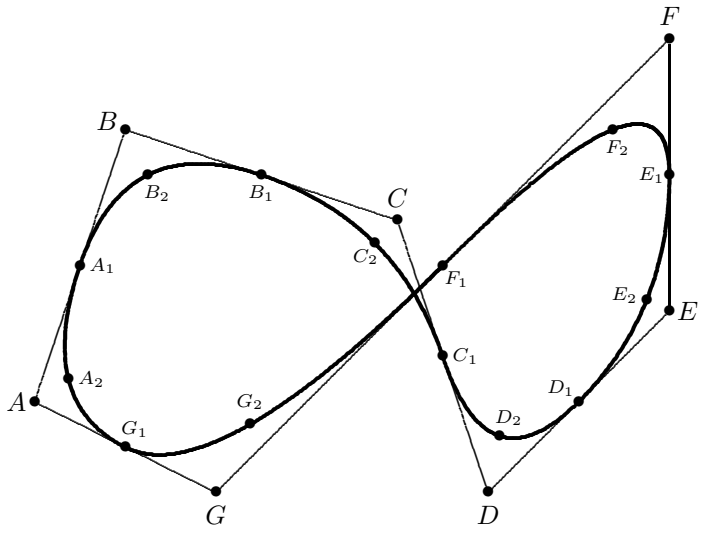
mathsPIC$_{Perl}$

version 1·0



Apostolos Syropoulos
Richard W. D. Nickalls

The single biggest problem we face is that of visualisation.

Richard P. Feynman (1918–1988)

The Mathematical Gazette (1996); 80, 267

mathsPIC$_{Perl}$ *version* 1·0

Apostolos Syropoulos,
Greek TEX Friends,
366, 28th October Street,
GR-671 00 Xanthi, Greece.
apostolo@ocean1.ee.duth.gr
`http://obelix.ee.duth.gr/~apostolo`

and

Richard W. D. Nickalls,
Department of Anaesthesia,
City Hospital,
Nottingham, UK.
dicknickalls@compuserve.com

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TEX Users Group: `http://www.tug.org/`
TEX Usenet group: `comp.text.tex`

TUGboat: `http://www.tug.org/TUGboat/`
The PracTEX Journal: `http://www.tug.org/pracjourn/`

CTAN (Comprehensive TEX Archive Network)
`ftp://ftp.tex.ac.uk/` `http://www.tex.ac.uk/`
`ftp://ftp.dante.de/` `http://www.dante.de/`

mathsPIC$_{Perl}$: CTAN: /graphics/pictex/mathspic/perl/

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Cover figure by
František Chvála

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Introduction

MathsPIC$_{Perl}$ is an open source Perl program for drawing mathematical diagrams and figures[1] (Nickalls, 1999a, 1999b; Syropoulos and Nickalls, 2000). MathsPIC is a 'filter' program which parses a plain text input-file (the mathsPIC file), and generates a plain text output-file containing commands for drawing a diagram. The current version of mathsPIC outputs TEX, LATEX and PICTEX commands in a `.tex` file which can then be run through TEX or LATEX in the usual way. It is anticipated that future versions will be able to generate output files in PostScript and SVG code.

Spaces and the comment % symbol are used in the same way as TEX, although unlike TEX, mathsPIC commands are *not* case-sensitive. PICTEX, TEX and LATEX commands can all be freely used in the mathsPIC file. MathsPIC also returns various parameter values in the output-file, e.g. angles, distances between points, center and radius of inscribed and exscribed circles, areas of triangles etc., since such values can be useful when making adjustments to a diagram.

The original motivation for mathsPIC arose from the need for an easy-to-use filter program for PICTEX. The advantage of PICTEX is that it is an extremely versatile system for drawing figures, and offers the convenience of having the graphics code within the TEX document itself (e.g. printer-independence). However, a significant disadvantage of PICTEX is that it does require you to specify the coordinates of all the points. Consequently, this can make PICTEX extremely awkward to use with complicated diagrams, particularly if several coordinates have to be re-calculated manually each time the diagram is adjusted. For example, suppose it is necessary to draw a triangle ABC with AB 5 cm, AC 3 cm, and included angle BAC 40 degrees, together with its incircle. One such triangle is shown in

[1] mathsPIC was first presented (MS-DOS version) at the EuroTEX'99 conference in Heidelberg, Germany. The Perl version first was first uploaded to CTAN in 2005. The mathsPIC$_{Perl}$ program is written in Perl 5.8.2 built for i86pc-Solaris. MathsPIC$_{Perl}$ can be freely downloaded from CTAN (http://www.tex.ac.uk/tex-archive/graphics/pictex/mathspic/perl/)

Figure 1.1 and the PICTEX commands for drawing it are as follows (point A is at the origin (0,0) and the units are in cm).

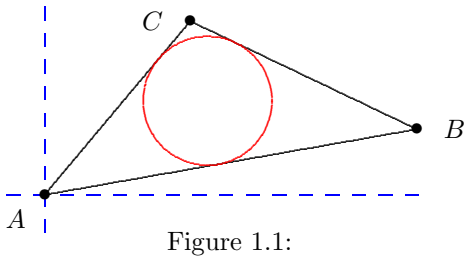


Figure 1.1:

```
\put {$\bullet$} at  0  0                 % point A
\put {$\bullet$} at  4.924039   0.8682409 % point B
\put {$\bullet$} at  1.928363   2.298133  % point C
\plot 0  0   4.924039  0.8682409    1.928363  2.298133   0  0 /
\circulararc 360 degrees from 3.0086 1.2452 center at 2.1568 1.2452
\put {$A$} at -0.5  0
\put {$B$} at  5.424039  .8682409
\put {$C$} at  1.428363  2.298133
```

Although point A can be placed at the origin for convenience it is then necessary to resort to geometry and a calculator to determine points B and C, since AB, AC, and the included angle are defined (see above). It is then necessary to recall the coordinates of all the points in order to write the `\plot` command. Finally, the `\circulararc` command requires even more geometry and calculation to figure out the radius of the incircle, the coordinates of its center, and the coordinates of the starting point of the arc-drawing routine. Furthermore, if the initial diagram is not a suitable shape or size, the calculator has to be used again for any adjustments. In practice, therefore, PICTEX requires a certain amount of planning and calculation for all but the simplest of diagrams.

MathsPIC overcomes all these difficulties by providing an environment for manipulating named points and variables, which has the effect of making even very complicated mathematical diagrams easy to create. For example, the equivalent mathsPIC commands for drawing Figure 1.1 are as follows (the units are in cm as before).

```
point(A){0,0}                 % A is at origin
point(B){A,polar(5,10 deg)}   % B is 5 cm from A; AB slope 10 deg
point(C){A,polar(3,50 deg)}   % C is 3 cm from A; BAC = 40 deg
drawPoint(ABC)                % put $\bullet$ at points A B C
```

```
drawline(ABCA)
drawIncircle(ABC)
var d = 0.5                          % d = 0.5 cm
text($A$){A, polar(-d,-140 deg)} % label for A
text($B$){B, shift(d,0)}         % label for B
text($C$){C, shift(-d,0)}        % label for C
```

MathsPIC facilitates the drawing of PICTEX diagrams because not only does it allow points to be defined in terms of other points (relative addressing), but it also allows the use of scalar variables which can be manipulated mathematically. Consequently, diagrams can be constructed in an intuitive way, much as one might with a compass and ruler; for example, constructing a point at a certain position in order to allow some other point to be constructed, perhaps to draw a line to. In other words, mathsPIC offers the freedom to create 'hidden' points having a sort of scaffolding function. In particular, this facility allows diagrams to be constructed in such a way that they remain functionally connected even when points are moved.

MathsPIC$_{Perl}$ offers a number of other useful facilities. Not only can files can be input recursively (using the `inputfile` command), but there is also a do–loop facility, and macros can be defined. In fact two sorts of macros can be used in the mathsPIC file, namely (a) special mathsPIC macros and (b) the familiar TeX macros. Macros can also be stored in a library file (an ordinary ASCII text file) and input as and when necessary. Furthermore, the standard LATEX packages can of course be used; e.g. the Color package and the Rotation package.

A powerful feature of mathsPIC$_{Perl}$ is its facility for accessing the Perl command-line. This allows users to write their own dedicated Perl programs for writing configurable chunks of mathsPIC code on-the-fly to files which are then input to draw either elements of a diagram or even complete diagrams (see Section 7.9). The ability to use Perl programs in this way is equivalent to having a powerful subroutine facility. It follows, therefore, that users can create their own libraries of useful Perl programs.

Finally, note that mathsPIC can also be viewed as a handy tool for exploring geometry since its `show` commands return the values of various parameters; for example, angles, the distance between points, and areas of triangles.

Full mathsPIC$_{Perl}$ file for Figure 1.1

The complete mathsPIC$_{Perl}$ file for drawing Figure 1.1 is as follows.

```
%% mpicpm01-1.m
\documentclass[a4paper]{article}
\usepackage{mathspic,color}
\begin{document}
\beginpicture
```

```
\normalcolor
\setdashes
\color{blue}%
paper{units(1cm) xrange(-0.5,5), yrange(-0.5,2.5) axes(XY)}
\setsolid
point(A){0,0}
point(B){A, polar(5, 10 deg)}
point(C){A, polar(3, 50 deg)}
\color{black}%
drawpoint(ABC)
drawLine(ABCA)
\color{red}%
drawIncircle(ABC)
\color{black}%
var d = 0.5
text($A$){A, polar(d,-140 deg)}
text($B$){B, shift(d,0)}
text($C$){C, shift(-d,0)}
\normalcolor
\endpicture
\end{document}
```

2

Installing mathsPIC

MathsPIC is a Perl program and will therefore run on any platform on which Perl is installed. Apart from minor differences regarding filename conventions, commands for creating, editing and deleting ASCII files and so on, the practicalities of running and using mathsPIC will be essentially the same whichever platform is being used.

The authors have developed mathsPIC on a Solaris x86 box and with GNU Linux, and consequently some of the code in this manual may reflect this perspective. For example, the following mathsPIC command to delete the file `temp.txt`

```
system("rm temp.txt")
```

uses the Unix 'remove' command `rm`. Clearly this particular command will differ between platforms but we assume that users will be familiar with their own local system commands. Non-Unix[1] users should read the Appendix in which we address installing Perl on a MS-Windows platform. The authors welcome any relevant platform-related information so we can include it in updates to this manual.

Current version

The latest version of mathsPIC can be downloaded from the following directory in CTAN.

```
CTAN: /tex-archive/graphics/pictex/mathspic/perl/
```

List of files

```
readme.txt          % this file
mathspic.pl         % mathsPIC program (perl)
```

[1]The term "Unix" here is used as a synonym for both Unix systems (e.g., Solaris, TrueUnix) and Unix-like systems (e.g., Linux, FreeBSD).

```
mathspic.sty          % style option
mathspic.1            % unix/Linux manpage file
HELP.TXT              % text version of the Unix manpage
mathspic.sh           % an example BASH file for running the program
MATHSPIC.BAT          % an example batch file (MS-Windows)
mathsPICa4.pdf        % manual (PDF) in A4 size
mathsPICa4.ps         % manual (PostScript) in A4 size
mathsPICa5.pdf        % manual (PDF) in A5 size
mathsPICa5.ps         % manual (PostScript) in A5 size
drawcube.pl           % perl program described in the manual
drawcurvedarrow.pl    % perl program described in the manual
grabtexdata.tex       % tex file (see manual) for accessing tex data
mathspic.lib          % example library file of macros
sourcecode.pdf/.html  % perl source code
sourcecode.nw         % perl source code (noweb)
figures.tgz           % compressed file of all figure files in manual
```

2.1 Unix/Linux

Place the files as follows (and then update your system's file index so it can locate the new files).

