exch sub 4 x dup mul sub div}
\newcommand{\FuncAlg}{(2-x*y[0])/(4-x^2)}
```

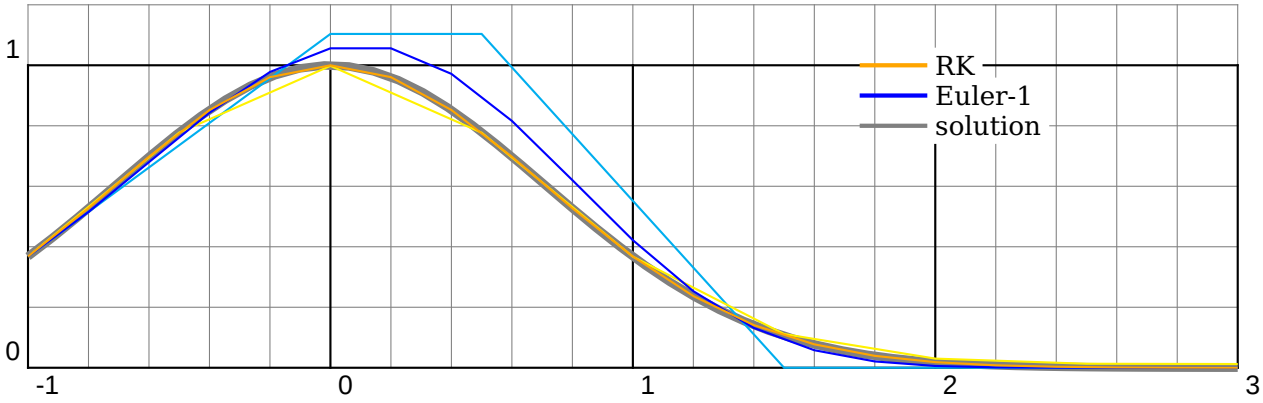



```
\psset{xunit=6.4, yunit=9.6, showpoints=false}
\begin{pspicture}(0,1)(2,1.7) \psgrid[subgriddiv=5]
 { \psset{linewidth=4\pslinewidth,linecolor=lightgray}
 \psplot{0}{1.8}{x dup dup mul 4 exch sub sqrt add 2 div}
 \psplot{1.8}{2}{x dup dup mul 4 exch sub sqrt add 2 div} }
 \def\InitCond{1}
 \def\Func{x mul 2 exch sub 4 x dup mul sub div}
 \psplotDiffEqn[linecolor=magenta, plotpoints=20]{0}{1.9}{\InitCond}{\Func}
 \psplotDiffEqn[linecolor=blue, plotpoints=191]{0}{1.9}{\InitCond}{\Func}
 \psplotDiffEqn[linecolor=red, method=rk4, plotpoints=11,%
   algebraic=true]{0}{1.9}{\InitCond}{(2-x*y[0])/(4-x^2)}
 \psplotDiffEqn[linecolor=Orange, method=rk4, plotpoints=21,%
   algebraic=true]{0}{1.9}{\InitCond}{(2-x*y[0])/(4-x^2)}
 \psset{linewidth=4\pslinewidth}
 \rput*(0.3,1.6){\psline[linecolor=magenta](-.75cm,0)}\rput*[l](0.3,1.6){\small Euler
   order 1 $h=0{,}1$}
 \rput*(0.3,1.55){\psline[linecolor=blue](-.75cm,0)}\rput*[l](0.3,1.55){\small Euler order
    1 $h=0{,}01$}
 \rput*(0.3,1.5){\psline[linecolor=Orange](-.75cm,0)}\rput*[l](0.3,1.5){\small RK order 4
   $h=0{,}19$}
```

```
18  \rput*(0.3,1.45){\psline[linecolor=red](-.75cm,0)}\rput*[l](0.3,1.45){\small RK order 4 $
      h=0{,}095$}
19  \rput*(0.3,1.4){\psline[linecolor=lightgray](-.75cm,0)}\rput*[l](0.3,1.4){\small exactly}
20 \end{pspicture}
```

$y' = -2xy$

For $y(-1) = \frac{1}{e}$ we get $y(x) = e^{-x^2}$.




```
\psset{unit=4}
\begin{pspicture}(-1,0)(3,1.1)\psgrid
  \psplot[linewidth=4\pslinewidth,linecolor=gray]{-1}{3}{Euler x dup mul neg
    exp}
  \psset{plotpoints=9}
  \psplotDiffEqn[linecolor=cyan]{-1}{3}{1 Euler div}{x -2 mul mul}
  \psplotDiffEqn[linecolor=yellow, method=rk4]{-1}{3}{1 Euler div}{x -2 mul
    mul}
  \psset{plotpoints=21}
  \psplotDiffEqn[linecolor=blue]{-1}{3}{1 Euler div}{x -2 mul mul}
  \psplotDiffEqn[linecolor=Orange, method=rk4]{-1}{3}{1 Euler div}{x -2 mul
    mul}
  \psset{linewidth=2\pslinewidth}
  \rput*(2,1){\psline[linecolor=Orange](-0.25,0)}
  \rput*[l](2,1){RK}
  \rput*(2,.9){\psline[linecolor=blue](-0.25,0)}
  \rput*[l](2,.9){\textsc{Euler}-1}
  \rput*(2,.8){\psline[linecolor=gray](-0.25,0)}
  \rput*[l](2,.8){solution}
\end{pspicture}
```

Spiral of Cornu

The integrals of Fresnel:

$$x = \int_0^t \cos\frac{\pi t^2}{2}\mathrm{d}t \tag{2}$$

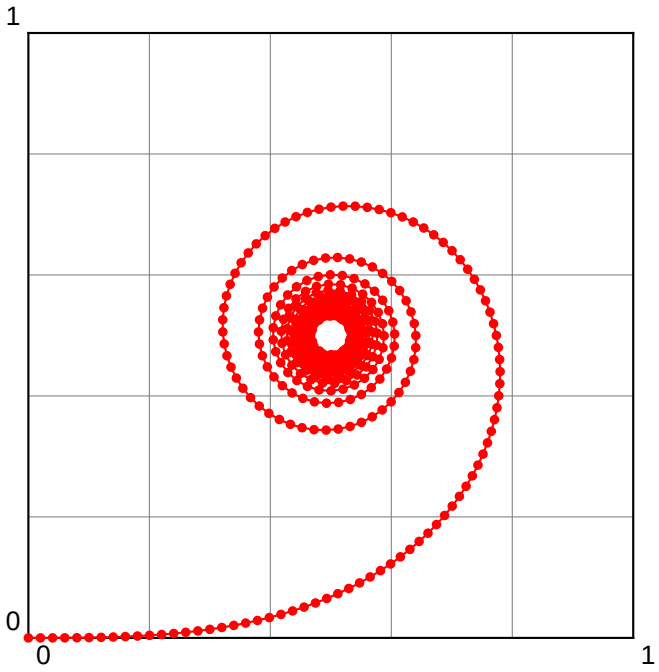
$$y = \int_0^t \sin\frac{\pi t^2}{2}\mathrm{d}t \tag{3}$$

with

$$\dot{x} = \cos\frac{\pi t^2}{2} \tag{4}$$

$$\dot{y} = \sin\frac{\pi t^2}{2} \tag{5}$$

```
\psset{unit=8}
\begin{pspicture}(1,1)\psgrid[subgriddiv=5]
  \psplotDiffEqn[whichabs=0,whichord=1,linecolor=red,method=rk4,algebraic=true
    ,%
    plotpoints=500,showpoints=true]{0}{10}{0 0}{cos(Pi*x^2/2)|sin(Pi*x^2/2)}
\end{pspicture}
```



Lotka-Volterra

The Lotka-Volterra model describes interactions between two species in an ecosystem, a predator and a prey. This represents our first multi-species model. Since we are considering two species, the model will involve two equations, one which describes how the prey population changes and the second which describes how the predator population changes.

For concreteness let us assume that the prey in our model are rabbits, and that the predators are foxes. If we let $R(t)$ and $F(t)$ represent the number of rabbits and foxes, respectively, that are alive at time t, then the Lotka-Volterra model is:

$$\dot{R} = a \cdot R - b \cdot R \cdot F \tag{6}$$

$$\dot{F} = e \cdot b \cdot R \cdot F - c \cdot F \tag{7}$$

where the parameters are defined by:

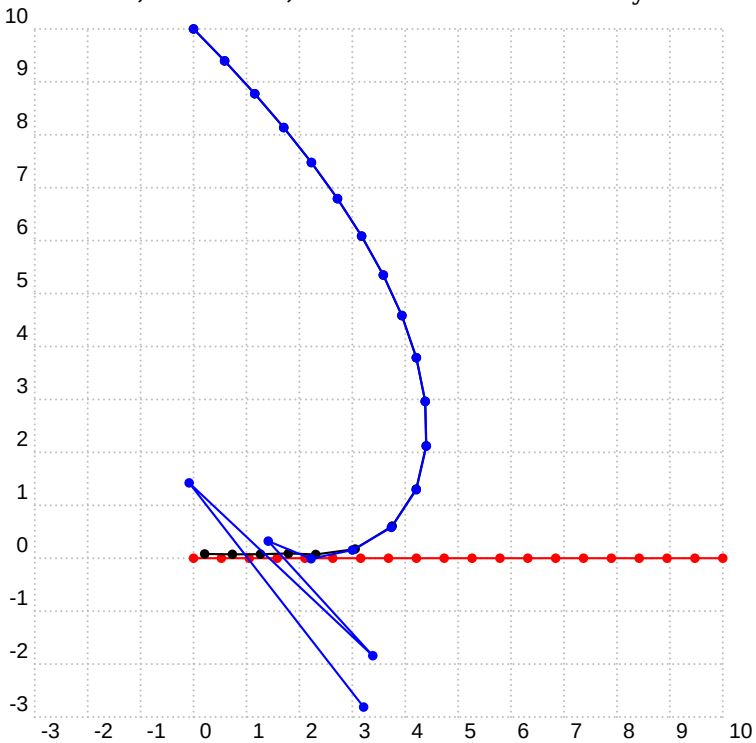
a is the natural growth rate of rabbits in the absence of predation,

c is the natural death rate of foxes in the absence of food (rabbits),

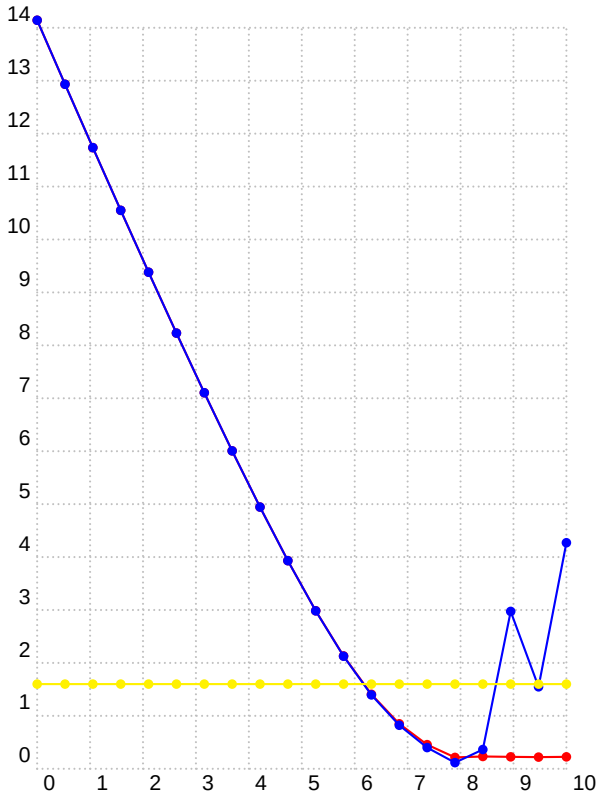
b is the death rate per encounter of rabbits due to predation,

e is the efficiency of turning predated rabbits into foxes.

The Stella model representing the Lotka-Volterra model will be slightly more complex than the single species models we've dealt with before. The main difference is that our model will have two stocks (reservoirs), one for each species. Each species will have its own birth and death rates. In addition, the Lotka-Volterra model involves four parameters rather than two. All told, the Stella representation of the Lotka-Volterra model will use two stocks, four flows, four converters and many connectors.



```
\def\InitCond{ 0 10 10}%% xa ya xl
\def\Faiglelapin{\Vaigle*(y[2]-y[0])/sqrt(y[1]^2+(y[2]-y[0])^2)|%
            -\Vaigle*y[1]/sqrt(y[1]^2+(y[2]-y[0])^2)|%
            -\Vlapin}
\def\Vlapin{1} \def\Vaigle{1.6}
\psset{unit=.7,subgriddiv=0,gridcolor=lightgray,method=adams,algebraic=true,%
  plotpoints=20,showpoints=true}
\begin{pspicture}[showgrid=true](-3,-3)(10,10)
 \psplotDiffEqn[plotfuncy=pop 0,whichabs=2,linecolor=red]{0}{10}{\InitCond}{\
   Faiglelapin}
 \psplotDiffEqn[whichabs=0,whichord=1,linecolor=black,method=rk4]{0}{10}{\InitCond}{\
   Faiglelapin}
  \psplotDiffEqn[whichabs=0,whichord=1,linecolor=blue]{0}{10}{\InitCond}{\Faiglelapin}
\end{pspicture}
```

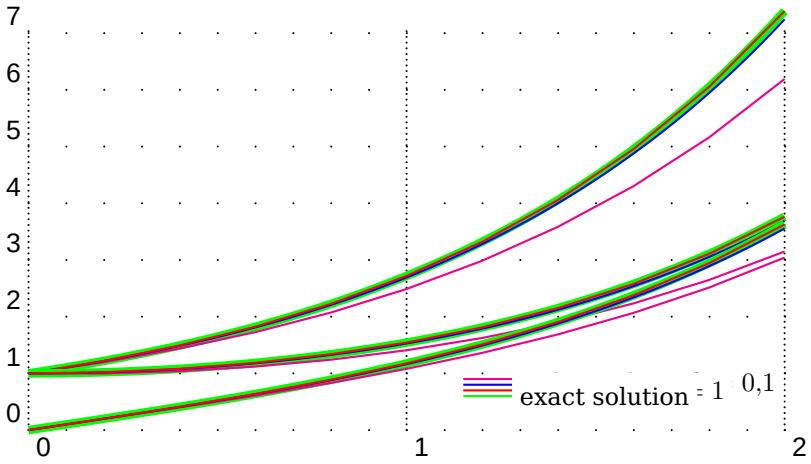