- Unix man page (`mathspic.1`)

  This file should be placed in the directory where the man pages of your TEX installation reside. This is either (a) with the distribution `man1` pages (typically: `/usr/share/man/man1/`) or (b) with other 'local' man pages (possibly: `/usr/local/TeX/man/man1/`).

- LATEX package (`mathspic.sty`)

  This file needs to be placed either (a) with the distribution style options (typically: `/usr/share/texmf/tex/latex/base/`) or (b) with other 'local' miscellaneous packages (possibly: `/usr/local/TeX/share/texmf/tex/latex/misc`).

- The mathsPIC program (`mathspic.pl`)

  This file should be placed where your shell can find it (typically in the directory `/usr/local/bin/`).

- The mathsPIC BASH script (`mathspic.sh`)

  This file should be placed where your shell can find it (typically in the directory `/usr/local/bin/`).

PICTEX

If you already have a recent TEX installation then PICTEX will be installed. However if for some reason PICTEX is not installed then locate the directory containing all the LATEX packages, and create a PICTEX subdirectory. Copy into this new directory all the files in the CTAN directory `CTAN:/tex-archive/graphics/pictex/addon/` (these are listed in Chapter 9).

Running mathsPIC

In Unix/Linux there are at least three ways of running a Perl program from the command-line, and these are described briefly below. The general command-line syntax is as follows.

$ perl [⟨*perl switches*⟩] mathspic.pl [⟨*mathspic switches*⟩] ⟨*inputfile*⟩ [-o ⟨*outputfile*⟩]

By default mathsPIC writes the output to a file having the same filename as the input file, but with the filename extension `.mt` (see also Chapter 3). If you forget to type an input filename, then mathsPIC writes the following line to the screen.

```
mathspic version 1.00 Feb 14, 2005
Usage: mathspic [-h] [-b] [-c] [-o <outfile>] <infile>
```

a—Invoking the Perl interpreter

The minimum required to process the script file `infile` is

```
perl mathspic.pl infile
```

b—Making the mathspic.pl program executable

This is the the most efficient, and is therefore the recommended method. Rename the mathsPIC program (`mathspic.pl`) to `mathspic`; make it executable; and then copy it to where the shell can find it (typically `/usr/local/bin`). Now mathsPIC can be run from any directory by typing

```
mathspic  infile
```

c—Using a batch file

mathsPIC can also be run via a batch file, and an example BASH file (`mathspic.sh` is included in the package. Rename the BASH file to `mathspic`; make it executable; and then copy it to where the shell can find it (typically `/usr/local/bin`). Now mathsPIC can be run from any directory by typing

```
mathspic  infile
```

2.2 MS-Windows

Locate the directory containing all the LaTeX packages, and create a mathspic subdirectory. Copy into this new directory the file `mathspic.sty`.

Perl

Locate the directory containing all the Perl `.pl` programs (typically the directory `c:\perl\bin\` for the ActivePerl implementation of Perl) and copy into this directory the file `mathspic.pl` (see Appendix for details regarding installing Perl on MS-Windows platforms).

PiCTeX

If you have a recent TeX installation then PiCTeX will be installed. However if for some reason PiCTeX is not installed then locate the directory containing all the LaTeX packages, and create a PiCTeX subdirectory. Copy into this new directory all the files in the CTAN directory `CTAN:/tex-archive/graphics/pictex/addon/` (these are listed in Chapter 9).

Running mathsPIC

In MS-Windows there are two main ways of running mathsPIC, and these are summarised below. The general command-line syntax is as follows.

$ perl [⟨*perl switches*⟩] mathspic.pl [⟨*mathspic switches*⟩] ⟨*inputfile*⟩ [-o ⟨*outputfile*⟩]

By default mathsPIC writes the output to a file having the same filename as the input file, but with the filename extension `.mt` (see also Chapter 3). If you forget to type an input filename, then mathsPIC writes the following line to the screen.

```
mathspic version 1.00 Feb 14, 2005
Usage: mathspic [-h] [-b] [-c] [-o <outfile>] <infile>
```

a—**Invoking the Perl interpreter**

Open a DOS box, and invoke the Perl interpreter at the command-line prompt. For example, the minimum required to process the script file `infile` is

```
perl mathspic.pl  infile
```

Note that there are advantages in accessing the DOS command prompt via the `programs` menu (i.e. `programs/accessories/command-prompt`) as this route allows you to customise the colors and fonts, and also enables the useful DOSKEY utility.

b—Using a batch file

mathsPIC can also be run via a batch file. Since this is probably the most convenient method on a MS-Windows platform, an example .BAT file (`MATHSPIC.BAT`) is included in the package. Place the .BAT file in a suitable directory in the PATH. Now mathsPIC can be run from any directory by typing

```
mathspic  infile
```

2.3 Files

The MathsPIC command-line actions one input file and (optionally) one output filename (prefixed by the `-o` switch). Each command or switch must be separated by at least one space, as in the following example.

```
$ mathspic inputfile -o outputfile
```

If the `outputfile` is not specified then mathsPIC will create an output-file having the same filename as the `inputfile` but with the filename extension `.mt`. For example, if you want an input-file called `myinfile.abc` to generate an output-file called `myoutfile.xyz` then use the following command.

```
$ mathspic myinfile.abc -o myoutfile.xyz
```

mathsPIC also writes to a log file (the `.mlg` file). This has the same filename as the input filename.

In practice, the authors find it convenient to use the filename extension `.m` for mathsPIC files (input-files), as this helps distinguish them from the other files which are generated. Thus `.m` files are mathsPIC files (input-files), while `.mt` files are output TEX files containing PICTEX commands ready for TEXing, and `.mlg` files are mathsPIC log-files.

2.4 Switches

There are four switches (`-h -c -b -o`) which are case-sensitive. If more than one switch is used then they must be separated by at least one space. The switches are as follows.

-h Help—gives basic information

-b Beep—a beep is sounded if mathsPIC detects an error. If an audible beep does not sound in the presence of an error, then check the PC configuration to see if the PC beep is disabled.

-c Disables comment line generation in the output file.

-o Output file name

2.5 Removing comment lines

Once a diagram has been finalised, it is sometimes convenient to remove all the various commented lines from the final output-file, particularly if the file is a large one. This can be easily done using the `-c` switch, which will stop mathsPIC writing any comments to the output `.mt` file. For example, the following command invokes disables the writing of comment lines to the output `.mt` file.

```
mathspic -c inputfile
```

2.6 Online help

In Unix systems typing the command

```
man  mathspic
```

will open the manpage help file. If this fails, then check that the man page file (`mathspic.1`) has been placed in the correct directory. MS-DOS users can load the equivalent file HELP.TXT into their text editor.

2.7 The mathsPIC package

Since some PICTEX commands are redefined by mathsPIC it is always necessary to use the mathsPIC package by using the following command in the preamble of the LATEX document.

```
\usepackage{mathspic}
```

2.8 Error-messages

A certain amount of syntax checking is performed by mathsPIC, and error-messages are written to the output-file (`.mt` file) and also to the log-file (`.mlg` file).

A line containing an error is prefixed by `%% ***`; the associated error-message appears on the next line and is prefixed by dots (`%% ...`). If the `-b` switch is used then a beep is sounded if an error occurs during processing.

Runtime errors most commonly arise when an argument has been omitted, or division by zero has been attempted. Syntax errors arise when mathsPIC commands are written incorrectly (e.g. missing bracket, or a command being spelled

incorrectly). A typical example with respect to a `draw` command would be if a point has not been previously defined resulting in a 'point-name' error as follows.

```
%% drawline(AB)
%% *** Line 15: drawline(AB
%% ***                    )
%% ... Error: Undefined point  B
```

Some other examples of error-messages are as follows.

```
%% drawline()
%% *** Line 22: drawline(
%% ***                   )
%% ... Error: Wrong number of points
```

```
%% *** Line 49:
%% ***          pointt(K2){4,6}
%% ... Error: command not recognized
```

```
%% drawline(PQ)
%% *** Line 52 : drawline(PQ
%% ***                     )
%% ... Error: points P and Q are the same
```

Since an error usually has an effect on the processing of later commands in the script (mathsPIC file), a single error can result in a cascade of error messages. In other words, the number of error messages is not a good guide to the number of errors—there may only be one small typo causing all the error messages.

2.9 Log-file

mathsPIC outputs a log-file (`.mlg` file) which contains details of all errors, relevant line numbers and file names (e.g. <myfile.m>). The format was designed to match that of a standard TEX log-file in order to be compatible with commonly used error-checking utilities.

For example, in the following code the errors in the 2nd, 3rd and 4th lines (combined with the fact that point B has not been defined) generate the error messages found in the associated log file (`.mlg` file) below.

```
point(A){5,5}
var d=
drawline(AB
var j=
text($B$){B, shift(d,0)}
```

The log file (`.mlg` file) shows the following:

```
2005/02/15    14:02:28
mathsPIC (Perl version 1.00 Feb 14, 2005)
Copyright (c) 2004 A Syropoulos & RWD Nickalls
Input file  = test.m
Output file = test.mt
Log file    = test.mlg
----
Line 14: var d=
                ***Error: Unexpected token
Line 15: drawline(AB
                     ***Error: Undefined point B
Line 15: drawline(AB
                     ***Error: Wrong number of points
Line 15: drawline(AB
                     ***Error: Missing ) after arguments of
Line 16: var j=
                ***Error: Unexpected token
Line 17: text($B$){B
                   , shift(d,0)}
***Error: undefined point/var
```

3

The mathsPIC script file

All commands for generating a diagram (the script) are written to a plain ASCII file, known as the mathsPIC file, using a text editor in the usual way. This file is then processed by the mathsPIC program (`mathspic.pl`) as described in the previous chapter. While the mathsPIC file can of course have any filename and extension, in this manual all mathsPIC files have the filename extension of `.m` in order to distinguish them from the various derived files.

We distinguish three types of command, namely (a) mathsPIC commands, (b) PICTEX commands, and (c) TEX or LATEX commands. All these commands are detailed in the subsequent three chapters. Since mathsPIC currently only outputs a TEX file then the mathsPIC file can also contain appropriate PICTEX, TEX and LATEX commands[1].