```
\def\InitCond{ 0 10 10}%% xa ya xl
\def\Faiglelapin{\Vaigle*(y[2]-y[0])/sqrt(y[1]^2+(y[2]-y[0])^2)|%
            -\Vaigle*y[1]/sqrt(y[1]^2+(y[2]-y[0])^2)|%
            -\Vlapin}
\def\Vlapin{1} \def\Vaigle{1.6}
\psset{unit=.7,subgriddiv=0,gridcolor=lightgray,method=adams,algebraic=true,%
  plotpoints=20,showpoints=true}
\begin{pspicture}[showgrid=true](10,12)
 \psplotDiffEqn[plotfuncy=dup 1 get dup mul exch dup 0 get exch 2 get sub dup
   mul add sqrt,linecolor=red,method=rk4]{0}{10}{\InitCond}{\Faiglelapin}
 \psplotDiffEqn[plotfuncy=dup 1 get dup mul exch dup 0 get exch 2 get sub dup
```

```
   mul add sqrt,linecolor=blue]{0}{10}{\InitCond}{\Faiglelapin}
 \psplotDiffEqn[plotfuncy=pop Func aload pop pop dup mul exch dup mul add sqrt,
   linecolor=yellow]{0}{10}{\InitCond}{\Faiglelapin}
\end{pspicture}
```

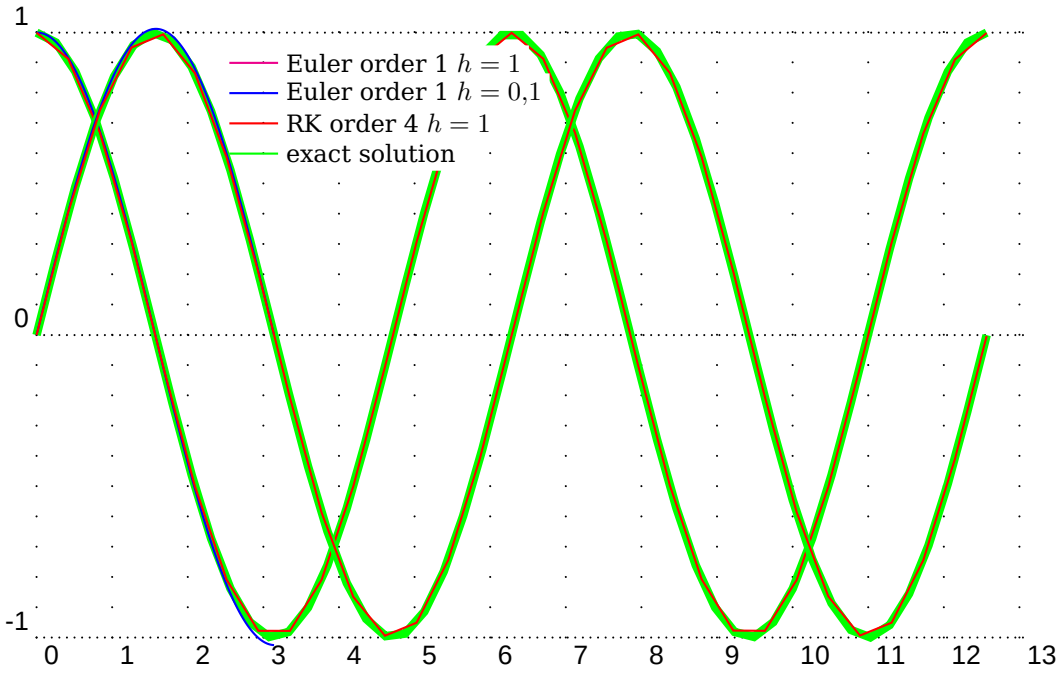
$y'' = y$

Beginning with the initial equation $y(x) = Ae^x + Be^{-x}$ we get the hyperbolic trigonometrical functions.




```
\def\Funct{exch} \psset{xunit=5cm, yunit=0.75cm}
\begin{pspicture}(0,-0.25)(2,7)\psgrid[subgriddiv=1,griddots=10]
 \psplot[linewidth=4\pslinewidth, linecolor=green]{0}{2}{Euler x exp} %%e^x
 \psplotDiffEqn[linecolor=magenta, plotpoints=11]{0}{2}{1 1}{\Funct}
 \psplotDiffEqn[linecolor=blue, plotpoints=101]{0}{2}{1 1}{\Funct}
 \psplotDiffEqn[linecolor=red, method=rk4, plotpoints=11]{0}{2}{1 1}{\Funct}
 \psplot[linewidth=4\pslinewidth, linecolor=green]{0}{2}{Euler dup x exp %%ch(x)
   exch x neg exp add 2 div}
 \psplotDiffEqn[linecolor=magenta, plotpoints=11]{0}{2}{1 0}{\Funct}
 \psplotDiffEqn[linecolor=blue, plotpoints=101]{0}{2}{1 0}{\Funct}
 \psplotDiffEqn[linecolor=red, method=rk4, plotpoints=11]{0}{2}{1 0}{\Funct}
 \psplot[linewidth=4\pslinewidth, linecolor=green]{0}{2}{Euler dup x exp
    exch x neg exp sub 2 div} %%sh(x)
 \psplotDiffEqn[linecolor=magenta, plotpoints=11]{0}{2}{0 1}{\Funct}
 \psplotDiffEqn[linecolor=blue, plotpoints=101]{0}{2}{0 1}{\Funct}
 \psplotDiffEqn[linecolor=red, method=rk4, plotpoints=11]{0}{2}{0 1}{\Funct}
 \rput*(1.3,.9){\psline[linecolor=magenta](-.75cm,0)}\rput*[l](1.3,.9){\small\textsc{
   Euler} order 1 $h=1$}
 \rput*(1.3,.8){\psline[linecolor=blue](-.75cm,0)}\rput*[l](1.3,.8){\small\textsc{Euler
   } order 1 $h=0{,}1$}
 \rput*(1.3,.7){\psline[linecolor=red](-.75cm,0)}\rput*[l](1.3,.7){\small RK order 4 $h
   =1$}
 \rput*(1.3,.6){\psline[linecolor=green](-.75cm,0)}\rput*[l](1.3,.6){\small exact
   solution}
\end{pspicture}
```

$y'' = -y$




```
\def\Funct{exch neg}
\psset{xunit=1, yunit=4}
\def\quatrepi{12.5663706144}%%4pi=12.5663706144
\begin{pspicture}(0,-1.25)(\quatrepi,1.25)\psgrid[subgriddiv=1,griddots=10]
 \psplot[linewidth=4\pslinewidth,linecolor=green]{0}{\quatrepi}{x RadtoDeg cos
   }%%cos(x)
 \psplotDiffEqn[linecolor=blue, plotpoints=201]{0}{3.1415926}{1 0}{\Funct}
 \psplotDiffEqn[linecolor=red, method=rk4, plotpoints=31]{0}{\quatrepi}{1 0}{\
   Funct}
 \psplot[linewidth=4\pslinewidth,linecolor=green]{0}{\quatrepi}{x RadtoDeg sin
   } %%sin(x)
 \psplotDiffEqn[linecolor=blue,plotpoints=201]{0}{3.1415926}{0 1}{\Funct}
 \psplotDiffEqn[linecolor=red,method=rk4, plotpoints=31]{0}{\quatrepi}{0 1}{\
   Funct}
 \rput*(3.3,.9){\psline[linecolor=magenta](-.75cm,0)}\rput*[l](3.3,.9){\small
   Euler order 1 $h=1$}
 \rput*(3.3,.8){\psline[linecolor=blue](-.75cm,0)}\rput*[l](3.3,.8){\small
   Euler order 1 $h=0{,}1$}
 \rput*(3.3,.7){\psline[linecolor=red](-.75cm,0)}\rput*[l](3.3,.7){\small RK
   order 4 $h=1$}
 \rput*(3.3,.6){\psline[linecolor=green](-.75cm,0)}\rput*[l](3.3,.6){\small
   exact solution}
\end{pspicture}
```

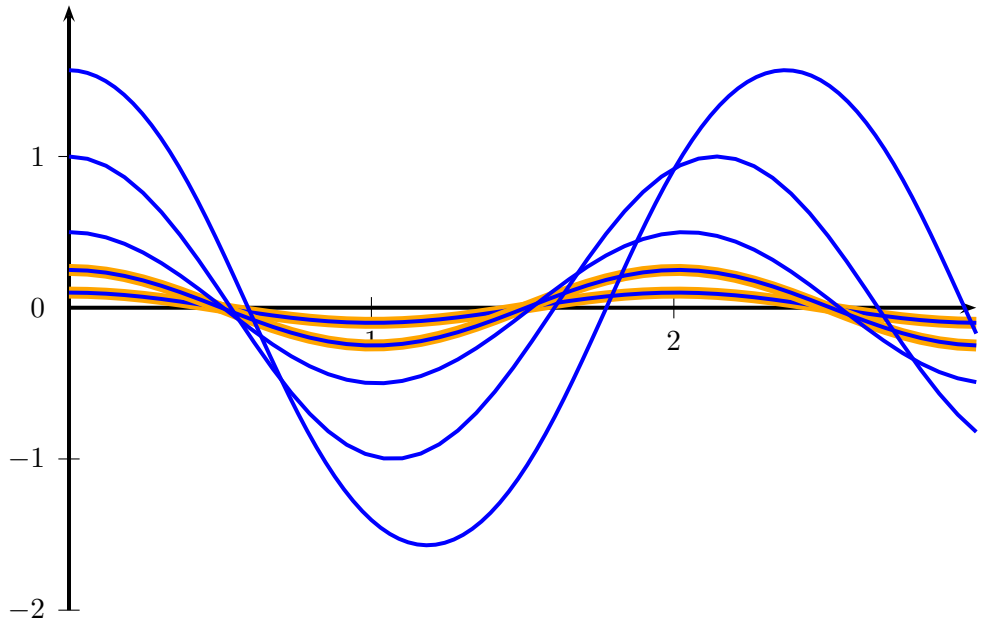
The mechanical pendulum: $y'' = -\frac{g}{l}\sin(y)$

For small oscillations $\sin(y) \simeq y$:

$$y(x) = y_0 \cos\left(\sqrt{\frac{g}{l}}x\right)$$

The function f is written in PostScript code:

```
exch RadtoDeg sin -9.8 mul %% y' -gsin(y)
```

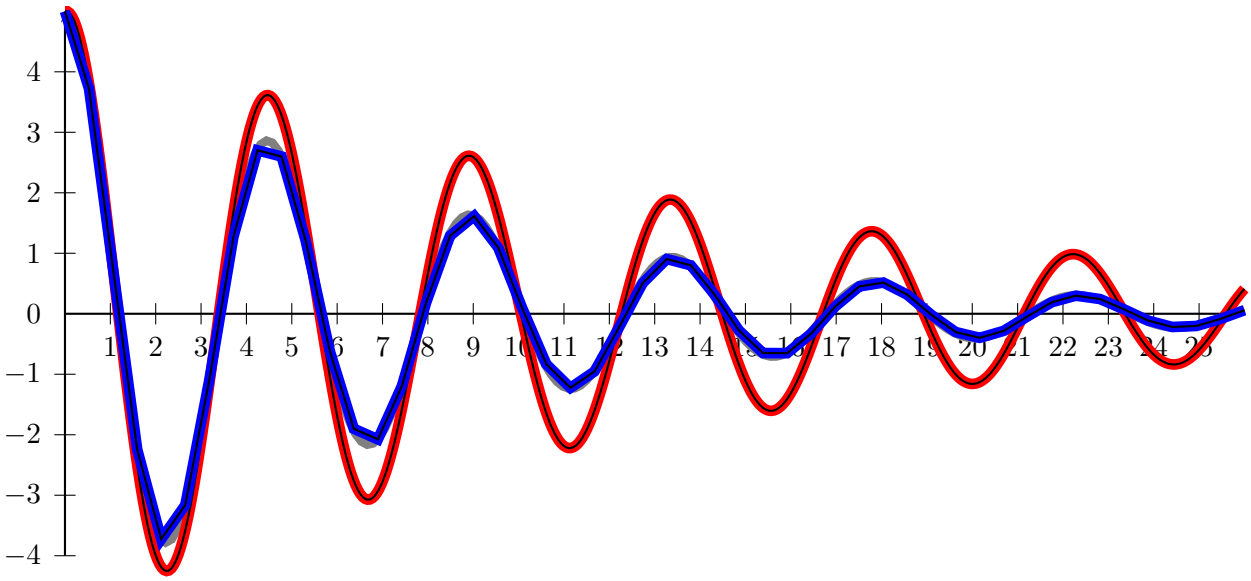



```
\def\Func{y[1]|-9.8*sin(y[0])}
\psset{yunit=2,xunit=4,algebraic=true,linewidth=1.5pt}
\begin{pspicture}(0,-2.25)(3,2.25)
  \psaxes{->}(0,0)(0,-2)(3,2)
  \psplot[linewidth=3\pslinewidth, linecolor=Orange]{0}{3}{.1*cos(sqrt(9.8)*x)
    }
  \psset{method=rk4,plotpoints=50,linecolor=blue}
  \psplotDiffEqn{0}{3}{.1 0}{\Func}
  \psplot[linewidth=3\pslinewidth,linecolor=Orange]{0}{3}{.25*cos(sqrt(9.8)*x)
    }
  \psplotDiffEqn{0}{3}{.25 0}{\Func}
  \psplotDiffEqn{0}{3}{.5 0}{\Func}
  \psplotDiffEqn{0}{3}{1 0}{\Func}
  \psplotDiffEqn[plotpoints=100]{0}{3}{Pi 2 div 0}{\Func}
\end{pspicture}
```

$y'' = -\frac{y'}{4} - 2y$

For $y_0 = 5$ and $y'_0 = 0$ the solution is:

$$5e^{-\frac{x}{8}}\left(\cos(\omega x) + \frac{\sin(\omega x)}{8\omega}\right) \text{ avec } \omega = \frac{\sqrt{127}}{8}$$

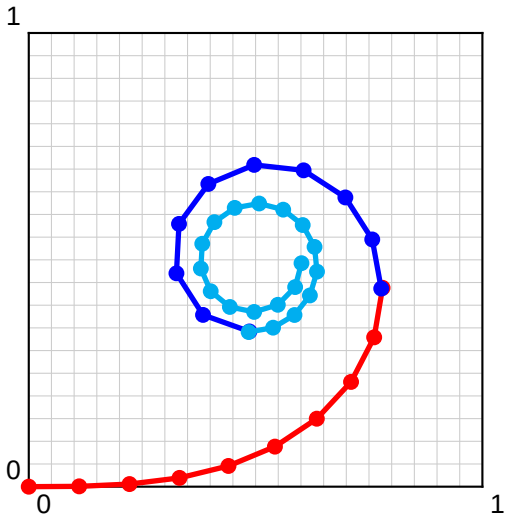



```
\psset{xunit=.6,yunit=0.8,plotpoints=500}
\begin{pspicture}(0,-4.25)(26,5.25)
  \psaxes{->}(0,0)(0,-4)(26,5)
  \psplot[plotpoints=200,linewidth=4\pslinewidth,linecolor=gray]{0}{26}{%
    Euler x -8 div exp x 127 sqrt 8 div mul RadtoDeg dup cos 5 mul exch sin
      127 sqrt div 5 mul add mul}
  \psplotDiffEqn[linecolor=red,linewidth=5\pslinewidth]{0}{26}{5 0}
    {dup 3 1 roll -4 div exch 2 mul sub}
  \psplotDiffEqn[linecolor=black,algebraic=true]{0}{26}{5 0} {y[1]|-y[1]/4-2*y
    [0]}
  \psset{method=rk4, plotpoints=50}
  \psplotDiffEqn[linecolor=blue,linewidth=5\pslinewidth]{0}{26}{5 0}{%
     dup 3 1 roll -4 div exch 2 mul sub}
  \psplotDiffEqn[linecolor=black,algebraic=true]{0}{26}{5 0}{y[1]|-y[1]/4-2*y
    [0]}
\end{pspicture}
```

22.3. Save final state of a equation

With the macros `\BeginSaveFinalState` and `\EndSaveFinalState` the end values of a differential equation can be saved and then used with the optional argument `GetFinalState` as starting values for another equation.

```
\psset{unit=10cm,linewidth=2pt}
\begin{pspicture}(1,1)\psgrid[subgridcolor=black!20,subgriddiv=20]
\BeginSaveFinalState
 \psplotDiffEqn[
  whichabs=0,whichord=1,linecolor=red,method=rk4,
  plotpoints=10,showpoints=true]{0}{1}{0 0}{
  pop pop
  x dup mul 2 div 180 mul cos %% dx/dt
  x dup mul 2 div 180 mul sin %% dy/dt
 }
 \psplotDiffEqn[GetFinalState,
  whichabs=0,whichord=1,linecolor=blue,method=rk4,%SaveFinalState,
  plotpoints=10,showpoints=true]{1}{2}{0 0}{
  pop pop
  x dup mul 2 div 180 mul cos %% dx/dt
  x dup mul 2 div 180 mul sin %% dy/dt
 }
 \psplotDiffEqn[GetFinalState,
  whichabs=0,whichord=1,linecolor=cyan,method=rk4,%SaveFinalState,
  plotpoints=19,showpoints=true]{2}{3}{0 0 }{
  pop pop
  x dup mul 2 div 180 mul cos %% dx/dt
  x dup mul 2 div 180 mul sin %% dy/dt
 }
\EndSaveFinalState
\end{pspicture}
```



23. \psMatrixPlot

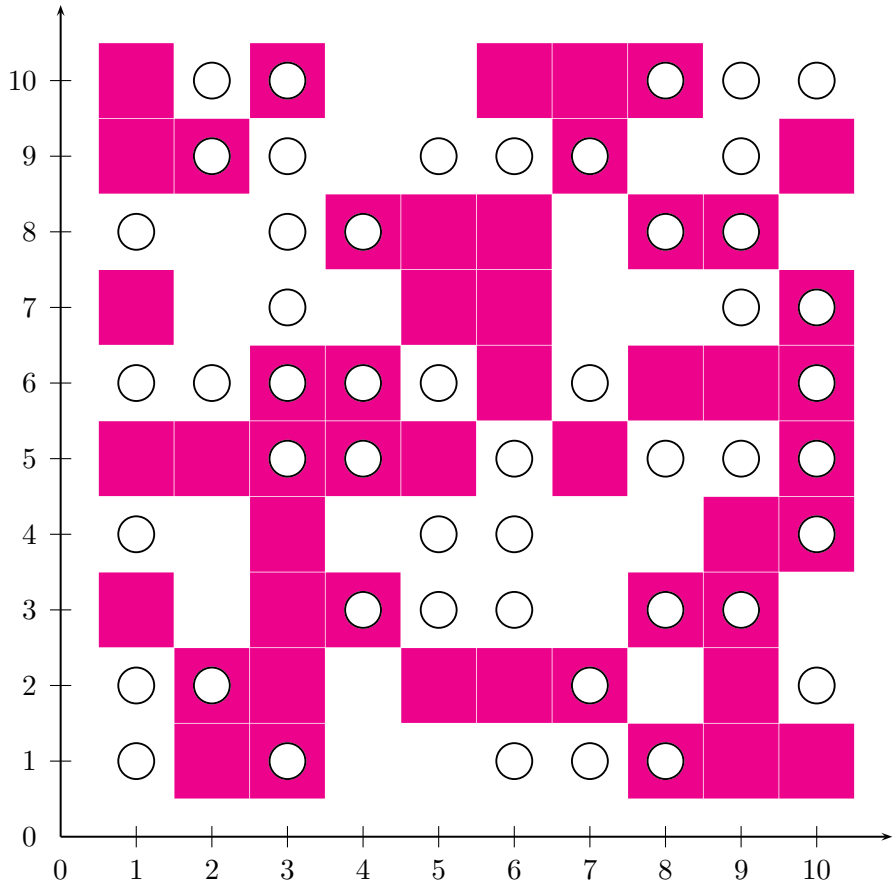
This macro allows you to visualize a matrix. The datafile must be defined as a PostScript matrix named `dotmatrix`:

```
/dotmatrix [ % <------------ important line
0 1 1 0 0 0 0 1 1 1
0 1 1 0 1 1 1 0 1 0
1 0 1 1 0 0 0 1 1 0
0 0 1 0 0 0 0 0 1 1
1 1 1 1 1 0 1 0 0 1
0 0 1 1 0 1 0 1 1 1
1 0 0 0 1 1 0 0 0 1
0 0 0 1 1 1 0 1 1 0
1 1 0 0 0 0 1 0 0 1
1 0 1 0 0 1 1 1 0 0
] def     % <------------ important line
```

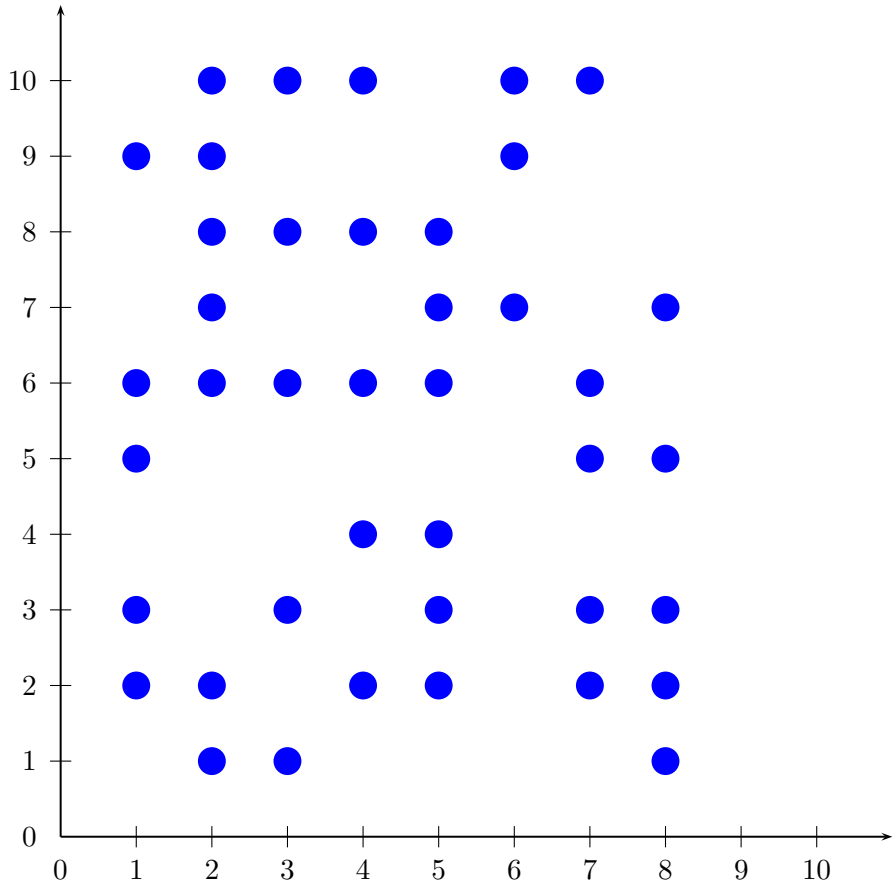
Only the value 0 is important, in which case nothing happens, and for all other cases a dot is printed. The syntax of the macro is:

\psMatrixPlot [Options] {*rows*}{*columns*}{*data file*}

The matrix is scanned line by line from the the first one to the last. In general it appears as a bottom-to-top version of the above listed matrix, the first row $0\,1\,1\,0\,0\,0\,0\,1\,1\,1$ is the first plotted line ($y = 1$). With the option `ChangeOrder=true` it looks exactly like the above view.



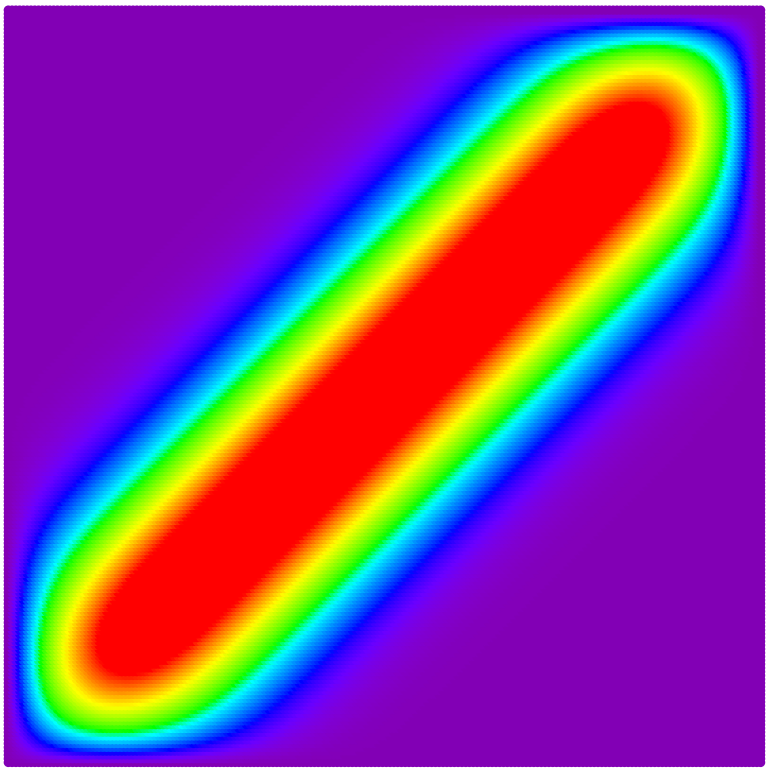

```
\begin{pspicture}(-0.5,-0.75)(11,11)
  \psaxes{->}(11,11)
  \psMatrixPlot[dotsize=1.1cm,dotstyle=square*,linecolor=magenta]%
    {10}{10}{matrix.data}
  \psMatrixPlot[dotsize=.5cm,dotstyle=o,ChangeOrder]{10}{10}{matrix.data}
\end{pspicture}
```



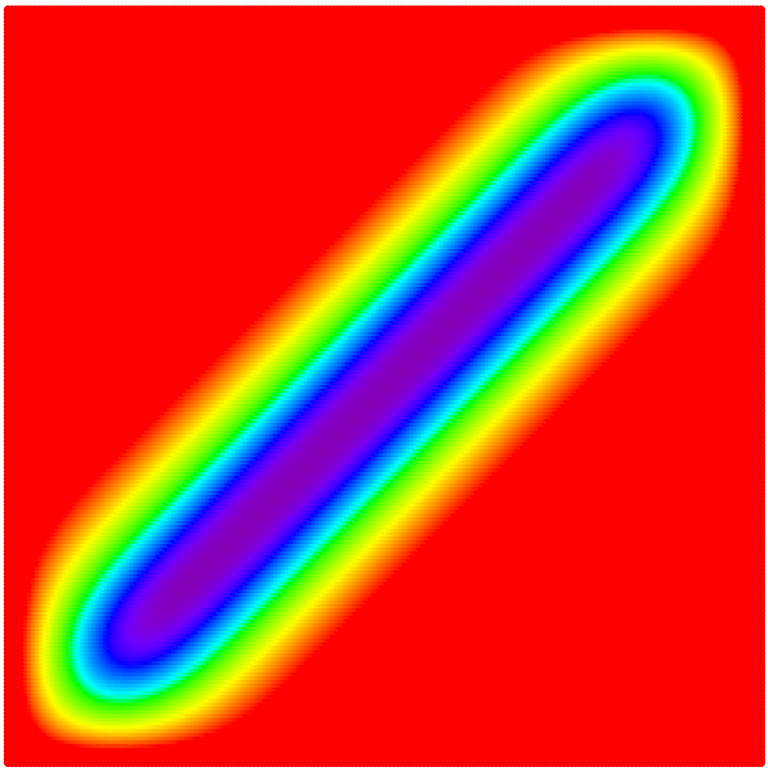