3.1 mathsPIC style option

Since some PICTEX commands are redefined by mathsPIC it is necessary to use the mathsPIC style option (`mathspic.sty`) by using the command

```
\usepackage{mathspic}
```

The file `mathspic.sty` inputs a number of PICTEX files and also redefines some commands. The full listing of `mathspic.sty` is as follows.

```
%% This is file ‘mathspic.sty’,
%% February 10, 2005
%% (c) copyright 2005 RWD Nickalls & A Syropoulos
\wlog{Package ‘mathspic’ A Syropoulo & RWD Nickalls (08/08/2004)}%
```

[1] However, it is anticipated that future versions of mathsPIC will be able output PostScript and SVG files, in which case only mathsPIC commands will be allowed.

```
\typeout{Loading mathsPIC package (c) RWD Nickalls & A Syropoulos
   08/08/2004}%
\ProvidesFile{mathspic.sty}%
   [2004/08/08 v1.0 Package `mathspic.sty']%
\def\fileversion{1.0}
\def\filedate{2004/08/08}
\ifx\fiverm\undefined
        \newfont\fiverm{cmr5}
\fi
%%----------mathsPIC logos---------------------
\newcommand{\mathsPIC}{\textsf{mathsPIC}}
\newcommand{\MathsPIC}{\textsf{MathsPIC}}
\newcommand{\mathsPICp}{\textsf{mathsPIC}%
      \kern-0.08em\raisebox{-0.15em}{\textit{\tiny P}}}
\newcommand{\MathsPICp}{\textsf{MathsPIC}%
      \kern-0.08em\raisebox{-0.15em}{\textit{\tiny P}}}
\newcommand{\mathsPICperl}{\textsf{mathsPIC}%
      \kern-0.08em\raisebox{-0.15em}{\textit{\tiny Perl}}}
\newcommand{\MathsPICperl}{\textsf{MathsPIC}%
      \kern-0.08em\raisebox{-0.15em}{\textit{\tiny Perl}}}
%---------redefine \linethickness---------
\let\Linethickness\linethickness%
%%---------load PiCTeX files for LaTeX---------
\input prepictex
\input pictexwd
\input postpictex
\endinput
%% End of file `mathspic.sty'.
```

Note that the line `\let\Linethickness\linethickness%` is placed before inputting `pictexwd.tex` since both PiCTeX and the LaTeX picture environment use the same command name, i.e. `\linethickness`.

3.2 Headers and footers

It is particularly useful to include in the mathsPIC file any TeX or LaTeX headers and footers which would otherwise have to be added manually to the output-file before LaTeXing the file. For example, a typical format which allows for both LaTeX 2_ε and pdfLaTeX processing[2], might be as follows (this works nicely with LaTeX 2_ε, `dvips`, `ps2pdf`, and pdfLaTeX in Linux). Note that it is important to load the `color` package (see Section 6.2) *after* `mathspic`.

[2]The `\ifx...\else...\fi` sequence is from `science.sty` (available on CTAN).

```
\documentclass[a4paper]{article}
\usepackage{mathspic}
\ifx\pdfoutput\undefined
    \usepackage[dvips]{color,graphicx}
\else
    \usepackage[pdftex]{color,graphicx}
    \usepackage{times,mathptmx}
    \pdfpagewidth=\paperwidth
    \pdfpageheight=\paperheight
\fi
\begin{document}

\beginpicture
....
....
\endpicture

\end{document}
```

For users of plain TEX a typical format might be as follows. Note the need in this case to include the line redefining the `\linethickness` command (in `mathspic.sty`)

```
\input latexpic.tex
\let\Linethickness\linethickness%  %% redefinition for mathsPIC
\input pictexwd.tex
\font\tiny=cmr5      %% used for drawing lines
\font\large=cmr12    %% used for drawing thicklines
\beginpicture
....
....
\endpicture
\bye
```

If it is necessary (or just simply convenient) to extend a TEX or LATEX command across several lines, then each additional line must be protected within the mathsPIC file using a leading `\␣...` sequence unless a line actually starts with a TEX command. A typical example is the following macro (used in Figure 7.6) which defines a 'display' maths formula. The macro is split across several lines, as follows.

```
\newcommand{\formula}{%
\     $\displaystyle \sum_{p\ge0} \Delta_{jp} z^{(p+1)}$%
\     }%
text(\formula){B1}
```

Note that when using TEX or LATEX commands *within* the PICTEX picture environment, it is very important to include the comment `%` symbol at the end of such lines, to prevent PICTEX accumulating additional `<space>` characters from the ends of non-PICTEX commands, since otherwise PICTEX incorporates such space characters into the horizontal distance used for representing x-coordinates, with the effect that all subsequent picture elements may be displaced slightly to the right.

3.3 Commands

The idea underlying the mathsPIC file (input-file) is that it should be able to contain everything required to generate the proposed figure (i.e. all mathsPIC commands, comments, TEX and LATEX commands including headers and footers, PICTEX commands, as well as lines to be copied verbatim) so that the output-file can be immediately TEXed to generate the graphic. Some general points relating to the mathsPIC file are as follows.

- mathsPIC commands are *not* prefixed by backslashes. They are therefore easily distinguished from TEX, LATEX and PICTEX commands.
- Each mathsPIC command must be on a separate line. This is because mathsPIC frequently adds data to the end of a line in the output-file (see below).
- As with TEX, spaces can be used to enhance readability. This is particularly useful when writing lists of points. For example the command `drawpoint(PQR1R2)` can be made easier to read by writing it as `drawpoint(P Q R1 R2)`.
- mathsPIC commands and point-names are *not* case sensitive. This allows the user to customise the commands to enhance readability. Thus the command `drawpoint` can be written as `drawPoint` or `DrawPoint` etc.
- Delimiters have a hierarchical structure as follows:
  Curved brackets contain the primary argument; e.g. `drawline(AB)`
  Braces contain required supporting arguments; e.g. `point(A){5,6}`
  Square brackets contain optional arguments;
  e.g. `point(D){midpoint(PQ)}[symbol=$\odot$]`
- Logically distinct groups within brackets must be separated by commas.
  e.g. `point(B2){A,polar(3,40deg)}[symbol=$\odot$, radius=2]`
- Comments are prefixed by the % symbol in the usual way. Lines having a leading % symbol are copied verbatim through to the output-file.

- Lines having a leading backslash command (i.e. where there is *no* inter-word space immediately following the backslash, e.g. `\setdashes` or `\begin{document}`) are copied verbatim through to the output-file. Consequently, all TEX, LATEX and PICTEX commands can be used in the normal way providing the command is restricted to a single line. However, if such commands do run on to the subsequent lines, these lines will need to be prevented from being processed as mathsPIC commands, by prefixing them with `\␣` (see below)—unless of course they also start with a backslash command.

- Lines having a leading `\␣` (i.e. where the `\` is followed immediately by one or more inter-word spaces `␣` e.g. `\  25.3  16.8`) are copied verbatim through to the output-file *without* the leading backslash.

- Data-files containing mathsPIC commands can be input using the `inputfile()` command. Files can also be input *verbatim* using the `inputfile*()` command (useful for inputting files containing only PICTEX commands and/or coordinate data; for example, a list of data points as part of a PICTEX `\plot` command).

- The `system()` command gives access to the command-line.

3.4 Macros

mathsPIC currently allows macros consisting of a single command, either with or without parameters. (see Section 4.2). MathsPIC macros are subject to a number of rules as follows:-

- Macros are created using the `%def` command, and destroyed using the `%undef` command.

- When a macro is used in a command then the macro-name *must* have a `&` prefix (to distinguish it as a macro).

- Macro names are case-sensitive (unlike all other mathsPIC command-names which are *not* case sensitive)

- Macros must evaluate to a 'numerical expression' (see Section 4.3) (i.e. not to strings).

It is strongly recommended that a `%` is placed at the end of the macro definition (as is done with LATEX commands) in order to prevent PICTEX from including additional horizontal whitespace.

No parameters

Examples of macros which do not take any parameters are the following two commands which create the two macros `fancydashes` and `plaindashes`.

```
%def fancydashes() dasharray(1pt,2pt,3pt,4pt)%
%def plaindashes() dasharray(1pt,1pt)%
```

Note that in the macro-definition command the curved bracket (the parameter bracket) at the end of the word `fancydashes()` remains empty if there are no parameters. This pair of curved brackets marks the end of the command-name and the beginning of the macro definition (i.e. some mathsPIC commands).

To use the macro (as a command) it is necessary to use the & prefix. The `()` brackets are only necessary if the macro takes parameter(s), as follows.

```
...
&fancydashes
drawline(AB)
&plaindashes
drawline(PQ)
...
```

The macro `fancydashes()` is deleted using the following command.

```
%undef fancydashes()
```

Single parameter

An example of a macro taking a single parameter is as follows:

```
%def thick(t) linethickness(t pt)%
```

Here the command `&thick(2)` is equivalent to the command `linethickness(2pt)`.

Multiple parameters

An example of a macro taking multiple parameters is as follows:

```
%def mypoint(P,x,y) point(P){x,y}%
```

Now, if we write the command `&mypoint(Q7,3,5)` this is processed to generate the point $Q7$ as shown in the following comment in the output file.

```
%% point(Q7){3,5}  Q7 = (3, 5)
```

It is anticipated that the macro facility will be upgraded in subsequent versions of mathsPIC to allow a multi-line macros facility.

3.4.1 Macro library

It may be useful to create a file for storing frequently used mathsPIC macros, say, the text file `mathspic.lib` (see also Section 4.1). For example, we could put together the various macros described so far into one file as follows:

```
%%--- mathspic.lib---
%def fancydashes() dasharray(1pt,2pt,3pt,4pt)%
%def plaindashes() dasharray(1pt,1pt)%
%def log10(a) log(a)/log(10)%
%def loge(a) log(a)%
%def mod(a) rem(a)%
%def d2r() _pi_/180%
%def r2d() 180/_pi_%
%%--- end of library ---
```

and input the file at the start (for processing by mathsPIC) by placing the command `inputfile(mathspic.lib)` in the mathsPIC file just after `\begin{document}`.

3.5 The plotting area

3.5.1 Axes

When drawing a new figure it is often useful to have a graduated ruled frame to guide placement of picture elements. This task is greatly simplified by using mathsPIC's one-line `paper` command, which has optional `axes` and `ticks` parameters[3]. The axes-codes used in the `axes()` option are `L` (Left), `R` (Right), `T` (Top), `B` (Bottom), `X` (X-axis), `Y` (Y-axis). For example, the following `paper` command generates a drawing area 5 cm × 5 cm with a ruled frame on four sides as shown in Figure 3.1a.

```
paper{units(1mm),xrange(0,50),yrange(0,50),axes(LRTB),ticks(10,10)}
```

This particular `paper` command is converted by mathsPIC into the following PICTEX code in the output-file (`.mt` file).

```
\setcoordinatesystem units <1mm,1mm>
\setplotarea x from  0 to  50 , y from  0 to  50
\axis left ticks numbered from  0 to  50 by 10 /
\axis right ticks numbered from  0 to  50 by 10 /
\axis top ticks numbered from  0 to  50 by 10 /
\axis bottom ticks numbered from  0 to  50 by 10 /
```

[3]Since PICTEX uses the name 'axis', mathsPIC recognises both spellings ('axis' and 'axes').

For graphs it is more usual for the axes to be centered on the origin $(0, 0)$, and this is provided for by the `XY` options. For example, Figure 3.1b was generated using the following `paper` command,

```
paper{units(1cm),xrange(-2,3),yrange(-2,3),axes(XY),ticks(1,1)}
```

which is converted by mathsPIC into the following PICTEX code in the output-file.

```
\setcoordinatesystem units <1cm, 1cm>
\setplotarea x from -2 to  3, y from -2 to  3
\axis left shiftedto x=0 ticks numbered from -2 to -1 by  1
      from  1 to  3 by  1  /
\axis bottom shiftedto y=0 ticks numbered from -2 to -1 by  1
      from  1 to  3 by  1  /
```

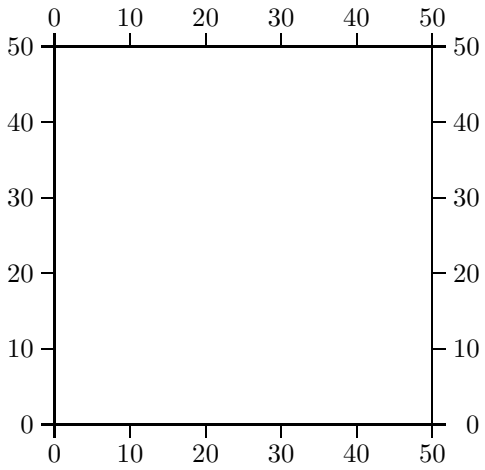
The tick-marks associated with an axis can be prevented by using a * after the axes-code (e.g. `axis(LBT*R*)` gives four axes but generates tick-marks only on the Left and Bottom axes). Note that any combination of axes-codes can be used. For example, the options ...`axes(LRTBX*Y*), ticks(10,10)` will generate a rectangular axes frame (with ticks) containing the XY axes (without ticks). The line-thickness of axes and tick-marks is controlled by the PICTEX `\linethickness` command.

Once the figure is finished, then the frame or axes can be easily adjusted or even removed. The figure can also be scaled in size simply by altering the `units` parameters. For example, the option `units(3cm,1cm)` will generate an X-axis having three times the scale as the Y-axis (see Figure 7.11). If complicated or more demanding axis configurations are required, then the PICTEX Manual (see Section 9.5) will need to be consulted. See also Section 8 for details on positioning figures within LATEX documents.

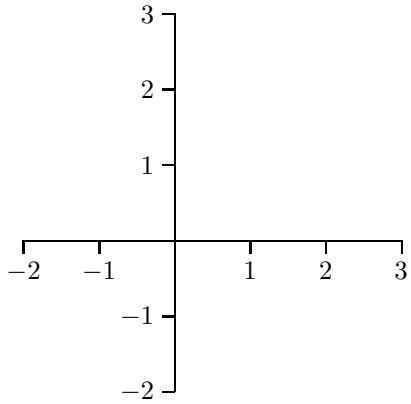
3.5.2 Second y-axis

Sometimes a second (different) y-axis is needed (on the right). An example of how this can be achieved is as follows.

```
paper{units(1cm),xrange(0,6),yrange(72,77),axes(LBT*),ticks(1,1)}
\axis right
\    label {\lines {weight\cr  (lbs)\cr {\ }\cr {\ } }}
\    ticks withvalues  0   1   2   3   4   5  /
\                 at  72  73  74  75  76  77 /  /
```



a. Using `...axes(LRTB)`



b. Using `...axes(XY)`

Figure 3.1:

Table 3.1: Conversion factors for the units used by LaTeX.
From: Beccari 1991 (with permission).

	mm	cm	pt	bp	pc	in	dd	cc	sp
1 mm	1,000	0,100	2,845	2,835	0,2371	0,03937	2,659	0,2216	186 467,98
1 cm	10,00	1,000	28,45	28,35	2,371	0,3937	26,59	2,216	1 864 679,8
1 pt	0,3515	0,03515	1,000	0,9963	0,08333	0,01384	0,9346	0,07788	65 536
1 bp	0,3528	0,03528	1,004	1,000	0,08365	0,01389	0,9381	0,07817	65 781,76
1 pc	4,218	0,4218	12,00	11,96	1,000	0,1660	11,21	0,9346	786 432
1 in	25,40	2,540	72,27	72,00	6,023	1,000	67,54	5,628	4 736 286,7
1 dd	0,3760	0,03760	1,070	1,066	0,08917	0,01481	1,000	0,08333	70 124,086
1 cc	4,513	0,4513	12,84	12,79	1,070	0,1777	12,00	1,000	841 489,04

3.5.3 Units

In addition to the usual units `mm`, `cm`, and `pt`, PiCTeX accommodates all the other units used by TeX (see Knuth (1990), Chapter 10), and also uses the same two-letter codes, namely `pc` (pica), `in` (inch), `bp` (big point), `dd` (didot), `cc` (cicero), `sp` (scaled point). The available units thus embrace the Metric system (mm, cm), the Didot system (didot, cicero), and the UK system (point, big point, pica, inch)—see Table A.3.

Note that if only *one* unit is indicated in the `units` option, then mathsPIC uses the *same* unit for both the x and y axes. Thus the option `units(1mm)` in the `paper` command is translated by mathsPIC into the following PiCTeX command in the output-file. Note that it is very important to include a numeric value with the units, or alternatively a variable with the units.

```
\setcoordinatesystem units <1mm,1mm>
```

If different scales are required (most commonly when drawing curves and equations) then both need to be specified in the mathsPIC `units` option. For example, if units of 1 cm and 2 mm are required for the x and y axes respectively, then this will be implemented by the mathsPIC command `units(1cm,2mm)`. However, when the x and y scales *are* different strange effects can occasionally occur, particularly if drawing ellipses or circular arcs. In view of this mathsPIC writes a warning note to the output-file and log-file when different units are being used. The drawing of complete circles will only be affected if the x-units is changed, since the mathsPIC starts the arc at a location having the same y-coordinate as that of the center. In general users are therefore recommended to avoid using different x and y units in the `paper` command if at all possible.

Note that variables can also be used to control the x and y units, as shown in the following example, where the radius (`r`) and the distance (`s`) between the label A and its point-location are fixed irrespective of scaling (i.e. with changes in the value of `u`) by dividing the relevant variables by the scaling value `u`.

```
var u = 1.5   %% units
paper{units(u mm), xrange(0,100), yrange(0,100)}
...
var r = 2/u, s = 4/u
point(A){30,20}[symbol=circle(r)]
text($A$){A, shift(-s,s)}
```

3.5.4 Tick-marks

It is recommended that integers are used with the `ticks` option, since PiCTeX sometimes gives unpredictable results if decimals are used with the `xrange` and `yrange` options in conjunction with the `ticks` option. In general PiCTeX gives more pleasing axes if integers are used throughout the `paper` command.

3.6 Points

Each point is associated with a point-name which is defined using the `point` command. For example, the following command allocates the point-name A to the coordinates (5,7).

```
point(A){5,7}
```

Once defined, points can be referred to by name. Consequently, points can be defined in relation to other points or lines simply by using point-names, as shown by the following commands.

```
point(C){midpoint(AB)}
point(E){intersection(AB,CD)}
point(J){Q, rotate(P, 25 deg)}  %% J = Q rotated about P by 25 deg
```

Points are interpreted according to their grouping and context. Thus two points represent either a line or its Pythagorean length. For example, the command `drawCircle(P,AB)` means draw a circle, center P with radius equal to the length of the line AB. A group of three points represents either a triangle, an angle, or two contiguous line-segments, depending on the circumstances.

3.6.1 Point-name

A point-name *must* begin with a *single* letter, and may have up to a *maximum* of three following digits. The following are valid point-names: $A, B, C3, d185$. Since mathsPIC is not case sensitive the points $d45$ and $D45$ are regarded as being the same point.

Sometimes it is necessary to re-allocate new coordinates to an existing point-name, in which case the `point*` command is used. This is often used during recursive operations whereby the mathsPIC file inputs another file (using the `inputfile` command) containing commands which alter the value of pre-existing points. For example, the following command increments the x-coordinate of point A by 5 units.

```
point*(A){xcoord(A)+5, ycoord(A)}
point(P){Q}    %% make P the same as Q
```

3.6.2 Point-symbol

The default point-symbol is • (`$\bullet$`). However, mathsPIC allows the optional use of any TEX character or string of characters to represent a particular point, by defining it in a following square bracket. For example, the point $A(5,10)$ can be represented by the △ symbol by defining it as follows.

```
point(A){5,10}[symbol=$\triangle$]
```

Other examples using the `circle()` and `square()` options are:

```
point(B){A, shift(2,6)}[symbol=circle(2)]
point(C){A, polar(3,26}[symbol=square(3)]
```

The argument for the circle is the radius, while the argument for the square is the side length.

The default point-symbol can also be changed to a circle, square, or any TEX character or string of characters by using the mathsPIC `PointSymbol` command. Note that the `PointSymbol` command only influences subsequent `point` commands. For example, the character ⊙ (`$\odot$`) can be made the new global point-symbol by using the command `PointSymbol($\odot$)`. The original default point-symbol (•) can be reinstituted (reset) using the command `PointSymbol(default)`. The point-symbol is drawn at the point-location using the `drawPoint` command; for example, `drawPoint(A)`, or `drawPoint(ABCD)`.

Since most TEX characters and symbols are typeset asymmetrically in relation to the baseline, they will not, in general, be positioned symmetrically over a point-location. Most characters are therefore not ideal for use as point-symbols, as they generally require some slight vertical adjustment in order to position them symmetrically. In view of this Table A.2 lists those TEX characters which *are* particularly suitable, since they are automatically positioned by TEX symmetrically with respect to a point-location (for example the ⊙ character `$\odot$`), and are therefore ideal for use in this setting.

3.6.3 Line-free zone

When lines are drawn to a point, the line will (unless otherwise instructed) extend to the point-location. However, this can be prevented by allocating an optional

circular line-free zone to a point by specifying the line-free radius in a following square bracket. For example, lines to a $\triangle$ symbol at point A can be prevented from being drawn through the triangle to its center by allocating a 5 unit line-free zone to the point, as follows.

```
point(A){3,10}[symbol=$\triangle$,radius=5]
```

If only the line-free radius is to be specified for the default point-symbol then we can use the command `pointsymbol(default,5)`. To change the line-free radius of an *existing* point then use the following command.

```
point*(A){A}[radius=10]
```

which is equivalent to

```
point*(A){xcoord(A), ycoord(A)}[radius=10]
```

Table 3.2: Useful point-symbols and their radii for 10–12pt fonts.

symbol		radius mm	symbol package
		10pt / 11pt / 12pt	
`$\circ$`	∘	0.70 / 0.75 / 0.80	standard
`$\odot$`	⊙	1.20 / 1.35 / 1.50	standard
`$\oplus$`	⊕	1.20 / 1.35 / 1.50	standard
`$\ominus$`	⊖	1.20 / 1.35 / 1.50	standard
`$\oslash$`	⊘	1.20 / 1.35 / 1.50	standard
`$\otimes$`	⊗	1.20 / 1.35 / 1.50	standard
`$\bigcirc$`	◯	1.70 / 1.85 / 2.05	standard
`$\bigodot$`	⨀	1.70 / 1.85 / 2.05	standard
`$\bigoplus$`	⨁	1.70 / 1.85 / 2.05	standard
`$\bigotimes$`	⨂	1.70 / 1.85 / 2.05	standard
`$\star$`	⋆	—	standard
`$\triangle$`	△	—	standard
`$\square$`	□	—	amssymb.sty
`$\blacksquare$`	■	—	amssymb.sty
`$\lozenge$`	◊	—	amssymb.sty
`$\blacklozenge$`	⧫	—	amssymb.sty
`$\bigstar$`	★	—	amssymb.sty
`$\boxdot$`	⊡	—	amssymb.sty
`$\boxtimes$`	⊠	—	amssymb.sty
`$\boxminus$`	⊟	—	amssymb.sty
`$\boxplus$`	⊞	—	amssymb.sty
`$\divideontimes$`	⋇	—	amssymb.sty

Table A.2 gives a list of useful point-symbols which TEX places symmetrically over a point-location (note that `$\Box$` and `$\Diamond$` are not placed symmetrically over a point location, but `$\square$` and `$\lozenge$` are). Other useful symbols are available from the `textcomp` fonts[4] (see also the 'symbol list' compiled by Pakin which shows virtually all the available symbols[5]).