```
\begin{pspicture}(-0.5,-0.75)(11,11)
  \psaxes{->}(11,11)
  \psMatrixPlot[dotscale=3,dotstyle=*,linecolor=blue]{10}{8}{matrix.data}
\end{pspicture}
```

With the colorType=1 the data is printed as continous color in the range of the wavelength. The smallest value of the data array is set to red and the biggest value is set to violett. All other values are substituted by the corresponding color of the wavlength. colorType=2 ist the same, but vice versa with the color, from violet to red. colorType=3 is the grayscale image and colorType=4 the same invers.

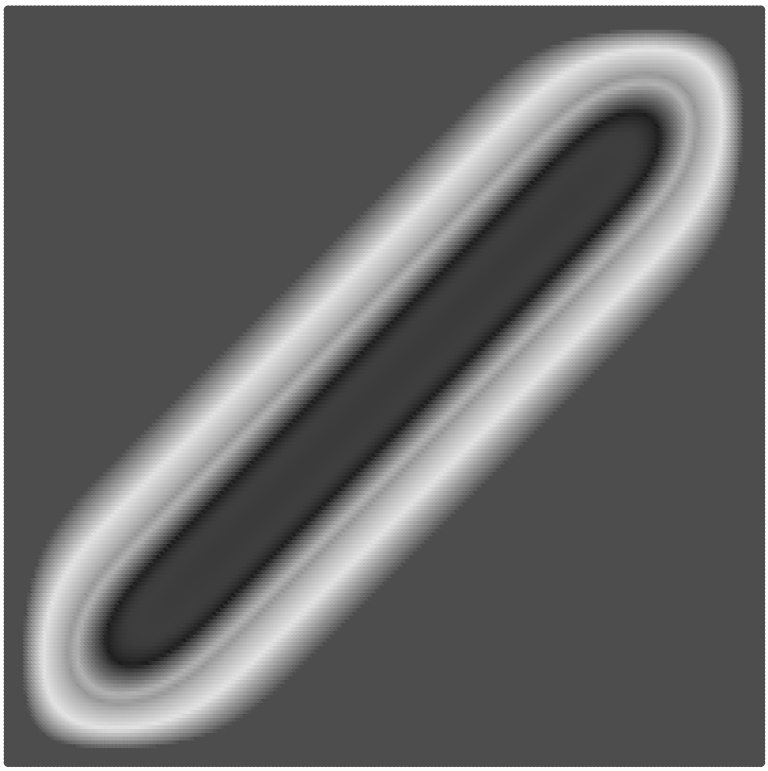
The following examples use a 200×200 matrix data, which is saved as /dotmatrix [...] in the file pstricks-add-doc.dat.



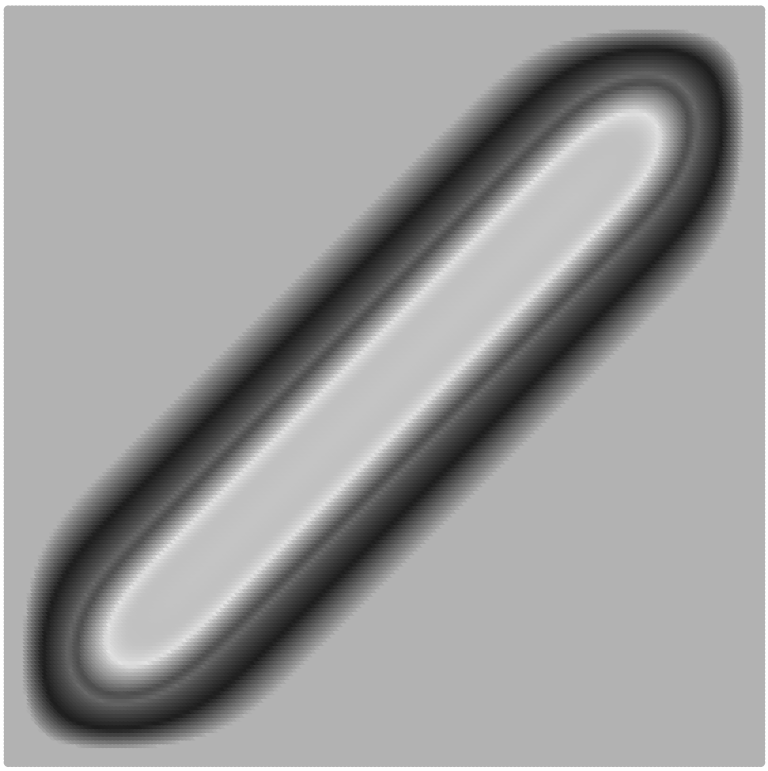
```
\begin{pspicture}(10,10)
  \psMatrixPlot[colorType=1,xStep=0.05,yStep=0.05]{200}{200}{dotmatrix.data}
\end{pspicture}
```



```
\begin{pspicture}(10,10)
  \psMatrixPlot[colorType=2,xStep=0.05,yStep=0.05]{200}{200}{dotmatrix.data}
\end{pspicture}
```



```
\begin{pspicture}(10,10)
  \psMatrixPlot[colorType=3,xStep=0.05,yStep=0.05]{200}{200}{dotmatrix.data}
\end{pspicture}
```

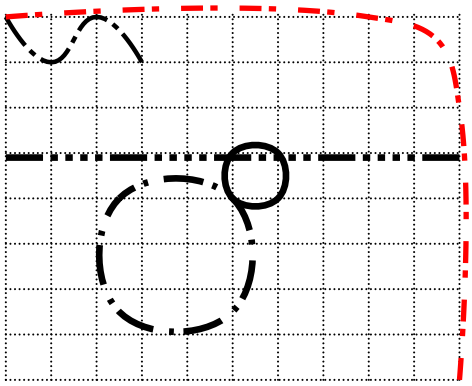


```
\begin{pspicture}(10,10)
  \psMatrixPlot[colorType=4,xStep=0.05,yStep=0.05]{200}{200}{dotmatrix.data}
\end{pspicture}
```

24. Dashed Lines

Tobias Nähring has implemented an enhanced feature for dashed lines. The number of arguments is no longer limited.

`dash=value1 unit value2 unit ...`

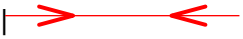


```
\psset{linewidth=2.5pt,unit=0.6}
\begin{pspicture}(-5,-4)(5,4)
 \psgrid[subgriddiv=0,griddots=10,gridlabels
   =0pt]
  \psset{linestyle=dashed}
  \pscurve[dash=5mm 1mm 1mm 1mm,linewidth
    =0.1](-5,4)(-4,3)(-3,4)(-2,3)
  \psline[dash=5mm 1mm 1mm 1mm 1mm 1mm 1mm 1
    mm 1mm 1mm](-5,0.9)(5,0.9)
  \psccurve[linestyle=solid](0,0)(1,0)(1,1)
    (0,1)
  \psccurve[linestyle=dashed,dash=5mm 2mm
    0.1 0.2,linetype=0](0,0)(-2.5,0)
    (-2.5,-2.5)(0,-2.5)
  \pscurve[dash=3mm 3mm 1mm 1mm,linecolor=
    red,linewidth=2pt](5,-4)(5,2)(4.5,3.5)
    (3,4)(-5,4)
\end{pspicture}
```

25. Arrows

25.1. Definition

`pstricks-add` defines the following "‘arrows"’:

Value	Example	Name
`-`		None
`<->`		Arrowheads.
`>-<`		Reverse arrowheads.
`<<->>`		Double arrowheads.
`>>-<<`		Double reverse arrowheads.
`|-|`		T-bars, flush to endpoints.
`|*-|*`		T-bars, centered on endpoints.
`[-]`		Square brackets.
`]-[`		Reversed square brackets.
`(-)`		Rounded brackets.
`)-(`		Reversed rounded brackets.
`o-o`		Circles, centered on endpoints.
`*-*`		Disks, centered on endpoints.
`oo-oo`		Circles, flush to endpoints.
`**-**`		Disks, flush to endpoints.
`|<->|`		T-bars and arrows.
`|>-<|`		T-bars and reverse arrows.
`h-h|`		left/right hook arrows.
`H-H|`		left/right hook arrows.
`v-v|`		left/right inside vee arrows.
`V-V|`		left/right outside vee arrows.
`f-f|`		left/right inside filled arrows.
`F-F|`		left/right outside filled arrows.
`t-t|`		left/right inside slash arrows.
`T-T|`		left/right outside slash arrows.

You can also mix and match, e.g., `->`, `*-)` and `[->` are all valid values of the `arrows` parameter. The parameter can be set with

`\psset{`*arrows=<type>*`}`

or for some macros with a special option, like

```
\psline[<general options>]{<arrow type>}(A)(B)
\psline[linecolor=red,linewidth=2pt]{|->}(0,0)(0,2)
```

25.2. Multiple arrows

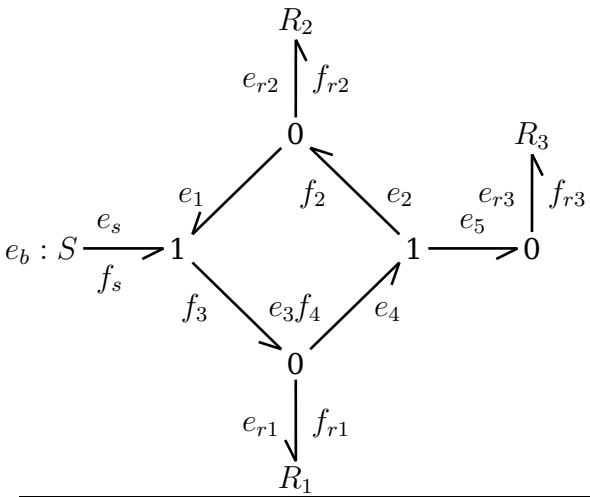
There are two new options which are only valid for the arrow type << or >>. `nArrow` sets both, the `nArrowA` and the `nArrowB` parameter. The meaning is declared in the following

tables. Without setting one of these parameters the behaviour is like the one described in the old PSTricks manual.

Value	Meaning
->>	-A
<<->>	A-A
<<-	A-
>>-	B-
-<<	-B
>>-<<	B-B
>>->>	B-A
<<-<<	A-B

Value	Example
\psline{->>}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=3]{->>}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=5]{->>}(0,1ex)(2.3,1ex)	
\psline{<<-}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=3]{<<-}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=5]{<<-}(0,1ex)(2.3,1ex)	
\psline{<<->>}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=3]{<<->>}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=5]{<<->>}(0,1ex)(2.3,1ex)	
\psline{<<-|}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=3]{<<-<<}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=5]{<<-o}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=3,nArrowsB=4]{<<-<<}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=3,nArrowsB=4]{>>->>}(0,1ex)(2.3,1ex)	
\psline[nArrowsA=1,nArrowsB=4]{>>->>}(0,1ex)(2.3,1ex)	

25.3. hookarrow




```
\psset{arrowsize=8pt,arrowlength=1,linewidth=1pt,nodesep=2pt,shortput=tablr}
```

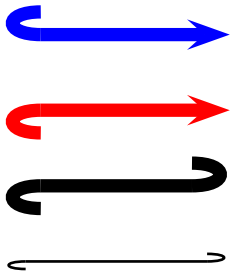
```
\large
\begin{psmatrix}[colsep=12mm,rowsep=10mm]
      &  & $R_2$       \\
      &  &  0  &  & $R_3$\\
$e_b:S$ & 1 &  & 1 & 0 \\
      &  &  0          \\
      &  &  $R_1$      \\
\end{psmatrix}
\ncline{h-}{1,3}{2,3}<{$e_{r2}$}>{$f_{r2}$}\ncline{-h}{2,3}{3,2}<{$e_1$}
\ncline{-h}{3,1}{3,2}^{$e_s$}_{$f_{s}$} \ncline{-h}{3,2}{4,3}>{$e_3$}<{$f_3$}
\ncline{-h}{4,3}{3,4}>{$e_4$}<{$f_4$} \ncline{-h}{3,4}{2,3}>{$e_2$}<{$f_2$}
\ncline{-h}{3,4}{3,5}^{$e_5$}
\ncline{-h}{3,5}{2,5}<{$e_{r3}$}>{$f_{r3}$}
\ncline{-h}{4,3}{5,3}<{$e_{r1}$}>{$f_{r1}$}
```

25.4. hookrightarrow and hookleftarrow

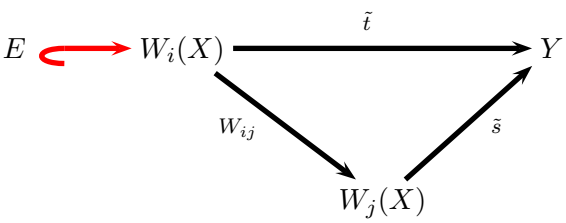
This is another type of arrow and is abbreviated with H. The length and width of the hook is set by the new options hooklength and hookwidth, which are by default set to

```
\psset{hooklength=3mm,hookwidth=1mm}
```

If the line begins with a right hook then the line ends with a left hook and vice versa:



```
\begin{pspicture}(3,4)
\psline[linewidth=5pt,linecolor=blue,hooklength=5mm,
  hookwidth=-3mm]{H->}(0,3.5)(3,3.5)
\psline[linewidth=5pt,linecolor=red,hooklength=5mm,hookwidth
  =3mm]{H->}(0,2.5)(3,2.5)
\psline[linewidth=5pt,hooklength=5mm,hookwidth=3mm]{H-H
  }(0,1.5)(3,1.5)
\psline[linewidth=1pt]{H-H}(0,0.5)(3,0.5)
\end{pspicture}
```




```
$\begin{psmatrix}
E&W_i(X)&&Y\\
&&W_j(X)
\psset{arrows=->,nodesep=3pt,linewidth
  =2pt}
\everypsbox{\scriptstyle}
\ncline[linecolor=red,arrows=H->,%
  hooklength=4mm,hookwidth=2mm
    ]{1,1}{1,2}
\ncline{1,2}{1,4}^{\tilde{t}}
\ncline{1,2}{2,3}<{W_{ij}}
\ncline{2,3}{1,4}>{\tilde{s}}
\end{psmatrix}$
```

25.5. ArrowInside Option

It is now possible to have arrows inside lines and not only at the beginning or the end. The new defined options

Name	Example	Output
ArrowInside	\psline[ArrowInside=->](0,0)(2,0)	
ArrowInsidePos	\psline[ArrowInside=->,% ArrowInsidePos=0.25](0,0)(2,0)	
ArrowInsidePos	\psline[ArrowInside=->,% ArrowInsidePos=10](0,0)(2,0)	
ArrowInsideNo	\psline[ArrowInside=->,% ArrowInsideNo=2](0,0)(2,0)	
ArrowInsideOffset	\psline[ArrowInside=->,% ArrowInsideNo=2,% ArrowInsideOffset=0.1](0,0)(2,0)	
ArrowInside	\psline[ArrowInside=->]{->}(0,0)(2,0)	
ArrowInsidePos	\psline[ArrowInside=->,% ArrowInsidePos=0.25]{->}(0,0)(2,0)	
ArrowInsidePos	\psline[ArrowInside=->,% ArrowInsidePos=10]{->}(0,0)(2,0)	
ArrowInsideNo	\psline[ArrowInside=->,% ArrowInsideNo=2]{->}(0,0)(2,0)	
ArrowInsideOffset	\psline[ArrowInside=->,% ArrowInsideNo=2,% ArrowInsideOffset=0.1]{->}(0,0)(2,0)	
ArrowFill	\psline[ArrowFill=false,% arrowinset=0]{->}(0,0)(2,0)	
ArrowFill	\psline[ArrowFill=false,% arrowinset=0]{«-»}(0,0)(2,0)	
ArrowFill	\psline[ArrowInside=->,% arrowinset=0,% ArrowFill=false,% ArrowInsideNo=2,% ArrowInsideOffset=0.1]{->}(0,0)(2,0)	

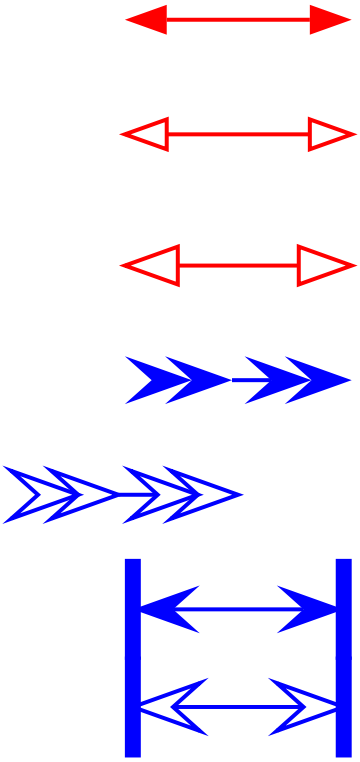
Without the default arrow definition there is only the one inside the line, defined by the type and the position. The position is relative to the length of the whole line. 0.25 means at 25% of the line length. The peak of the arrow gets the coordinates which are calculated by the macro. If you want arrows with an absolute position difference, then choose a value greater than 1, e. g. 10 which places an arrow every 10 pt. The default unit pt cannot be changed.

> The ArrowInside takes only arrow definitions like -> into account. Arrows from right to left (<-) are not possible and ignored. If you need such arrows, change the order of the pairs of coordinates for the line or curve macro.

25.6. ArrowFill Option

By default all arrows are filled polygons. With the option ArrowFill=false there are ”white“ arrows. Only for the beginning/end arrows are they empty, the inside arrows

are overpainted by the line.



```
\psset{arrowscale=2.5}
\psline[linecolor=red,arrowinset=0]{<->}(-1,0)(2,0)
```

```
\psset{arrowscale=2.5}
\psline[linecolor=red,arrowinset=0,ArrowFill=false
  ]{<->}(-1,0)(2,0)
```

```
\psset{arrowscale=2.5}
\psline[linecolor=red,arrowinset=0,arrowsize=0.2,
 ArrowFill=false]{<->}(-1,0)(2,0)
```

```
\psline[linecolor=blue,arrowscale=4,
 ArrowFill]{>>->>}(-1,0)(2,0)
```

```
\psline[linecolor=blue,arrowscale=4,
 ArrowFill=false]{>>->>}(-1,0)(2,0)
\rule{3cm}{0pt}\\[30pt]
```

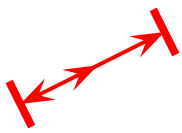
```
\psline[linecolor=blue,arrowscale=4,
 ArrowFill]{>|->|}(-1,0)(2,0)
```

```
\psline[linecolor=blue,arrowscale=4,
 ArrowFill=false]{>|->|}(-1,0)(2,0)%
```

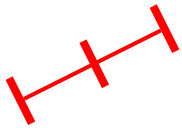
25.7. Examples

All examples are printed with `\psset{arrowscale=2,linecolor=red}`.

\psline



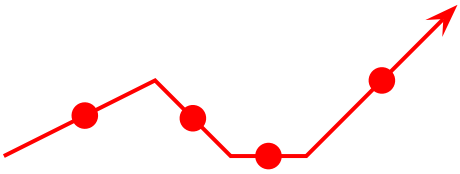
```
\begin{pspicture}(2,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=->]{|<->|}(2,1)
\end{pspicture}
```



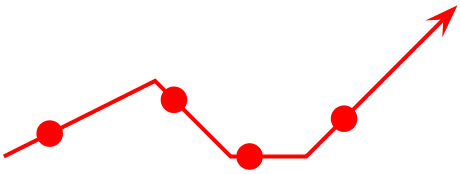
```
\begin{pspicture}(2,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=-|]{|-|}(2,1)
\end{pspicture}
```

```
\begin{pspicture}(2,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=->,ArrowInsideNo=2]{->}(2,1)
\end{pspicture}
```

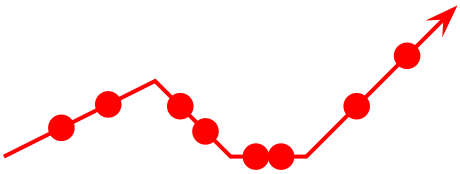
```
\begin{pspicture}(2,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=->,ArrowInsideNo=2,ArrowInsideOffset
  =0.1]{->}(2,1)
\end{pspicture}
```



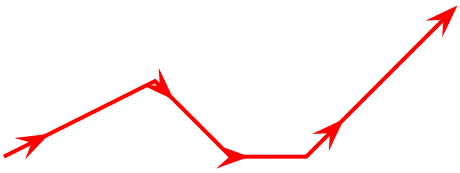
```
\begin{pspicture}(6,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=-*]{->}(0,0)(2,1)(3,0)
  (4,0)(6,2)
\end{pspicture}
```



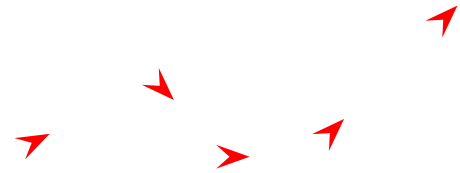
```
\begin{pspicture}(6,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=-*,ArrowInsidePos
  =0.25]{->}(0,0)(2,1)(3,0)(4,0)(6,2)
\end{pspicture}
```



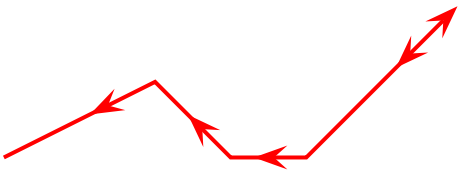
```
\begin{pspicture}(6,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=-*,ArrowInsidePos
  =0.25,ArrowInsideNo=2]{->}%
   (0,0)(2,1)(3,0)(4,0)(6,2)
\end{pspicture}
```



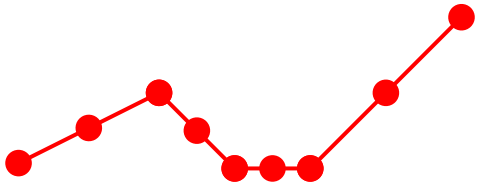
```
\begin{pspicture}(6,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=->, ArrowInsidePos
  =0.25]{->}%
      (0,0)(2,1)(3,0)(4,0)(6,2)
\end{pspicture}
```



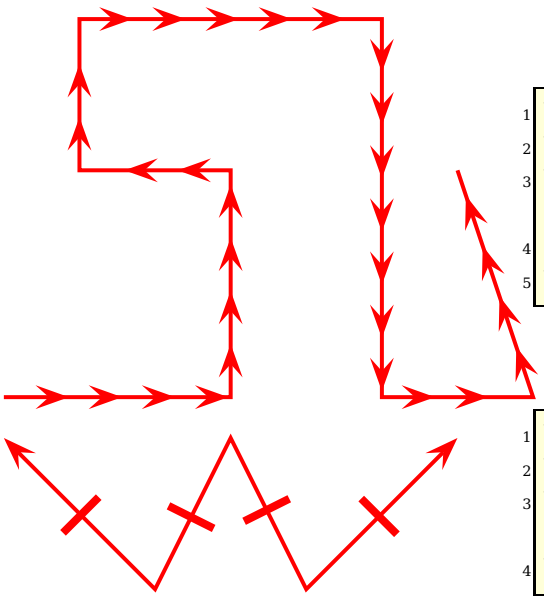
```
\begin{pspicture}(6,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[linestyle=none,ArrowInside=->,
  ArrowInsidePos=0.25]{->}%
      (0,0)(2,1)(3,0)(4,0)(6,2)
\end{pspicture}
```



```
\begin{pspicture}(6,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=-<, ArrowInsidePos
  =0.75]{->}%
    (0,0)(2,1)(3,0)(4,0)(6,2)
\end{pspicture}
```



```
\begin{pspicture}(6,2)
\psset{arrowscale=2,ArrowFill=true,
  ArrowInside=-*}
\psline(0,0)(2,1)(3,0)(4,0)(6,2)
\psset{linestyle=none}
\psline[ArrowInsidePos=0](0,0)(2,1)(3,0)
  (4,0)(6,2)
\psline[ArrowInsidePos=1](0,0)(2,1)(3,0)
  (4,0)(6,2)
\end{pspicture}
```

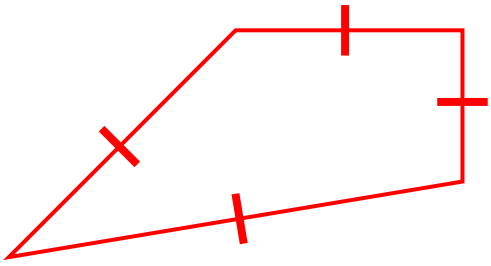


```
\begin{pspicture}(6,5)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=->,ArrowInsidePos
  =20](0,0)(3,0)%
    (3,3)(1,3)(1,5)(5,5)(5,0)(7,0)(6,3)
\end{pspicture}
```

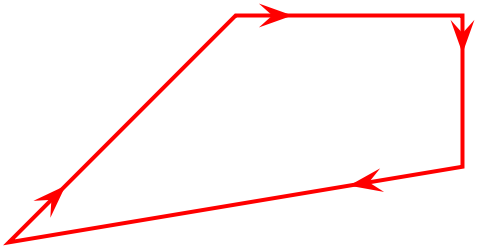


```
\begin{pspicture}(6,2)
\psset{arrowscale=2,ArrowFill=true}
\psline[ArrowInside=-|]{<->}(0,2)(2,0)
  (3,2)(4,0)(6,2)
\end{pspicture}
```

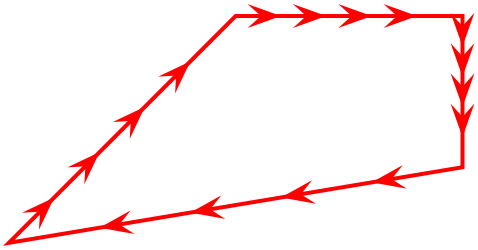
\pspolygon



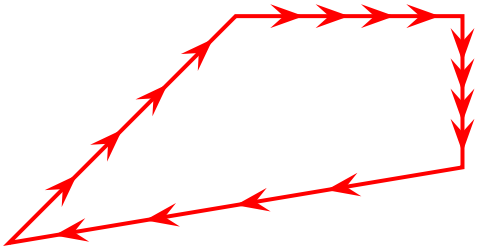
```
\begin{pspicture}(6,3)
\psset{arrowscale=2}
\pspolygon[ArrowInside=-|](0,0)(3,3)(6,3)
  (6,1)
\end{pspicture}
```



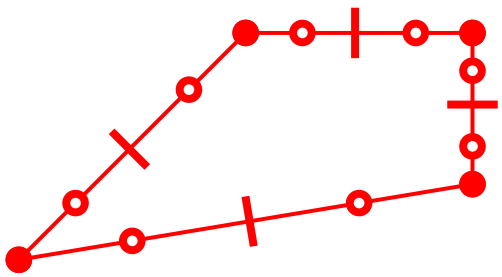
```
\begin{pspicture}(6,3)
\psset{arrowscale=2}
\pspolygon[ArrowInside=->,ArrowInsidePos
  =0.25]%
    (0,0)(3,3)(6,3)(6,1)
\end{pspicture}
```



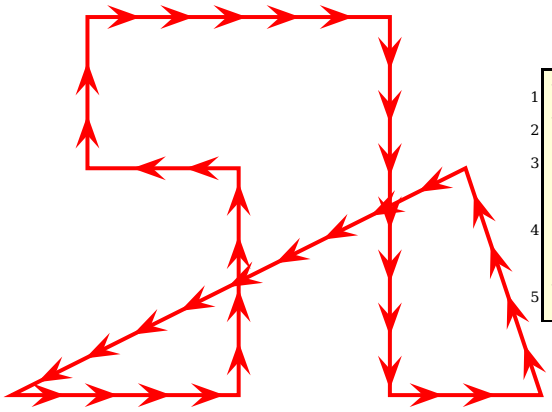
```
\begin{pspicture}(6,3)
\psset{arrowscale=2}
\pspolygon[ArrowInside=->,ArrowInsideNo=4]
  %
    (0,0)(3,3)(6,3)(6,1)
\end{pspicture}
```



```
\begin{pspicture}(6,3)
\psset{arrowscale=2}
\pspolygon[ArrowInside=->,ArrowInsideNo=4,
  %
  ArrowInsideOffset=0.1](0,0)(3,3)(6,3)
    (6,1)
\end{pspicture}
```

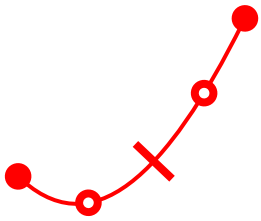


```
\begin{pspicture}(6,3)
\psset{arrowscale=2}
 \pspolygon[ArrowInside=-|](0,0)(3,3)(6,3)
   (6,1)
 \psset{linestyle=none,ArrowInside=-*}
 \pspolygon[ArrowInsidePos=0](0,0)(3,3)
   (6,3)(6,1)
 \pspolygon[ArrowInsidePos=1](0,0)(3,3)
   (6,3)(6,1)
 \psset{ArrowInside=-o}
 \pspolygon[ArrowInsidePos=0.25](0,0)(3,3)
   (6,3)(6,1)
 \pspolygon[ArrowInsidePos=0.75](0,0)(3,3)
   (6,3)(6,1)
\end{pspicture}
```

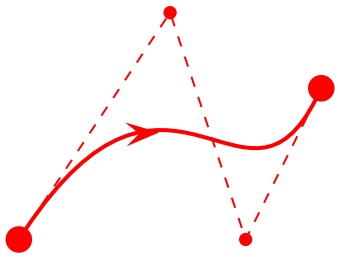