For example, the following commands will draw lines between points ABC, such that the lines just touch the edge of the ⊙ point-symbol (line-free radius 1.2 mm; 10pt font).

```
pointSymbol($\odot$, 1.2)
point(A){1,1}
point(B){2,2}
point(C){1,3}
drawline(ABC)
```

It is often useful to adjust the line-free radius associated with a particular point before drawing lines or arrows to it, in order to optimise the distance between an object centered at the point and the line or arrow. For example, one can use the `point*` command to set a line-free radius of 2 units for a pre-existing point (P), as follows.

```
point*(P){P}[radius=2]
```

By way of illustration, this command is used in drawing Figure 3.2 where arrows are being drawn from various directions (B, S) to a text box centered on point P ⊙ (the code is shown below as `mpicpm03-2.m`). By setting the line-free radius (dashed circles) associated with point P before drawing each particular arrow, one can easily adjust and optimise the distance between the arrowhead and the text box. The arrowshape used here is the default shape which is defined as follows (see Section 7.3 for details).

```
arrowshape(2mm,30,40)
```

```
%% mpicpm03-2.m (Figure 3.2)
\usepackage{mathspic}
\beginpicture
paper{units(1cm),xrange(0,6),yrange(0,3),axes(LBT*R*),ticks(1,1)}
point(P){4,2}[symbol=$\odot$]
point(B){2,0.5}
point(S){1,2}
drawPoint(PBS)
```

[4] See Harold Harders' useful file (`textcomp.tex`) which shows the characters of the `textcomp` font together with their names. It can be found at `CTAN:/tex-archive/info/texcomp-info/`.

[5] `CTAN:/info/symbols/`

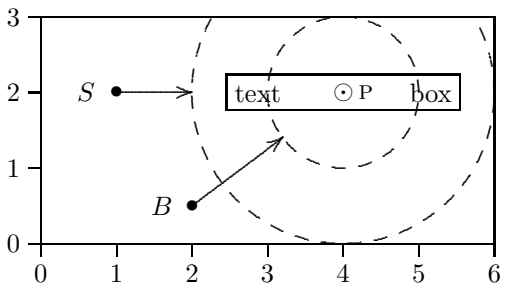


Figure 3.2:

```
\setdashes
\inboundscheckon        %% restrict circles to drawing area
drawcircle(P,1)
drawcircle(P,2)
\setsolid
%% change line-free radius of P to 1cm
point*(P){P}[radius=1]
drawArrow(BP)           %% draw arrow from B (below)
%% change line-free radius of P to 2cm
point*(P){P}[radius=2]
drawArrow(SP)           %% draw arrow from S (side)
text($S$){S, shift(-0.4,0)}
text($B$){B, shift(-0.4,0)}
text(\textsc{p}){P, shift(0.3,0)}
\newcommand{\textbox}{\fbox{text\hspace{17mm}box}}%
text(\textbox){P}
\endpicture
```

Of course, sometimes it is convenient just to draw the arrows a certain length from one point towards another point. For example, in order to draw an arrow 1 unit long from point A towards point B we could use the following two commands

```
point(Z){pointonline(AB,1)} % Z is point 1 unit from A towards B
drawArrow(AZ)
```

3.6.4 Order of points

The order of points in mathsPIC commands is sometimes significant. For example, the command `point(D){PointOnLine(AB,23)}` defines the point D as being 23 units *from A in the direction of B*.

3.7 Lines

mathsPIC draws lines using its `drawLine` and `drawThickline` commands. For example, a line from P_1 to P_2 is drawn with the command `drawLine(P1P2)`. If a line is to be drawn through several points (say, J_1, J_2, J_3, J_4, J_5) and can be drawn without 'lifting the pen', then this can be achieved using the single mathsPIC command `drawLine(J1J2J3J4J5)`. Several unconnected lines can also be drawn using one command by separating each line sequence with a comma; for example, `drawLine(J1J2,J3J4J5,J1J3)`.

A line can also be drawn a specified distance from one point towards (or away from) another point, using the following two-step approach. For example, the following commands draws a line a distance d units from point A *towards* point B.

```
point(Z){pointonline(AB,d)}
drawline(AZ)
```

Note that the order of the points AB and the sign of the distance `d` are important. For example, the following commands will draw a line a distance d units from point B *away from* point A.

```
point(Z){pointonline(BA,-d)}
drawline(BZ)
```

Since the PiCTeX `\putrule` command for drawing horizontal or vertical lines is much more memory efficient than the `\plot` command, mathsPIC automatically invokes the `\putrule` command for horizontal and vertical lines.

3.7.1 Line thickness

mathsPIC

mathsPIC uses the `linethickness()` command. For example, to switch to a linethickness of `2pt` we would use the mathsPIC command

```
linethickness(2pt)
```

The default value is 0·4pt, and resetting to this value is achieved by the following command

```
linethickness(default)
```

Sometimes when drawing thick lines it is useful to be able to manipulate the line ends (e.g. when drawing shapes with horizontal and vertical lines). Consequently it is useful to be able to access the numeric value of the current linethickness (in the units defined by the `paper` command), and this can be done using the var command as follows.

```
var t = _linethickness_
```

The mathsPIC `drawLine()` command uses the current dot size. However, the mathsPIC `drawThickline()` command uses the `\large` dot size, but then resets the dot size to the default `\tiny`. For example, the commands

```
point(A){5,5}
point(B){10,10}
drawThickline(AB)
```

will result in the following code in the output-file.

```
%% point(A){5,5}     (5,5)
%% point(B){10,10}   (10, 10)
%% drawThickline(AB)
\setplotsymbol  ({\usefont{OT1}{cmr}{m}{n}\large .})%
{\setbox1=\hbox{\usefont{OT1}{cmr}{m}{n}\large .}%
 \global\linethickness=0.31\wd1}%
\plot 5.00000 5.00000 10.00000 10.00000 / %% PQ
\setlength{\linethickness}{0.4pt}%
\setplotsymbol  ({\usefont{OT1}{cmr}{m}{n}\tiny .})%
```

PICTEX

PICTEX draws lines using two different methods depending on whether the lines are (a) horizontal or vertical, (b) any other orientation. Furthermore these two groups use different commands for controlling line-thickness, as follows.

Horizontal and vertical lines (rules): Horizontal and vertical lines are drawn using the PICTEX `\putrule` command[6] and consequently the thickness of such lines is controlled by the PICTEX
`\linethickness` command (the default line-thickness is 0·4pt). For example, the following PICTEX command changes the thickness to 1pt.

```
\linethickness=1pt
```

Note also that the PICTEX `\linethickness` command can also be reset to its default value (0·4pt) by the PICTEX `\normalgraphs` command (see chapter on PICTEX commands), which resets all PICTEX graph-drawing parameters to their default values, including `\linethickness`.

Since the graph axes are drawn using horizontal and vertical lines PICTEX draws them using the `\putrule` command, i.e. using the `\linethickness` command. For example, the following commands can be used to draw thick axes.

[6] Note that the PICTEX `\putrule` command employs the TEX and LATEX `\rule` command, and so is only used for horizontal and vertical lines.

```
\linethickness=2pt
paper{units(1mm),xrange(0,50),yrange(0,50),axes(XY)}
\linethickness=0.4pt    %% reset to default
```

Other lines and curves: PICTEX draws all other lines (non-horizontal non-vertical) and curves are drawn using the PICTEX `\plot` command which draws a continuous line of dots. Consequently the thickness of these lines is controlled by the size of the dot, which is defined using the PICTEX `\setplotsymbol` command, the default size of dot being `{\tiny .}`. Larger dots therefore generate thicker lines. For example, the following PICTEX command sets the dot to a larger size.

```
\setplotsymbol({\Large .})
```

3.7.2 Recommendations

In general it is recommended that the mathsPIC `linethickness()` command is used as this automatically sets both the PICTEX `\putrule` and `\setplotsymbol()` commands. However, under certain circumstances it may be convenient to set the PICTEX commands directly, as described below.

If you do use PICTEX commands for drawing lines you need to remember that since PICTEX uses two groups of commands for controlling the thickness of lines (i.e. `\linethickness` and `\setplotsymbol`) it is important to use pairs of equivalent commands for 'rules' (horizontal and vertical lines) and dots (all other lines) when changing line-thickness. These are shown in Table A.1 for a 10-point font (note that the default sizes are 0·4-point and `\tiny`).

Table 3.3: Equivalent PICTEX commands for a 10-point font

rules (horizontal/vertical)	all other lines
`\linethickness=1.35pt`	`\setplotsymbol({\Large .})`
`\linethickness=1.1pt`	`\setplotsymbol({\large .})`
`\linethickness=0.9pt`	`\setplotsymbol({\normalsize .})`
`\linethickness=0.4pt`	`\setplotsymbol({\tiny .})`

If macros are required, then this can be done easily with a TEX macro using the PICTEX commands directly. For example, the following code draws a medium-thick line AB by invoking the command `\mediumthickline`.

```
\newcommand{\mediumthickline}{%
            \linethickness=1.1pt%
            \setplotsymbol({\large .})}%
```

```
...
\mediumthickline%
drawline(AB)
```

3.8 Text

Text is typeset using the `text` command and, by default, is centered both horizontally and vertically at a defined point. For example, the words 'point Z' would be placed at the point Z using the command `text(point $Z$){Z}`.

Text can be located relative to a point-location using the `shift(`dx`,`dy`)` or `polar(`r`,`θ`)` commands. For example, points $P_1P_2P_3$ could have their labels located 4 units from each point as follows.

```
var d = 4
text($P_1$){P1,shift(-d,0)}
text($P_2$){P2,polar(d,10 deg)}
text($P_3$){P3,polar(d,0.29088 rad)}
```

Optionally, text can be positioned relative to a given point using appropriate combinations of the *case sensitive* PICTEX options `l t r B b` to align the **l**eft edge, **r**ight edge, **t**op edge, **B**aseline, **b**ottom edge of the text respectively, as described in the PICTEX manual. For example in the diagram below (Figure 3.3) the text box `a nice box` is aligned such that the right edge of the text box is centered vertically at the point P using the `[r]` option as follows.

```
point(P){25,5}
text(\fbox{a nice box}){P}[r]
```

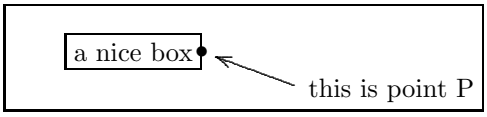


Figure 3.3:

The mathsPIC code for Figure 3.3 is as follows.

```
%% mpicpm03-3.m (Figure 3.3)
\usepackage{mathspic}
\framebox{\vbox{
\beginpicture
paper{units(1mm),xrange(0,28),yrange(0,10)}
point(P){25,5}[symbol=$\bullet$,radius=2]
```

```
text(\fbox{a nice box}){P}[r]
drawpoint(P)
point(J){P,polar(15,-20deg)}[radius=2]
text(this is point P){J}[l]
drawarrow(JP)
\endpicture
\  }}  %% end of framebox
```

Text can also be placed at a point-location (using a `DrawPoint` command), if the text is defined as the optional point-symbol (in square brackets) associated with a `point` command. Although this is useful in certain circumstances, this method is somewhat less flexible than the `text` command, since the `drawPoint` command centers the point-symbol vertically and horizontally over the point-location.