```
\begin{pspicture}(6,5)
\psset{arrowscale=2}
 \pspolygon[ArrowInside=->,ArrowInsidePos
   =20]%
   (0,0)(3,0)(3,3)(1,3)(1,5)(5,5)(5,0)
     (7,0)(6,3)
\end{pspicture}
```

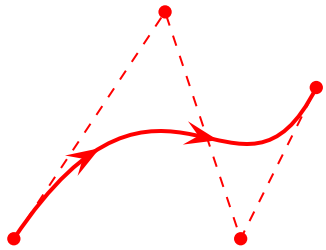
\psbezier



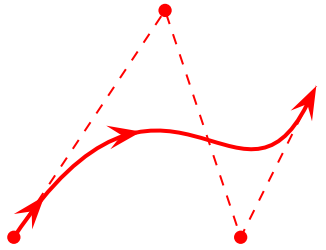
```
\begin{pspicture}(3,3)
\psset{arrowscale=2}
  \psbezier[ArrowInside=-|](0,1)(1,0)(2,1)(3,3)
  \psset{linestyle=none,ArrowInside=-o}
  \psbezier[ArrowInsidePos=0.25](0,1)(1,0)(2,1)(3,3)
  \psbezier[ArrowInsidePos=0.75](0,1)(1,0)(2,1)(3,3)
  \psset{linestyle=none,ArrowInside=-*}
  \psbezier[ArrowInsidePos=0](0,1)(1,0)(2,1)(3,3)
  \psbezier[ArrowInsidePos=1](0,1)(1,0)(2,1)(3,3)
\end{pspicture}
```



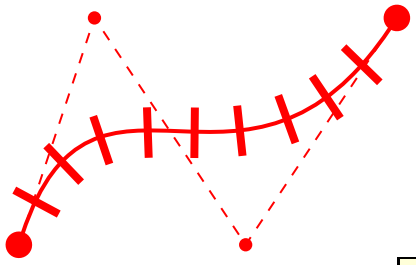
```
\begin{pspicture}(4,3)
\psset{arrowscale=2}
\psbezier[ArrowInside=->,showpoints]%
  {*-*}(0,0)(2,3)(3,0)(4,2)
\end{pspicture}
```



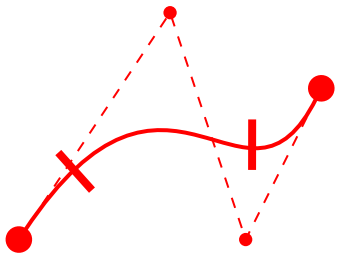
```
\begin{pspicture}(4,3)
\psset{arrowscale=2}
  \psbezier[ArrowInside=->,showpoints=true,
     ArrowInsideNo=2](0,0)(2,3)(3,0)(4,2)
\end{pspicture}
```



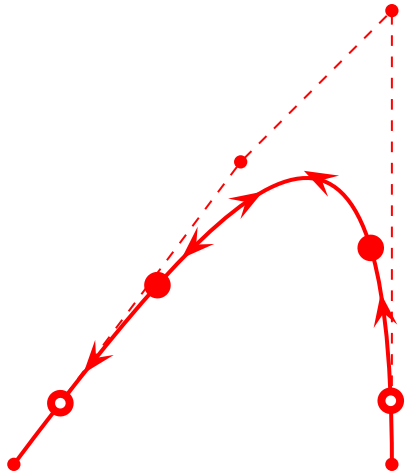
```
\begin{pspicture}(4,3)
\psset{arrowscale=2}
  \psbezier[ArrowInside=->,showpoints=true,
    ArrowInsideNo=2,ArrowInsideOffset=-0.2]%
     {->}(0,0)(2,3)(3,0)(4,2)
\end{pspicture}
```



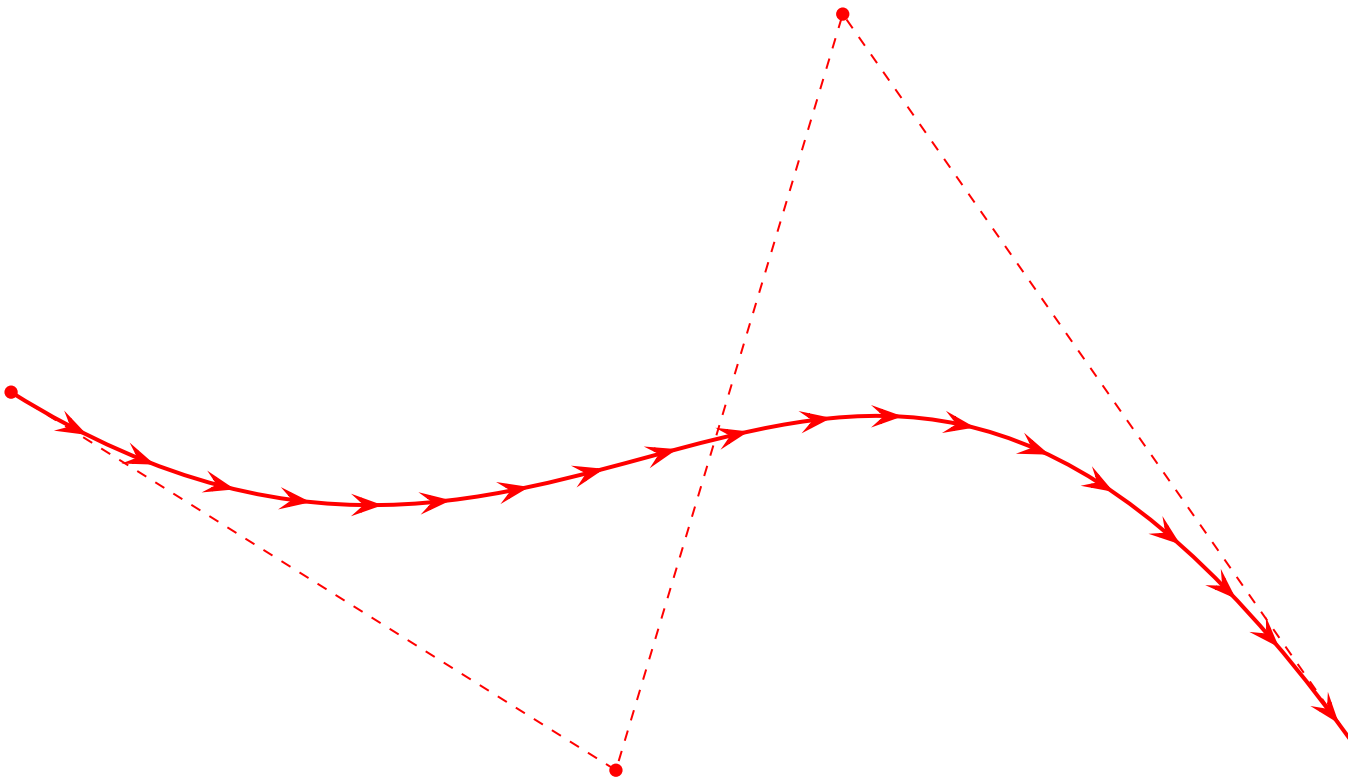
```
\begin{pspicture}(5,3)
\psset{arrowscale=2}
  \psbezier[ArrowInsideNo=9,ArrowInside=-|,%
    showpoints=true]{*-*}(0,0)(1,3)(3,0)(5,3)
\end{pspicture}
```



```
\begin{pspicture}(4,3)
\psset{arrowscale=2}
  \psset{ArrowInside=-|}
  \psbezier[ArrowInsidePos=0.25,showpoints=true
    ]{*-*}(2,3)(3,0)(4,2)
  \psset{linestyle=none}
  \psbezier[ArrowInsidePos=0.75](0,0)(2,3)(3,0)(4,2)
\end{pspicture}
```



```
\begin{pspicture}(5,6)
\psset{arrowscale=2}
  \pnode(3,4){A}\pnode(5,6){B}\pnode(5,0){C}
  \psbezier[ArrowInside=->,%
    showpoints=true](A)(B)(C)
  \psset{linestyle=none,ArrowInside=-<}
  \psbezier[ArrowInsideNo=4](0,0)(A)(B)(C)
  \psset{ArrowInside=-o}
  \psbezier[ArrowInsidePos=0.1](0,0)(A)(B)(C)
  \psbezier[ArrowInsidePos=0.9](0,0)(A)(B)(C)
  \psset{ArrowInside=-*}
  \psbezier[ArrowInsidePos=0.3](0,0)(A)(B)(C)
  \psbezier[ArrowInsidePos=0.7](0,0)(A)(B)(C)
\end{pspicture}
```



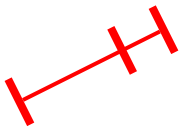
```
\begin{pspicture}(-3,-5)(15,5)
 \psbezier[ArrowInsideNo=19,%
    ArrowInside=->,ArrowFill=false,%
    showpoints=true]{->}(-3,0)(5,-5)(8,5)(15,-5)
\end{pspicture}
```

\pcline

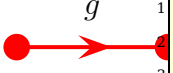
These examples need the package `pst-node`.

```
\begin{pspicture}(2,1)
\psset{arrowscale=2}
\pcline[ArrowInside=->](0,0)(2,1)
\end{pspicture}
```

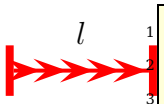
```
\begin{pspicture}(2,1)
\psset{arrowscale=2}
\pcline[ArrowInside=->]{<->}(0,0)(2,1)
\end{pspicture}
```



```
\begin{pspicture}(2,1)
\psset{arrowscale=2}
\pcline[ArrowInside=-|,ArrowInsidePos=0.75]{|-|}(0,0)(2,1)
\end{pspicture}
```



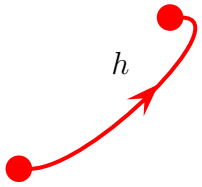

```
\psset{arrowscale=2}
\pcline[ArrowInside=->,ArrowInsidePos=0.65]{*-*}(0,0)(2,0)
\naput[labelsep=0.3]{\large$g$}
```



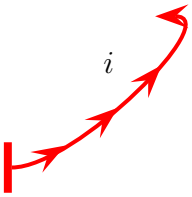

```
\psset{arrowscale=2}
\pcline[ArrowInside=->,ArrowInsidePos=10]{|-|}(0,0)(2,0)
\naput[labelsep=0.3]{\large$l$}
```

\pccurve

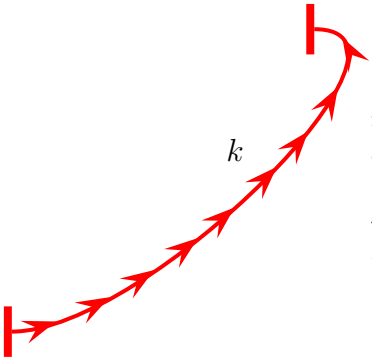
These examples also need the package pst-node.




```
\begin{pspicture}(2,2)
\psset{arrowscale=2}
\pccurve[ArrowInside=->,ArrowInsidePos=0.65,showpoints=true
  ]{*-*}(0,0)(2,2)
\naput[labelsep=0.3]{\large$h$}
\end{pspicture}
```




```
\begin{pspicture}(2,2)
\psset{arrowscale=2}
\pccurve[ArrowInside=->,ArrowInsideNo=3,showpoints=true
  ]{|->}(0,0)(2,2)
\naput[labelsep=0.3]{\large$i$}
\end{pspicture}
```

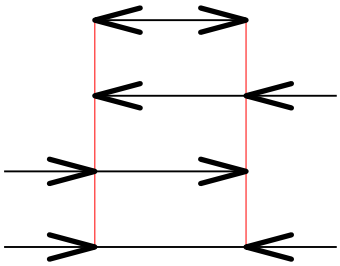



```
\begin{pspicture}(4,4)
\psset{arrowscale=2}
\pccurve[ArrowInside=->,ArrowInsidePos=20]{|-|}(0,0)
  (4,4)
\naput[labelsep=0.3]{\large$k$}
\end{pspicture}
```

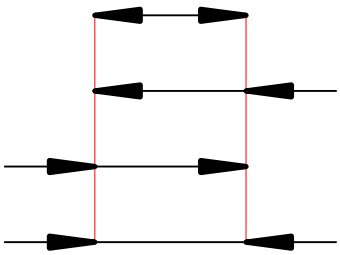
25.8. Special arrows v-V,t-T, and f-F

Possible optional arguments are

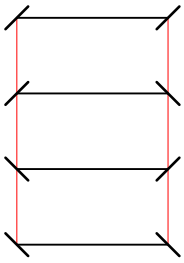
name	meaning
veearrowlength	default is 3mm
veearrowangle	default is 30
veearrowlinewidth	default is 0.35mm
filledveearrowlength	default is 3mm
filledveearrowangle	default is 15
filledveearrowlinewidth	default is 0.35mm
tickarrowlength	default is 1.5mm
tickarrowlinewidth	default is 0.35mm



```
\psset{unit=5mm}
\begin{pspicture}(4,6)
  \psset{dimen=middle,arrows=c-c,
    arrowscale=2,linewidth=.25mm}
  \psline[linecolor=red,linewidth=.05mm](0,0)(0,6)
  \psline[linecolor=red,linewidth=.05mm](4,0)(4,6)
  \psline{v-v}(0,6)(4,6)
  \psline{v-V}(0,4)(4,4)
  \psline{V-v}(0,2)(4,2)
  \psline{V-V}(0,0)(4,0)
\end{pspicture}
```



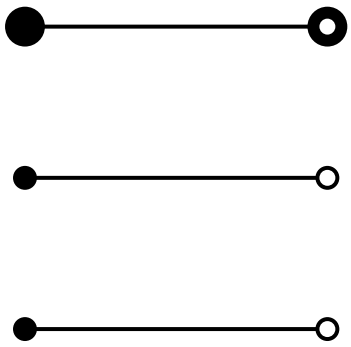
```
\psset{unit=5mm}
\begin{pspicture}(4,6)
  \psset{dimen=middle,arrows=c-c,
    arrowscale=2,linewidth=.25mm}
  \psline[linecolor=red,linewidth=.05mm](0,0)(0,6)
  \psline[linecolor=red,linewidth=.05mm](4,0)(4,6)
  \psline{f-f}(0,6)(4,6)
  \psline{f-F}(0,4)(4,4)
  \psline{F-f}(0,2)(4,2)
  \psline{F-F}(0,0)(4,0)
\end{pspicture}
```



```
\psset{unit=5mm}
\begin{pspicture}(4,6)
  \psset{dimen=middle,arrows=c-c,linewidth=.25mm}
  \psline[linecolor=red,linewidth=.05mm](0,0)(0,6)
  \psline[linecolor=red,linewidth=.05mm](4,0)(4,6)
  \psline{t-t}(0,6)(4,6)
  \psline{t-T}(0,4)(4,4)
  \psline{T-t}(0,2)(4,2)
  \psline{T-T}(0,0)(4,0)
\end{pspicture}
```

25.9. Special arrow option arrowLW

Only for the arrowtype o and ∗ it is possible to set the arrowlinewidth with the optional keyword arrowLW. When scaling an arrow by the keyword arrowscale the width of the borderline is also scaled. With the optional argument arrowLW the line width can be set separately and is not taken into account by the scaling value.