3.9 Variables and constants

3.9.1 Scalar variables

Numeric scalar variables are defined using the `var` *name* `=` *value* command as for example

```
var r=6
```

The name requirement is the same as that for points; an initial (single) letter optionally followed by a maximum of 3 digits. Sometimes the `var` command too restrictive as regards the variable-name, in which case a more intuitive variable-name can be allocated by using a mathsPIC macro (see Section 3.4). For example, we can allocate the name `WeightInKg` to some value, say 22·6 Kg, using the following macro definition (see also Section 4.1 for other examples).

```
%def WeightInKg()22.6
```

However, you have to then remember to use the macro with the `&` prefix (see Section 3.4).

The *value* can be either a number (e.g. 4·32 or 63), an existing variable name (e.g. `r3`), a pair of point names e.g. `AB` (i.e. representing the Pythagorean distance between the two points), or a numerical expression(e.g. `3*k/2`). Thus the command `var r3=20` allocates 20 to the variable name `r3`, which could then be used, for example, as the radius in the circle command `drawcircle(C3,r3)`.

New values can be re-allocated to existing variable-names using the same `var` command.

If it is necessary to use the same letter for a point and a variable (or constant), then a convenient strategy to to consider using upper case for points and lower case for variables and constants.

Note that several variables can be allocated in a single statement, as follows:

```
var r=6, j22=r*6/5, d=180
```

3.9.2 Scalar constants

Constants can be allocated using the `const` command as follows. A constant can be any numerical expression.

```
const j26=23.653
```

If you subsequently try and change the value of a constant, then mathsPIC will issue an appropriate error message.

3.9.3 Mathematics

All the usual mathematical operations can used with variables (see Section 4.1), both when defining a variable, and in places where variables can be used as parameters. When using 'scientific' notation mathsPIC allows either `e` or `E`; for example, `var j25=7E-2` and `point(P){3, 2.34e2}`. The constants π and e are available as `_Pi_` and `_e_`. The following are examples of valid commands.

```
var r = 6, j = r*tan(0.34)/27, d3=AB
point(C){5,5}
drawCircle(C,r/3)
var e=_e_, p1=_Pi_
var j25=7E-2
var t = _linethickness_
text($P$){P, shift(-5.564e-1,0)}
```

3.9.4 Scientific notation

While mathsPIC *does* allow the use of the '`E`' or '`e`' format of so-called 'scientific' notation (see above) it is important to remember that TEX does not, and consequently this influences how mathsPIC displays small numbers when they appear in the output file.

One of the curious anomalies of TEX is that it cannot manipulate numeric values in scientific notation, and will generate an error message whenever it finds the letter `E` or `e` as part of a number. Consequently mathsPIC automatically converts all numbers destined to appear within a PICTEX command in the output-file into 'true' decimal format (i.e. not `E` notation). mathsPIC also reduces such numbers to only five decimal places, and consequently quantities with an absolute value less than 0·00001 are therefore effectively reduced to zero (0·00000).

This is demonstrated in the following example, where the coordinates s_i appear in the output file in scientific notation when in commented lines, but in

decimal notation in the PICTEX `\put...` commands. Note also that in this example the y-coordinate of J_{45} appears as zero in the `\put...` command but as `2.32857142857143e-06` when shown as the value `s5`.

```
var r = 163/7, s1=r/1E3, s2=r/1E4, s3=r/1E5, s4=r/1E6, s5=r/1E7
point(J12){s1,s2}
point(J23){s2,s3}
point(J34){s3,s4}
point(J45){s4,s5}
drawpoint(J12 J23 J34 J45)
```

appears in the output file as

```
%% var r=163/7, s1=r/1E3,s2=r/1E4,s3=r/1E5,s4=r/1E6,s5=r/1E7
%% r = 23.2857142857143
%% s1 = 0.0232857142857143
%% s2 = 0.00232857142857143
%% s3 = 0.000232857142857143
%% s4 = 2.32857142857143e-05
%% s5 = 2.32857142857143e-06
%% point(J12){s1,s2}  J12 = (0.02329, 0.00233)
%% point(J23){s2,s3}  J23 = (0.00233, 0.00023)
%% point(J34){s3,s4}  J34 = (0.00023, 0.00002)
%% point(J45){s4,s5}  J45 = (0.00002, 0.00000)
%% drawpoint(J12 J23 J34 J45)
\put {$\bullet$} at 0.02329 0.00233 %% J12
\put {$\bullet$} at 0.00233 0.00023 %% J23
\put {$\bullet$} at 0.00023 0.00002 %% J34
\put {$\bullet$} at 0.00002 0.00000 %% J45
```

3.10 The LOOP environment

This operates as a simple 'DO...LOOP' allowing a chunk of code to be input multiple times. It takes a single argument, namely the loop number. The commands for this environment are as follows.

`beginloop` ⟨*expr*⟩
`...`
`endloop`

When using a 'DO-LOOP' one usually has to initialise some parameters, and then increment the parameters with each passage of the loop. In particular, it is often convenient to use a loop counter so that one can see in the output file which particular loop is being processed at any stage. It is also useful to include an obvious marker at the begining and end of the repeated section. All these are

included in the following code which produces Figure 3.4 by inputting a section of the code 40 times.

```
%% mpicpm03-4.m (Figure 3.4)
\usepackage{mathspic}
\beginpicture
paper{units(1mm), xrange(0,60), yrange(0,60) axes(LB), ticks(10,10)}
point(S){7,55}   % Start position
drawpoint(S)
%% initialise parameters
var n=0     % initialise mathspic counter
var a=-180  % start angle degrees
var d=50    % start length
beginLOOP 40   % loop 40 times
   var n=n+1, a = a+90, d = d-1 %% increment counter, angle, length
   point*(P){S,polar(d,a deg)} % generate new point P
   drawline(SP) % draw line from OLD S to NEW P
   point*(S){P} %% reallocate S <-- P
endLOOP
drawpoint(P)
\endpicture
```

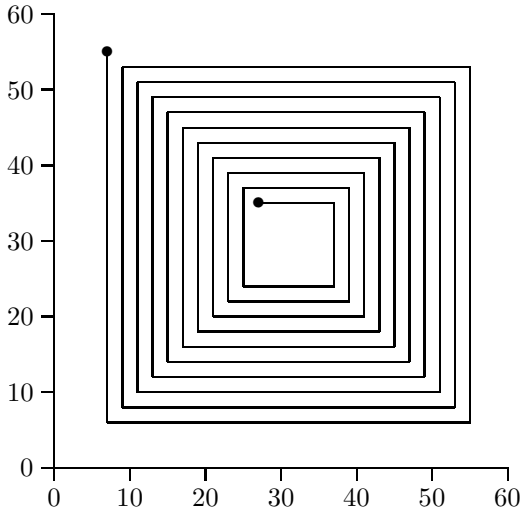


Figure 3.4:

4

mathsPIC commands

All mathsPIC commands (except macros) are case-*in*sensitive. This is a design feature which allows the user to customise the commands and make them easier to read. mathsPIC macros, however, *are* case-sensitive, but since macro-names are created by the user they are customised from the outset by definition.

The arguments of mathsPIC commands are either strings (any legitimate TEX or LATEX commands or characters which can be put into an `\hbox`), point-names (e.g. A, B2, C345), or numerical expressions. Where appropriate, mathsPIC allows scalar quantities in commands to be represented by either a numeric value (e.g. 0·432), a variable name (e.g. r2), two point names representing the Pythagorean distance between two points (e.g. AB), or even a mathematical expression[1]. For example, the structure of the command `DrawCircle(`⟨*centre*⟩`,`⟨*radius*⟩`)` is quite flexible, as follows.

```
point(C){5,5}
drawCircle(C,4.32)
drawCircle(C,r2)
drawcircle(C,AB)
drawCircle(C, r3*tan(0.6)/4)
```

4.1 Mathematics

A leading zero must always be used for decimals whose absolute value is < 1. The argument of trigonometric functions is in radians. Inverse trigonometric functions return a value in radians.

[1] See the definition of 'numerical expression' in Section 4.3.

- **Constants:**
  for π (3·14159...) use `_Pi_` or `_pi_`;
  for 'e' (2·718281...) use `_E_` or `_e_`
- **Trigonometric functions:** (arguments must be in radians)
  `sin(), cos(), tan(), asin(), acos(), atan()`
- **Remainder:** `rem()`; e.g. `var r = 12 rem(5)` $\rightarrow 2$
- **Square root:** `sqrt()`; e.g. `var s = sqrt(14)`
- **Exponentiation:** `**`; e.g. `var j = r**2`
- **Integer:** `int()`; e.g. `var s = int(3.867)` $\rightarrow 3$
- **Sign:** `sgn()` (returns -1, 0, or +1); e.g. `var s = sgn(-2.987)` $\rightarrow -1$
- **Line thickness:** `_linethickness_` (returns current value of the linethickness in current units); e.g. `var t = _linethickness_`
- **Area of triangle:** `area(ABC)` e.g. `var t = area(ABC)`

4.2 Macros

mathsPIC allows the definition of one-line macros with or without arguments, which evaluate to a 'numerical expression' (see Section 4.3) (i.e. not strings). Macro definition has the following syntax:

`%def` ⟨*macro-name*⟩ `(` [⟨*parameters*⟩] `)` ⟨*macro-code*⟩

where ⟨*parameters*⟩ is a list of comma separated strings (e.g. x,y,z). Always place a `%` symbol at the end of the ⟨*macro-code*⟩ to limit additonal white space. The ⟨*macro-code*⟩ can be delimited using round brackets is necessary. Examples of valid macros are as follows:

```
%def two()2%    % a macro called two
%def two()(2)%
```

Once a macro is defined it can be used or it can be undefined. A macro is removed (undefined) using the `%undef` command as follows.

`%undef` ⟨*macro-name*⟩

Macros (see Section 3.4) are very useful in mathematics. Remember (a) that if a macro does not use parameters then the `()` are not required as part of the command when it is used as a variable, (b) that the macro-name must have the `&` prefix when it is used in a mathsPIC command, and (c) it is very important to

place a % symbol at the end of the macro command in order to stop PICTEX from collecting any following white space and distorting the diagram.

Macros without a parameter can be very useful since they can be used to allocate a meaningful variable-name (or constant-name). For example, we can allocate the variable name `SpeedOfLight` to the value $2{\cdot}9979 \times 10^8$ metres per second[2] and then manipulate it as follows.

```
%def SpeedOfLight()2.9979e8% metres/sec
var m=1000,  E = m*(&SpeedOfLight**2)
```

Note the use of the & symbol in the `var` command above. After running the above commands through mathsPIC the output file would show the allocation of the variable `E` as follows.

```
%def SpeedOfLight()2.9979e8% metres/sec
%% var m=1000, E = m*(2.9979e8**2)
%% m = 1000
%% E = 8.98740441e+19
```

By way of another example, it is often useful to have meaningful names for the factors used for converting degrees to radians and *vice versa* (e.g. $d2r$, $r2d$), as provided by the following two macros (without parameters).

```
%def d2r()_pi_/180%    % degrees to radians
%def r2d()180/_pi_%    % radians to degrees
```

For example, a variable of 30 degrees (say, `d30`) could be converted to radians (say, `r30`) in a `var` command using the new `d2r` command as follows (remembering to include the & prefix for the macro),

```
var d30=30, r30=d30*&d2r
```

which is processed via mathsPIC to

```
%% var d30=30, r30=d30*_pi_/180
%% d30 = 30
%% r30 = 0.523598775598299
```

Macros which take a parameter can be useful in a slightly different way. For example, since Perl does not have separate commands for $log_{10}()$ and $log_e()$—it only has one `log` command, namely `log()` for $log_e()$—you may wish to define separate commands to make it easy to distinguish between the two. This is easily done with macros taking a single parameter as follows.