```
\begin{pspicture}(4,6)
\psline[arrowscale=3,arrows=*-o](0,5)(4,5)
\psline[arrowscale=3,arrows=*-o,
  arrowLW=0.5pt](0,3)(4,3)
\psline[arrowscale=3,arrows=*-o,
  arrowLW=0.3333\pslinewidth](0,1)(4,1)
\end{pspicture}
```

26. Transparent colors

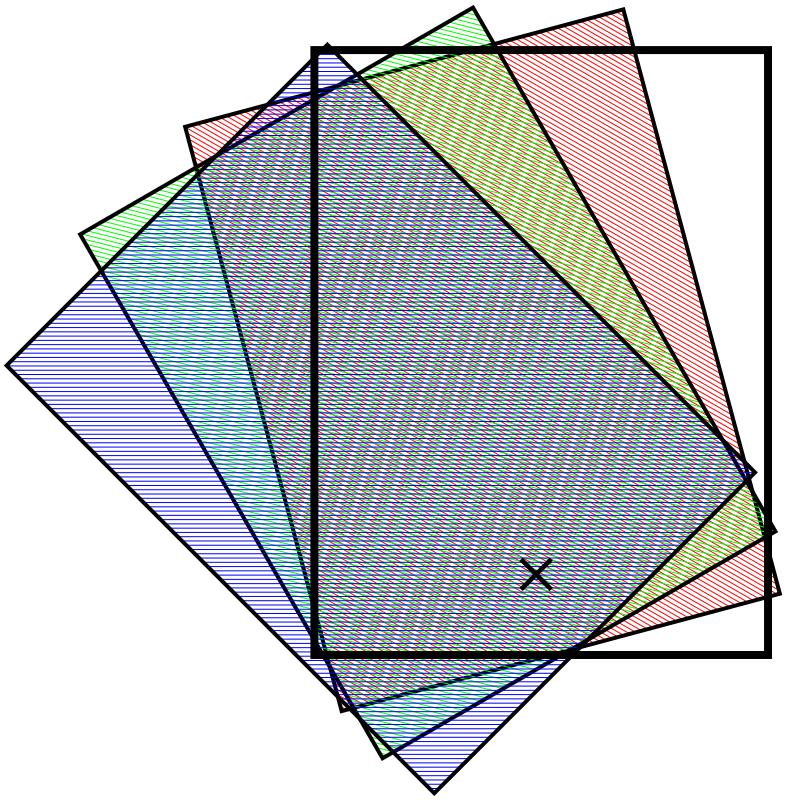
Transparency is now part of the main pstricks package. But pay attention, the names and syntax have changed and you need to run ps2pdf with the option -dCompatibilityLevel=1.4.

27. „Manipulating transparent colors”

pstricks-add supports real transparency and a simulated one with hatch lines:

```
\def\defineTColor{\@ifnextchar[{\defineTColor@i}{\defineTColor@i[]}}
\def\defineTColor@i[#1]#2#3{% transparency "Colors"
  \newpsstyle{#2}{%
    fillstyle=vlines,hatchwidth=0.1\pslinewidth,
    hatchsep=1\pslinewidth,hatchcolor=#3,#1%
  }%
}
\defineTColor{TRed}{red}
\defineTColor{TGreen}{green}
\defineTColor{TBlue}{blue}
```

There are three predefined "’transparent"‘ colors TRed, TGreen, TBlue. They are used as PSTricks styles and not as colors:



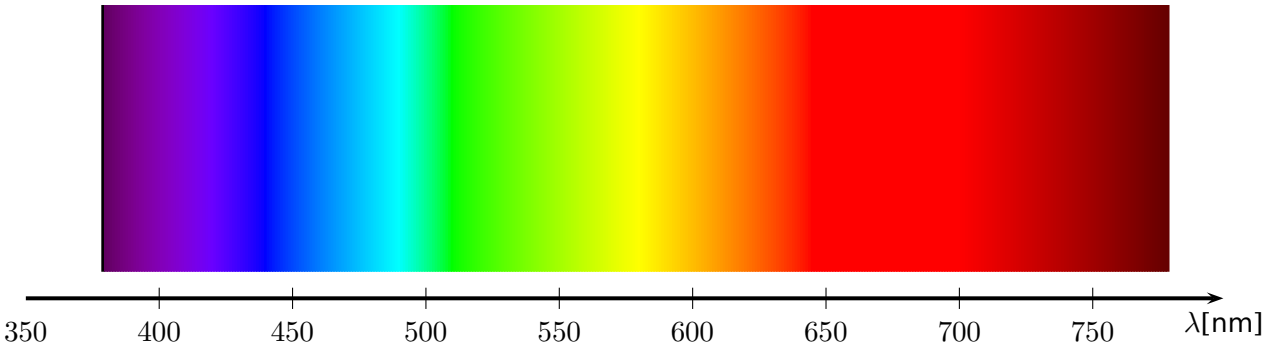
```
\begin{pspicture}(-3,-5)(5,5)
\psframe(-1,-3)(5,5) % objet de base
\psrotate(2,-2){15}{%
  \psframe[style=TRed](-1,-3)(5,5)}
\psrotate(2,-2){30}{%
  \psframe[style=TGreen](-1,-3)(5,5)}
\psrotate(2,-2){45}{%
  \psframe[style=TBlue](-1,-3)(5,5)}
\psframe[linewidth=3pt](-1,-3)(5,5)
\psdots[dotstyle=+,dotangle=45,dotscale=3](2,-2) % centre de la rotation
\end{pspicture}
```

28. Calculated colors

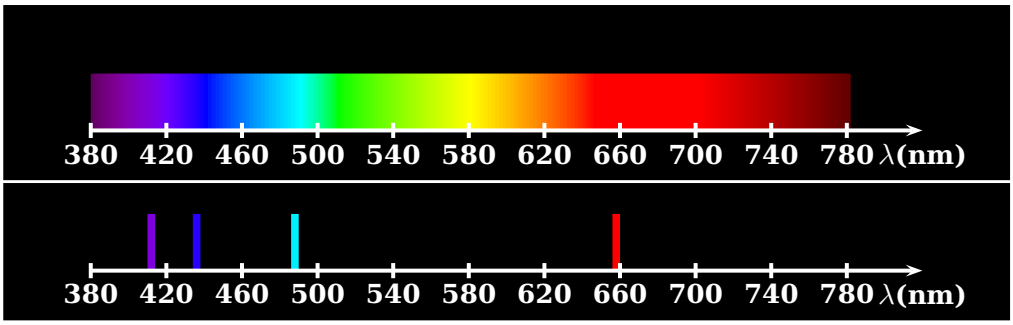
The `xcolor` package (version 2.6) has a new feature for defining colors:

```
\definecolor[ps]{<name>}{<model>}{< PS code >}
```

`model` can be one of the color models, which `PostScript` will understand, e.g. `rgb`. With this definition the color is calculated on the `PostScript` side.




```
\definecolor[ps]{bl}{rgb}{tx@addDict begin Red Green Blue end}%
\psset{unit=1bp}
\begin{pspicture}(0,-30)(400,100)
\multido{\iLAMBDA=0+1}{400}{%
  \pstVerb{
    \iLAMBDA\space 379 add dup /lambda exch def
    tx@addDict begin wavelengthToRGB end
  }%
  \psline[linecolor=bl](\iLAMBDA,0)(\iLAMBDA,100)%
}
\psaxes[yAxis=false,Ox=350,dx=50bp,Dx=50]{->}(-29,-10)(420,100)
\uput[-90](420,-10){$\lambda$[\textsf{nm}]}
\end{pspicture}
```



Spectrum of hydrogen emission (Manuel Luque)

```
\newcommand{\Touch}{%
\psframe[linestyle=none,fillstyle=solid,fillcolor=bl,dimen=middle](0.1,0.75)}
\definecolor[ps]{bl}{rgb}{tx@addDict begin Red Green Blue end}%
% Echelle 1cm <-> 40 nm
%       1 nm <-> 0.025 cm
\psframebox[fillstyle=solid,fillcolor=black]{%
\begin{pspicture}(-1,-0.5)(12,1.5)
\multido{\iLAMBDA=380+2}{200}{%
  \pstVerb{
    /lambda \iLAMBDA\space def
    lambda
    tx@addDict begin wavelengthToRGB end
  }%
 \rput(! lambda 0.025 mul 9.5 sub 0){\Touch}
}
```

```
\multido{\n=0+1,\iDiv=380+40}{11}{%
   \psline[linecolor=white](\n,0.1)(\n,-0.1)
   \uput[270](\n,0){\textbf{\white\iDiv}}}
   \psline[linecolor=white]{->}(11,0)
   \uput[270](11,0){\textbf{\white$\lambda$(nm)}}
\end{pspicture}}

\psframebox[fillstyle=solid,fillcolor=black]{%
\begin{pspicture}(-1,-0.5)(12,1)
 \pstVerb{
   /lambda 656 def
   lambda
   tx@addDict begin wavelengthToRGB end
 }%
 \rput(! 656 0.025 mul 9.5 sub 0){\Touch}
 \pstVerb{
   /lambda 486 def
   lambda
   tx@addDict begin wavelengthToRGB end
 }%
 \rput(! 486 0.025 mul 9.5 sub 0){\Touch}
  \pstVerb{
   /lambda 434 def
   lambda
   tx@addDict begin wavelengthToRGB end
 }%
 \rput(! 434 0.025 mul 9.5 sub 0){\Touch}
 \pstVerb{
   /lambda 410 def
   lambda
   tx@addDict begin wavelengthToRGB end
 }%
 \rput(! 410 0.025 mul 9.5 sub 0){\Touch}
\multido{\n=0+1,\iDiv=380+40}{11}{%
   \psline[linecolor=white](\n,0.1)(\n,-0.1)
   \uput[270](\n,0){\textbf{\white\iDiv}}}
   \psline[linecolor=white]{->}(11,0)
   \uput[270](11,0){\textbf{\white$\lambda$(nm)}}
\end{pspicture}}

Spectrum of hydrogen emission (Manuel Luque)
```

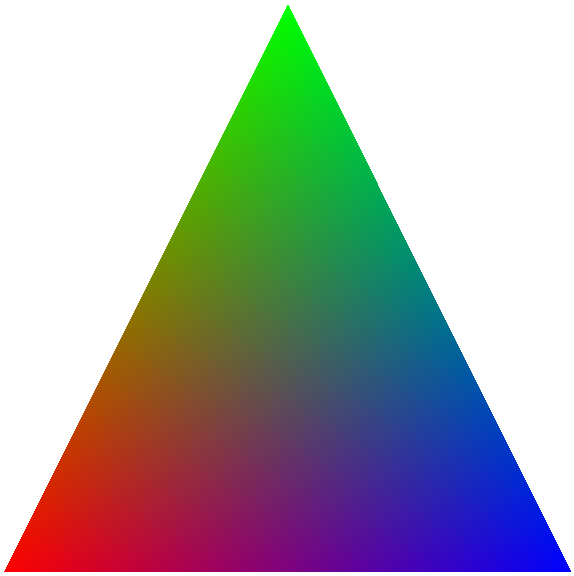
29. Gouraud shading

Gouraud shading is a method used in computer graphics to simulate the differing effects of light and colour across the surface of an object. In practice, Gouraud shading is used to achieve smooth lighting on low-polygon surfaces without the heavy computational requirements of calculating lighting for each pixel. The technique was first presented by Henri Gouraud in 1971.

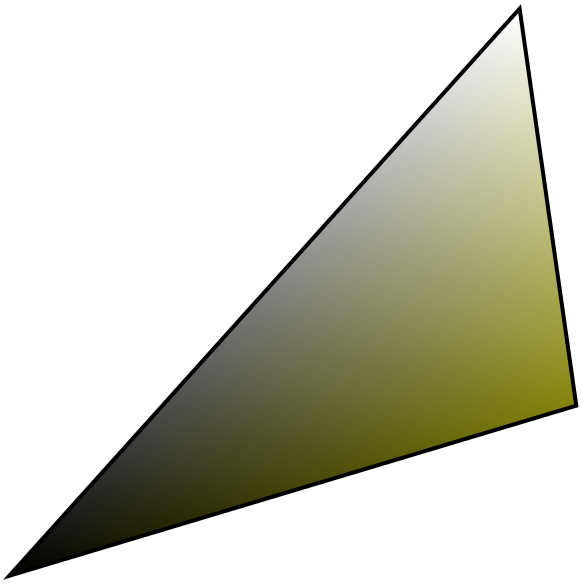
http://www.wikipedia.org

PostScript level 3 supports this kind of shading and it can only be seen with Acroread 7 or later. The syntax is easy:

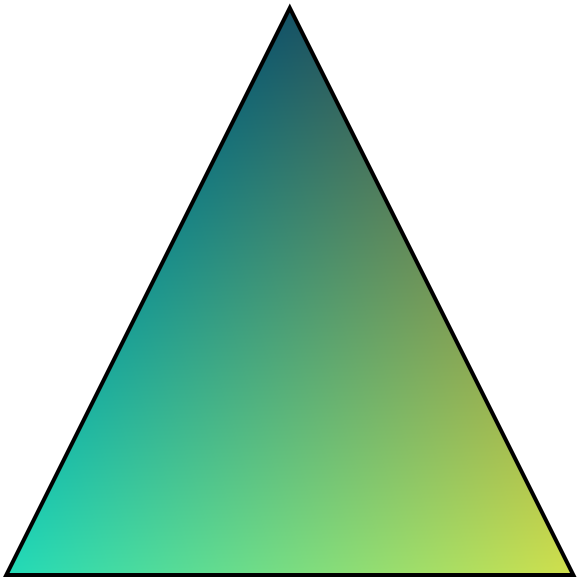
```
\psGTriangle(x1,y1)(x2,y2)(x3,y3){color1}{color2}{color3}
```



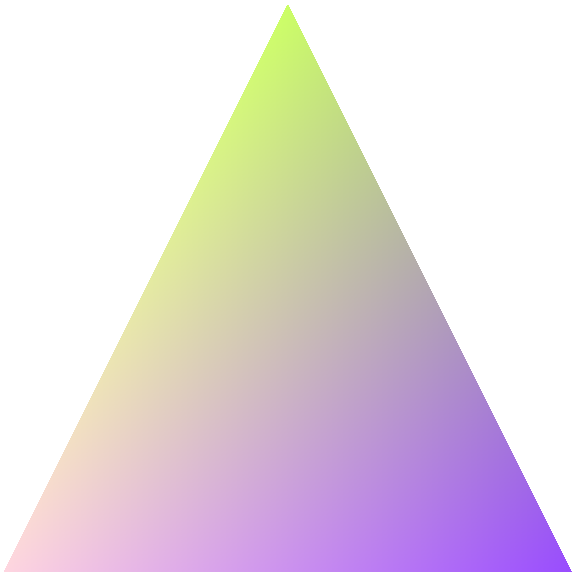
```
\begin{pspicture}(0,-.25)(10,10)
  \psGTriangle(0,0)(5,10)(10,0){red}{green}{blue}
\end{pspicture}
```



```
\begin{pspicture}(0,-.25)(10,10)
  \psGTriangle*(0,0)(9,10)(10,3){black}{white!50}{red!50!green!95}
\end{pspicture}
```



```
\begin{pspicture}(0,-.25)(10,10)
  \psGTriangle*(0,0)(5,10)(10,0){-red!100!green!84!blue!86}
                        {-red!80!green!100!blue!40}
                        {-red!60!green!30!blue!100}
\end{pspicture}
```