[2] Lloyd S (2000). Ultimate physical limits to computation. *Nature*; 406, 1047–1054 (August 31, 2000).

```
%def loge(a)  log(a)%
%def log10(a) log(a)/log(10)%
```

Now if you type the command `&loge(5)` in the mathsPIC file you will generate the value $log_e(5)$. Similarly, the command `&log10(3)` $\rightarrow log_{10}(3)$.

Making a macro library

If you regularly use particular macros then these can be easily stored in an ASCII file as a library (say, `mathspic.lib`) as follows.

```
%%--- mathspic.lib---
%def log10(a)log(a)/log(10)%
%def loge(a)log(a)%
%def mod(a)rem(a)%
%def d2r() _pi_/180%
%def r2d() 180/_pi_%
%%---end of library---
```

This library file can then be input at the beginning of the mathsPIC script, as follows.

```
inputfile{mathspic.lib}
```

4.3 Command definitions

Names of points, constants and variables

The names of points, constants and variables all conform to the same name convention, as follows: The name *must* begin with a *single* letter (either upper or lower case), and may have up to a *maximum* of three following digits.

While constants and variables should not have the same name, it is quite possible for points and variables (and constant) to have the same name. Consequently, it is a useful rule to arrange for points to have uppercase letters and for variables and constants have lowercase letters.

Numerical expression

When dealing with commands we will refer frequently to the term 'numerical expression' by which is meant either (a) a number (integer or decimal), (b) a numeric variable or constant (defined using the `var` or `const` command), (c) any mathsPIC function, macro, or mathematical expression which evaluates to a number, or (d) a pair of point names (e.g. `AB`) representing the Pythagorean distance between the two points. A leading zero must be used with decimal fractions having an absolute

value less than one. The syntax of the numerical expression, which we will refer to as ⟨*expr*⟩ is therefore as follows:

⟨*expr*⟩ ::= ⟨*two-points*⟩ | ⟨*number*⟩ | ⟨*variable*⟩ | ⟨*maths*⟩

Unit

When dealing with commands we will refer frequently to the term 'unit' by which is meant one of the valid TEX units (see Knuth (1986) p. 57).

⟨*unit*⟩ ::= ⟨*mm*⟩ | ⟨*cm*⟩ | ⟨*pt*⟩ | ⟨*pc*⟩ | ⟨*in*⟩ | ⟨*dd*⟩ | ⟨*cc*⟩ | ⟨*sp*⟩

Line thickness

Commands and parameters which control line-thickness are described in Section 3.7.1.

4.3.1 Backslash

- `\...` `\␣␣...`

- **Notes**

  A line having a *leading* backslash is processed (copied verbatim) slightly differently depending on whether the character following the backslash is a space or not.

  A leading backslash *followed by a non-space character* tells mathsPIC to copy the whole line verbatim (*including* the backslash) through to the output-file (thus a line leading with the LATEX command `\begin{document}` will be copied unchanged).

  However, a leading backslash *followed by one or more spaces*, (e.g. \␣␣...) tells mathsPIC to copy the rest of the line verbatim through to the output-file, but *without* the leading backslash.

4.3.2 ArrowShape

This command defines the shape of an arrowhead, and allows arrowheads to be customised (see Section 7.3 for details).

- **Syntax**

  `ArrowShape(` ⟨*expr*⟩ [⟨*units*⟩] , ⟨*expr*⟩ , ⟨*expr*⟩ `)`

  `ArrowShape(default)`

- **Notes**

  The first parameter is the length of the arrow head itself. If ⟨*units*⟩ are not given then the current default units will be applied. The last two parameters are angles (default is degrees) which define the shape of the arrow head (see Section 7.3 for details).

  The default arrow shape is equivalent to the command `Arrowshape(2mm,30,40)`. This default arrowhead shape can be reset using `Arrowshape(default)` command.

- **Examples**

```
Arrowshape(4mm,30,60)
var h = 3
Arrowshape((3*h)mm,30,60)
drawArrow(AB)
Arrowshape(default)
drawArrow(PQ)
```

4.3.3 beginLoop ... endLoop environment

—see Loop

4.3.4 beginSkip ... endSkip environment

—see Skip

4.3.5 Const

The `const` command is used to define scalar constants.

- **Syntax**

  `const` ⟨*name*⟩ `=` ⟨*expr*⟩ [`,` ⟨*name*⟩ `=` ⟨*expr*⟩] ...

- **Notes**

  The constant name follows the same naming convention as points and variables (see Section 4.3). The scalar argument can be any numeric expression. There is no terminal comma. If a new value is allocated to an existing constant name then mathsPIC issues an error message.

- **Example**

```
const h=5
const r = 20, r4 = r3*tan(0.3)
```

4.3.6 DashArray

The `dasharray` command takes an arbitrary number of paired arguments that are used to specify a dash–gap–dash... pattern.

- **Syntax**

  `dasharray ( DASH , GAP [ DASH , GAP ] ... )`

  DASH `::=` ⟨*expr*⟩ ⟨*unit*⟩

  GAP `::=` ⟨*expr*⟩ ⟨*unit*⟩

- **Notes**

  There must be an even number of arguments. If a variable or expression is used then it should be separated from the unit either by a ␣ or with round brackets ( ) as shown below.

  Macros are useful for allocating names to frequently used dashArray commands.

- **Example**

```
dasharray(6pt, 2pt, 1pt, 2pt)
var d=2
dasharray(6pt, 2pt, 1pt, d pt)
dasharray(6pt, 2pt, 1pt, (d)pt)
dasharray(6pt, 2pt, 1pt, (3*d)pt)
%def fancydashes()dasharray(6pt, 2pt, 1pt, 2pt)%
```

4.3.7 DrawAngleArc

This command draws an arc in the specified angle, a distance *radius* from the angle.

- **Syntax**

  `drawAnglaArc{` ANGLE , RADIUS , LOCATION , DIRECTION `}`

  `drawAnglaArc{` ANGLE RADIUS LOCATION DIRECTION `}`

  ANGLE `::= angle(` ⟨*three-points*⟩ `)`

  RADIUS `::= radius(` ⟨*expr*⟩ `)`

  LOCATION `::= internal | external`

  DIRECTION `::= clockwise | anticlockwise`

- **Notes**

  The angle location is either *internal* ($\leq 180°$) or *external* ($\geq 180°$). The direction of the arc is either *clockwise* or *anticlockwise*, and this direction must correspond with the letter sequence specified for the angle. Strange and unexpected results will be produced if the four parameters are not internally consistent. The parameter order `angle/radius/internal/clockwise` etc is important.

- **Examples**

```
DrawAngleArc{angle(ABC), radius(3), external, clockwise}
var r = 2
DrawAngleArc{angle(PQR), radius(r), internal, anticlockwise}
```

4.3.8 DrawAngleArrow

This command draws an arrow in the specified angle, a distance *radius* from the angle.

- **Syntax**

  `drawAnglaArrow{` ANGLE , RADIUS , LOCATION , DIRECTION `}`

  `drawAnglaArrow{` ANGLE RADIUS LOCATION DIRECTION `}`

  ANGLE `::= angle(` ⟨*three-points*⟩ `)`

  RADIUS `::= radius(` ⟨*expr*⟩ `)`

  LOCATION `::= internal | external`

  DIRECTION `::= clockwise | anticlockwise`

- **Notes**

  The angle location is either *internal* ($\leq 180°$) or *external* ($\geq 180°$). The direction of the arrow is either *clockwise* or *anticlockwise*, and this direction must correspond with the letter sequence specified for the angle. Strange and unexpected results will be produced if the four parameters are not internally consistent. The parameter order `angle/radius/internal/clockwise` etc is important.

  The radius can be any numerical expression.

- **Examples**

```
DrawAngleArrow{angle(ABC), radius(3), external, clockwise}
var r = 2
DrawAngleArrow{angle(PQR), radius(r), internal, anticlockwise}
```

4.3.9 DrawArrow

This command draws an arrow(s) joining two points.

- **Syntax**

  `drawArrow (` ⟨*two-points*⟩ [`,` ⟨*two-points*⟩] ... `)`

- **Notes**

  The direction of the arrow is in the point order specified. The shape of the arrowhead is controlled by the `ArrowShape` command (see Section 7.3). Commands and parameters which control line-thickness are described in Section 3.7.1.

- **Examples**

```
drawArrow(AB)
drawArrow(FG, HJ)
```

4.3.10 DrawCircle

Draws a circle with its centre at a given point and with a given radius.

- **Syntax**

  `DrawCircle (` CENTRE , RADIUS `)`

  CENTRE `::=` ⟨*point*⟩

  RADIUS `::=` ⟨*expr*⟩

- **Notes**

  Note that PICTEX draws circles with the `\circulararc` command, using a radius equivalent to the distance from the centre to the point at which it starts drawing the arc. Consequently, if the units of the x and y axes are different, circles may be drawn strangely. MathsPIC therefore generates a message to this effect in the output-file if different units are selected for the two axes in the `units` command.

- **Examples**

```
drawCircle(C2,5)
var r2=3
drawCircle(C2,r2)
drawCircle(C2,(r2/tan(1.2)) )
drawCircle(C2,AB)
```

4.3.11 DrawCircumcircle

Draws the circumcircle of a triangle defined by three points

- **Syntax**

  `DrawCircumcircle(` ⟨*three-points*⟩ `)`

- **Example**

  ```
  drawCircumcircle(ABC)
  ```

4.3.12 DrawCurve

Draws a smooth quadratic curve through three points in the order specified.

- **Syntax**

  `DrawCurve (` ⟨*three-points*⟩ `)`

- **Notes**

  This command will be upgraded in the next version to apply to more than three points.

  Note that curves drawn using this command do *not* break to avoid line-free zones associated with the points (the `drawLine` command for straight lines *does* acknowledge line-free zones).

- **Example**

  ```
  drawCurve(ABC)
  ```

4.3.13 DrawExcircle

Draws the excircle touching a given side of a triangle.

- **Syntax**

  `DrawExcircle(` TRIANGLE , SIDE `)`

  TRIANGLE `::=` ⟨*three-points*⟩

  SIDE `::=` ⟨*two-points*⟩

- **Example**

  ```
  drawExcircle(ABC,BC)
  ```

4.3.14 DrawIncircle

Draws the incircle of a triangle defined by three points

- **Syntax**

  `DrawIncircle(` ⟨*three-points*⟩ `)`

- **Example**

```
drawIncircle(ABC)
```

4.3.15 DrawLine

This command draws a line(s) between sets of two or more points.

- **Syntax**

  `drawLine (` LINE [`,` LINE] `...` `)`

  LINE `::=` ⟨*two-points*⟩ [⟨*point*⟩] ...

- **Notes**

  Lines are drawn in the point order specified. Commands and parameters which control line-thickness are described in Section 3.7.1.