```
\definecolor{rose}{rgb}{1.00, 0.84, 0.88}
\definecolor{vertpommepasmure}{rgb}{0.80, 1.0, 0.40}
\definecolor{fushia}{rgb}{0.60, 0.30, 1.0}
\begin{pspicture}(0,-.25)(10,10)
  \psGTriangle(0,0)(5,10)(10,0){rose}{vertpommepasmure}{fushia}
\end{pspicture}
```

A. \resetOptions

Sometimes it is difficult to know what options, which are changed inside a long document, are different to the default ones. With this macro all options belonging to pst-plot can be reset. This refers to all options of the packages pstricks, pst-plot and pst-node.

B. PostScript

PostScript uses the stack system and the LIFO system, "'Last In, First Out"'.

Table 4: Some primitive PostScript macros

Function	*Meaning* *on stack before* $\rightarrow$ *after*
add	$x \quad y \rightarrow x+y$
sub	$x \quad y \rightarrow x-y$
mul	$x \quad y \rightarrow x \times y$
div	$x \quad y \rightarrow x \div y$
sqrt	$x \rightarrow \sqrt{x}$
abs	$x \rightarrow \lvert x \rvert$
neg	$x \rightarrow -x$
cos	$x \rightarrow \cos(x)$ (x in degrees)
sin	$x \rightarrow \sin(x)$ (x in degrees)
tan	$x \rightarrow \tan(x)$ (x in degrees)
atan	$y \quad x \rightarrow \angle(\vec{Ox};\vec{OM})$ (in degrees of $M(x,y)$)
ln	$x \rightarrow \ln(x)$
log	$x \rightarrow \log(x)$
array	$n \rightarrow v$ (of dimension n)
aload	$v \rightarrow x_1 \quad x_2 \quad \cdots \quad x_n \quad v$
astore	$x_1 \quad x_2 \quad \cdots \quad x_n \quad v \rightarrow [v]$
pop	$x \rightarrow$ -
dup	$x \rightarrow x \quad x$

C. List of all optional arguments for pstricks-add

Key	Type	Default
CMYK	boolean	true
intSeparator	ordinary	[none]
braceWidth	ordinary	[none]
bracePos	ordinary	[none]
braceWidthInner	ordinary	[none]
braceWidthOuter	ordinary	[none]
veearrowlength	ordinary	3mm
veearrowangle	ordinary	30
veearrowlinewidth	ordinary	0.35mm
filledveearrowlength	ordinary	3mm
filledveearrowangle	ordinary	15
filledveearrowlinewidth	ordinary	0.35mm
tickarrowlength	ordinary	1.5mm
tickarrowlinewidth	ordinary	0.35mm
hooklength	ordinary	3mm
hookwidth	ordinary	1mm
ArrowFill	boolean	true
nArrowsA	ordinary	2
nArrowsB	ordinary	2
nArrows	ordinary	2
ArrowInside	ordinary	[none]
ArrowInsidePos	ordinary	0.5
ArrowInsideNo	ordinary	1
ArrowInsideOffset	ordinary	0
randomPoints	ordinary	1000
color	boolean	true
blName	command	
bcName	command	
brName	command	
clName	command	
ccName	command	
crName	command	
tlName	command	
tcName	command	
trName	command	
method	ordinary	[none]
whichabs	ordinary	[none]
whichord	ordinary	[none]
plotfuncx	ordinary	[none]
plotfuncy	ordinary	[none]
expression	ordinary	[none]

Continued on next page

Continued from previous page

Key	Type	Default
buildvector	boolean	true
varsteptol	ordinary	[none]
adamsorder	ordinary	[none]
StepType	ordinary	[none]
Derive	ordinary	[none]
Tnormal	boolean	true
GetFinalState	boolean	true
filename	ordinary	[none]
saveData	boolean	true
colorType	ordinary	0
chartStyle	ordinary	[none]
chartColor	ordinary	[none]
chartSep	ordinary	[none]
chartStack	ordinary	[none]
chartStackDepth	ordinary	[none]
chartStackWidth	ordinary	[none]
chartHeight	ordinary	[none]
userColor	ordinary	[none]
chartNodeI	ordinary	[none]
chartNodeO	ordinary	[none]

References

[1] Hendri Adriaens. xkeyval package. CTAN:/macros/latex/contrib/xkeyval, 2004.

[2] Denis Girou. Présentation de PSTricks. *Cahier GUTenberg*, 16:21–70, April 1994.

[3] Michel Goosens, Frank Mittelbach, Sebastian Rahtz, Denis Roegel, and Herbert Voß. *The LaTeX Graphics Companion*. Addison-Wesley Publishing Company, Reading, Mass., 2007.

[4] Alan Hoenig. *TeX Unbound: LaTeX & TeX Strategies, Fonts, Graphics, and More*. Oxford University Press, London, 1998.

[5] Laura E. Jackson and Herbert Voß. Die plot-funktionen von pst-plot. *Die TeXnische Komödie*, 2/02:27–34, June 2002.

[6] Nikolai G. Kollock. *PostScript richtig eingesetzt: vom Konzept zum praktischen Einsatz*. IWT, Vaterstetten, 1989.

[7] Frank Mittelbach and Michel Goosens et al. *The LaTeX Companion*. Addison-Wesley Publishing Company, Boston, second edition, 2004.

[8] Frank Mittelbach and Michel Goosens et al. *Der LaTeX Begleiter*. Pearson Education, München, zweite edition, 2005.

[9] Herbert Voß. *Chaos und Fraktale selbst programmieren: von Mandelbrotmengen über Farbmanipulationen zur perfekten Darstellung*. Franzis Verlag, Poing, 1994.

[10] Herbert Voß. Die mathematischen Funktionen von PostScript. *Die TEXnische Komödie*, 1/02, March 2002.

[11] Herbert Voß. *PSTricks Grafik für TEX und LATEX*. DANTE – Lob.media, Heidelberg/Hamburg, fifth edition, 2008.

[12] Herbert Voß. *Mathematiksatz in LATEX*. Lehmanns Media/DANTE, Berlin/Heidelberg, first edition, 2009.

[13] Timothy Van Zandt. *PSTricks - PostScript macros for generic TEX*. http://www.tug.org/application/PSTricks, 1993.

[14] Timothy Van Zandt. *multido.tex - a loop macro, that supports fixed-point addition*. CTAN:/graphics/pstricks/generic/multido.tex, 1997.

[15] Timothy Van Zandt. *pst-plot: Plotting two dimensional functions and data*. CTAN:graphics/pstricks/generic/pst-plot.tex, 1999.

[16] Timothy Van Zandt and Denis Girou. Inside PSTricks. *TUGboat*, 15:239–246, September 1994.

Index

Symbols

\h*AmacroB*, 5
(-), 85
)-(, 85
*, 97
-, 85
*-), 85
-, 85
-, 85
->, 85, 88
-dCompatibilityLevel, 97
-<<, 86
->>, 86
<-, 88
<->, 85
<<->>, 85
>-<, 85
[->, 85
[-], 85
]-[, 85
<<-, 86
<<-<<, 86
<<->>, 86
>>-, 86
>>-<<, 85, 86
>>->>, 86

A

abs, 103
add, 103
algebraic, 33, 37
algebraic=true, 40, 42, 57, 65
aload, 103
angle, 24
array, 103
ArrowFill, 88
ArrowInside, 88
ArrowInsideNo, 88
ArrowInsideOffset, 88
ArrowInsidePos, 88
arrowLW, 97
arrows, 85
arrowscale, 97
astore, 103
atan, 103

B

B, 15
b, 15
\BeginSaveFinalState, 76
brace, 16
bracePos, 15
braceWidth, 15
braceWidthInner, 15
braceWidthOuter, 15
buildvector, 57

C

C, 15
c, 15
\cancel, 31
cardioid, 39
ChangeOrder, 77
chartColor, 11
chartFillColor?, 11
chartNodeI, 11
chartNodeO, 11
chartSep, 11
color, 20
colorType, 80
cos, 103
curvature, 36

D

dash, 83
default, 37, 44
Derive, 37–39, 42
div, 103
dotmatrix, 77
dup, 103

E

\EndSaveFinalState, 76
Environment
– pspicture, 24

F

false, 88
File
– pstricks-add-doc.dat, 80
fillcolor, 15
filledveearrowangle, 96
filledveearrowlength, 96
filledveearrowlinewidth, 96
fillstyle
– eofill, 2
Fresnel, 69

G
GetFinalState, 76
Gouraud, 100

H
H, 87
hooklength, 87
hookwidth, 87
hydrogen, 99

I
i, 33
infimum, 33
InsideArrow, 2
intSeparator, 23

K
Keyvalue
– B, 15
– b, 15
– C, 15
– c, 15
– default, 44
– i, 33
– infimum, 33
– l, 15
– R, 33
– r, 15
– Riemann, 33
– s, 33
– supremum, 33
– t, 15
– u, 33
– upper, 33
Keyword
– algebraic, 33, 37
– algebraic=true, 40, 42, 57, 65
– angle, 24
– ArrowFill, 88
– ArrowInside, 88
– ArrowInsideNo, 88
– ArrowInsideOffset, 88
– ArrowInsidePos, 88
– arrowLW, 97
– arrows, 85
– arrowscale, 97
– bracePos, 15
– braceWidth, 15
– braceWidthInner, 15
– braceWidthOuter, 15
– buildvector, 57
– ChangeOrder, 77
– chartColor, 11
– chartFillColor?, 11
– chartNodeI, 11
– chartNodeO, 11
– chartSep, 11
– color, 20
– colorType, 80
– curvature, 36
– dash, 83
– Derive, 37–39
– fillcolor, 15
– filledveearrowangle, 96
– filledveearrowlength, 96
– filledveearrowlinewidth, 96
– GetFinalState, 76
– hooklength, 87
– hookwidth, 87
– InsideArrow, 2
– intSeparator, 23
– labelFontSize, 2
– lower, 33
– method, 57, 58
– nodesepA, 15
– nodesepB, 15
– opacity, 31
– plotfuncx, 57
– plotfuncy, 57
– plotpoints, 44
– randomPoints, 20

– ref, 15
– rot, 15
– StepType, 33
– strokeopacity, 31
– tickarrowlength, 96
– tickarrowlinewidth, 96
– ticksize, 2
– tickstyle, 2
– Tnormal, 36, 39
– trueAngle, 24, 26
– unit, 22
– userColor, 11
– varrkiv, 58
– VarStep, 44
– varStep, 47
– VarStepEpsilon, 6, 44
– varsteptol, 6, 58
– veearrowangle, 96
– veearrowlength, 96
– veearrowlinewidth, 96
– whichabs, 57
– whichord, 57
– xunit, 24
– xyLabel, 2
– yunit, 24

L

l, 15, 33
labelFontSize, 2
Lissajou curve, 40
ln, 103
log, 103
Lotka-Volterra, 70
lower, 33

M

Macro
– \h*AmacroB*, 5
– \BeginSaveFinalState, 76
– \cancel, 31
– \EndSaveFinalState, 76
– \multirput, 7
– \ncline, 10
– \parametricplot, 49
– \psbezier, 2
– \psbrace∗, 15
– \psCancel∗, 31
– \psChart, 11
– \psComment∗, 10
– \pscurve, 36
– \psDefPSPNodes, 24
– \psdice, 22
– \psFormatInt, 23
– \psGetDistance, 5
– \psGetSlope, 5
– \psHomothetie, 14
– \pslineByHand, 6
– \pslinewidth, 15
– \psMatrixPlot, 77
– \psplot, 44
– \psplotDiffEqn, 57
– \psplotTangent∗, 37
– \psplotTangent, 36
– \psplotTangentLine, 36
– \psRandom, 20
– \psRelLine, 25
– \psRelNode, 24, 25
– \psrotate, 8
– \psset, 85, 87
– \psStep, 33
– \psTangentLine, 36
– \rmultiput∗, 7
– \rmultiput, 7
– \rput, 8, 11, 22
– \specialCoor, 16
matrix, 77
method, 57, 58
mul, 103
\multirput, 7

N

\ncline, 10
neg, 103
nodesepA, 15
nodesepB, 15

O

o, 97
o-o, 85
oo-oo, 85
opacity, 31
oscillation, 74

P
Package
– pst-func, 2
– pst-node, 103
– pst-plot, 2, 103
– pst-xkey, 2
– pstricks, 15, 103
– pstricks-add, 2, 23, 37, 85, 97
– xkeyval, 2
Package option
– -dCompatibilityLevel, 97
\parametricplot, 49
plotfuncx, 57
plotfuncy, 57
plotpoints, 44
pop, 103
PostScript, 103
– abs, 103
– add, 103
– aload, 103
– array, 103
– astore, 103
– atan, 103
– cos, 103
– Derive, 42
– div, 103
– dotmatrix, 77
– dup, 103
– ln, 103
– log, 103
– mul, 103
– neg, 103
– pop, 103
– sin, 103
– sqrt, 103
– sub, 103
– tan, 103
Program
– ps2pdf, 97
ps2pdf, 97
\psbezier, 2
\psbrace*, 15
\psCancel*, 31
\psChart, 11
\psComment*, 10
\pscurve, 36
\psDefPSPNodes, 24
\psdice, 22
\psFormatInt, 23
\psGetDistance, 5
\psGetSlope, 5
\psHomothetie, 14
\pslineByHand, 6
\pslinewidth, 15
\psMatrixPlot, 77
pspicture, 24
\psplot, 44
\psplotDiffEqn, 57
\psplotTangent, 36
\psplotTangent*, 37
\psplotTangentLine, 36
\psRandom, 20
\psRelLine, 25
\psRelNode, 24, 25
\psrotate, 8
\psset, 85, 87
\psStep, 33
pst-func, 2
pst-node, 103
pst-plot, 2, 103
pst-xkey, 2
\psTangentLine, 36
pstricks, 15, 103
pstricks-add, 2, 23, 37, 85, 97
pstricks-add-doc.dat, 80

R
R, 33
r, 15
randomPoints, 20
ref, 15
Riemann, 33
Riemann, 33
\rmultiput, 7
\rmultiput*, 7
rot, 15
\rput, 8, 11, 22
Runge-Kutta, 58

S
s, 33

sin, 103
\specialCoor, 16
Spectrum, 99
sqrt, 103
StepType, 33
strokeopacity, 31
sub, 103
supremum, 33
Syntax
– (-), 85
–)-(, 85
– *, 97
– **-**, 85
– *-), 85
– *-*, 85
– -, 85
– ->, 85, 88
– -<<, 86
– ->>, 86
– <-, 88
– <->, 85
– <<->>, 85
– >-<, 85
– [->, 85
– [-], 85
–]-[, 85
– <<-, 86
– <<-<<, 86
– <<->>, 86
– >>-, 86
– >>-<<, 85, 86
– >>->>, 86
– H, 87
– o, 97
– o-o, 85
– oo-oo, 85

T
t, 15
tan, 103
tickarrowlength, 96
tickarrowlinewidth, 96
ticksize, 2
tickstyle, 2
Tnormal, 36, 39
true, 33
trueAngle, 24, 26

U
u, 33
unit, 22
upper, 33
userColor, 11

V
Value
– default, 37
– false, 88
– l, 33
– lower, 33
– true, 33
varrkiv, 58
VarStep, 44
varStep, 47
VarStepEpsilon, 6, 44
varsteptol, 6, 58
veearrowangle, 96
veearrowlength, 96
veearrowlinewidth, 96

W
whichabs, 57
whichord, 57

X
xkeyval, 2
xunit, 24
xyLabel, 2

Y
yunit, 24