  Note that the `drawline` command uses the PICTEX `\putrule` command for horizontal and vertical lines, and the `\plot` command for lines of all other orientations.

- **Examples**

```
drawLine(AB)
drawLine(FG, HJ)
var d = 3
```

4.3.16 DrawPerpendicular

Draws the perpendicular from a point to a line.

- **Syntax**

  `DrawPerpendicular(` ⟨*point*⟩ `,` LINE `)`

  LINE `::=` ⟨*two-points*⟩

- **Example**

```
drawPerpendicular(P, AB)
```

4.3.17 DrawPoint

Draws a symbol at the point-location.

- **Syntax**

  `DrawPoint(` ⟨*point*⟩ [⟨*point*⟩] `...)`

- **Notes** There must be no commas in the list of points (spaces are allowed).

- **Example**

```
drawpoint(T4)
drawpoint(ABCDEF)
drawpoint(P1 P2 P3 P4)
```

4.3.18 DrawRightangle

Draws the standard right-angle symbol in the internal angle specified, and at specified size.

- **Syntax**

  `DrawRightangle(` ⟨*three-points*⟩ `,` ⟨*expr*⟩ `)`

- **Example**

```
drawRightangle(ABC,3)
```

4.3.19 DrawSquare

Draws a square at a given point with a given side-length.

- **Syntax**

  `DrawSquare(` ⟨*point*⟩ `,` ⟨*expr*⟩ `)`

- **Example**

```
drawSquare(P,5)
drawSquare(P,s2)
drawSquare(P, s2*4/(3*j))
drawSquare(P,AB)
```

4.3.20 DrawThickArrow

This command draws a thickarrow(s) joining two points.

- **Syntax**

  `drawThickArrow (` ⟨*two-points*⟩ [`,` ⟨*two-points*⟩] ... `)`

- **Notes**

  The direction of the arrow is in the point order specified. The shape of the arrowhead is controlled by the `ArrowShape` command (see Section 7.3). Commands and parameters which control line-thickness are described in Section 3.7.1.

- **Examples**

```
drawThickArrow(AB)
drawThickArrow(FG, HJ)
```

4.3.21 DrawThickLine

This command draws a thick line(s) between sets of two or more points.

- **Syntax**

  `drawThickLine (` LINE [`,` LINE] `...` `)`

  LINE `::=` ⟨*two-points*⟩ [⟨*point*⟩] ...

- **Notes**

  Lines are drawn in the point order specified. Commands and parameters which control line-thickness are described in Section 3.7.1.

  Note that the `drawThickLine` command uses the PiCTeX `\putrule` command for horizontal and vertical lines, and the `\plot` command for lines of all other orientations.

- **Examples**

```
drawThickLine(AB)
drawThickLine(FG, HJ)
var d = 3
```

4.3.22 InputFile

Inputs a plain text file containing mathsPIC commands, one or more times.

- **Syntax**

  `InputFile(` ⟨*file-name*⟩ `) [` LOOP `]`

  LOOP `::=` ⟨*expr*⟩

- **Notes**

  Optionally, the file can be input [LOOP] times, in which case this command can be used to implement something akin to a primitive DO–LOOP if the file contains mathsPIC commands.

  See also the LOOP command (a beginLOOP...endLOOP environment).

  If LOOP is not an integer then mathsPIC will round the value down to the nearest integer. Note that the `inputfile*` command has no [LOOP] option.

- **Example**

  The following command inputs the file `newfile.dat` 4 times in succession.

  ```
  inputFile(myfile.dat)[4]
  ```

  The `inputfile*` command is used to input a file in *verbatim*, i.e. a file with *no* mathsPIC commands. For example, a file containing only PICTEX commands or data-points for plotting etc. A typical example might be the following file (curve-A.dat) which would be input verbatim using the command `inputfile*(curve-A.dat)`.

  ```
  %% curve-A.dat
  \setquadratic
  \plot
   0     0
   3.56  4.87
   8.45  9.45
   5     7
   2.34  3.23 /
  \setlinear
  ```

4.3.23 LineThickness

Sets a particular linethickness.

- **Syntax**

  `Linethickness (` ⟨*expr*⟩ ⟨*units*⟩ `)`

  `Linethickness (default)`

- **Notes**

  This command also sets the font to `cmr` and plotsymbol to `{\CM .}`, and also sets the rule thickness for drawing horizontal and vertical lines. For example the command `linethickness(2pt)` results in the following commands in the output `.mt` file.

```
\linethickness=2.00000pt\Linethickness{2.00000pt}%
\font\CM=cmr10 at 19.94451pt%
\setplotsymbol  ({\CM .})%
```

  The command `linethickness(default)` restores the working linethickness to the default value of 0·4pt.

  The current value of linethickness (in the current units as defined in the `paper` command) can be accessed as the value `_linethickness_` as follows.

```
var t = _linethickness_
```

  See also—the chapter on PICTEX commands as there is a similar PICTEX command with the same name (but with a different syntax).

- **Example**

```
linethickness(2pt)
linethickness(default)
var t = _linethickness_
```

4.3.24 Loop environment

This environment cycles a block of code a number of times.

- **Syntax**

  `beginLoop` ⟨*expr*⟩`...endLoop`

- **Notes** The block of code which lies within the environment is input ⟨*expr*⟩ times.

- **Example**

```
beginLoop 5
...
endLoop
```

4.3.25 Paper

Defines the plot area and scale, and optional axes and tick marks.

- **Syntax**

  `Paper{` UNITS , XRANGE , YRANGE , AXES , TICKS `}`

  `Paper{` UNITS XRANGE YRANGE AXES TICKS `}`

  UNITS `::= units(` ⟨*expr*⟩ ⟨*units*⟩ [, ⟨*y-expr*⟩ ⟨*y-units*⟩] `)`

  XRANGE `::= xrange(` ⟨*low-expr*⟩ , ⟨*high-expr*⟩ `)`

  YRANGE `::= yrange(` ⟨*low-expr*⟩ , ⟨*high-expr*⟩ `)`

  AXES `::= axes(` [⟨*L*⟩[*]] [⟨*R*⟩[*]] [⟨*T*⟩[*]] [⟨*B*⟩[*]] [⟨*X*⟩[*]] [⟨*Y*⟩[*]] `)`

  TICKS `::= ticks(` ⟨*x-expr*⟩ , ⟨*y-expr*⟩ `)`

- **Notes**

  The following statement sets up a rectangular drawing area 5 cm × 5 cm with axes on the Left (y-axis) and Bottom (x-axis), and tick marks at 1 cm intervals.

  ```
  paper{units(1cm),xrange(0,5),yrange(0,5),axes(LB),ticks(1,1)}
  ```

  All combinations of the axis-codes (XYLRTB) are allowed, and a * following an axis-code (e.g. L*) disables the drawing of ticks on the specified axis.

  If it is necessary to have *different* unit scales for the x and y axes, say 1 cm and 2 mm respectively, then this is implemented by `units(1cm,2mm)`. If only a single unit is specified (e.g. `units(3cm)`) then mathsPIC automatically makes this the unit scale for *both* axes. If the `unit` option is omitted PICTEX will use the last defined units (within the same picture environment), the default units being *xunit*=1pt and *yunit*=1pt (see the PICTEX Manual, page 3; Wichura, 1992).

  If different units or different sizes of the same unit are used for the x and y scales then mathsPIC issues a warning message to this effect.

- **Example**

  ```
  paper{units(1cm),xrange(0,10),yrange(0,10),axes(XY)}
  var j=5
  paper{units(1cm),xrange(0,j),yrange(0,5),axes(LBT*R*),ticks(1,1)}
  var u = 3
  paper{units((u)mm),xrange(0,50),yrange(0,50),axes(LBTB)}
  ```

4.3.26 Point

Allocates coordinates to a point-name.

- **Syntax**

  `Point [*]` (⟨*point*⟩) { ⟨*point*⟩ } [OPTION [, OPTION]]

  `Point [*]` (⟨*point*⟩) { LOCATION } [OPTION [, OPTION]]

  LOCATION ::= ⟨*x-expr*⟩ , ⟨*y-expr*⟩

  LOCATION ::= `xcoord(` ⟨*point*⟩ `)` , `ycoord(` ⟨*point*⟩ `)`

  LOCATION ::= `midpoint(` ⟨*two-points*⟩ `)`

  LOCATION ::= `intersection(` ⟨*two-points*⟩ , ⟨*two-points*⟩ `)`

  LOCATION ::= `PointOnLine(` ⟨*point*⟩ , ⟨*expr*⟩ `)`

  LOCATION ::= `perpendicular(` ⟨*point*⟩ , ⟨*two-points*⟩ `)`

  LOCATION ::= `Circumcirclecenter(` ⟨*three-points*⟩ `)`

  LOCATION ::= `Incirclecenter(` ⟨*three-points*⟩ `)`

  LOCATION ::= `Excirclecenter(` ⟨*three-points*⟩ , ⟨*two-points*⟩ `)`

  LOCATION ::= ⟨*point*⟩ , POINT-FUNCTION

  POINT-FUNCTION ::= `shift(` ⟨*x-expr*⟩ , ⟨*y-expr*⟩ `)`

  POINT-FUNCTION ::= `polar(` ⟨*r-expr*⟩ , ⟨*θ-expr*⟩ `)`

  POINT-FUNCTION ::= `rotate(` ⟨*point*⟩ , ⟨*θ-expr*⟩ `)`

  POINT-FUNCTION ::= `vector(` ⟨*two-points*⟩ `)`

  OPTION ::= `symbol =` CHARS | `radius =` ⟨*expr*⟩

  CHARS ::= ⟨*string*⟩ | `square(` ⟨*expr*⟩ `)` | `circle(` ⟨*expr*⟩ `)`

- **Notes**

  The default point-symbol is the `$\bullet$`. An optional alternative point-symbol (or string of characters) can be specified within square brackets e.g. `[symbol=$\triangle$]`

  By default lines drawn to a 'point' are drawn to the point location. However, the radius of an optional line-free zone (line-free radius) can be specified within an optional square bracket e.g. `[symbol=$\triangle$,radius=2]`. A line-free radius option can be specified by itself, for example `[radius=2]`.

  The `polar(r,theta)` defaults to radians for the angle theta. If degrees are required then need to append < *deg* >; e.g. `polar(r,theta deg)`. Note that `direction()` or `directiondeg()` can be used instead of theta.

  An optional `symbol=circle()` or `symbol=square()` can also be used as the *symbol*. In these cases a numeric expression is required as the argument, and

is taken to be the side length (for `square()`) or circle-radius (for `circle()`). If a radius ⟨*expr*⟩ is also included then the square will have associated with it a line-free radius of the specified value, e.g. `[symbol=square(2), radius=5]`; and similarly if the symbol is a circle.

Note (1) there must be a comma between the options, and (2) the options are not order specific. If no line-free radius value is specified, the line-free radius used is the current (default) value).

Points can also be defined relative to *previously defined* points. For example, as the intersection of two existing lines, or as a +ve or −ve extension (in the direction indicated by the letters) between two previously defined points, (e.g. the `PointOnLine()` construction).

If the command `point(){}` is used to reallocate new parameters to an existing point-name then mathsPIC will generate a warning message indicating that an existing point-name is being reallocated. For example, the following code

```
point(S){6,6}
point(S){7,7}
```

will generate the following warning message in the output file, but still reallocate the point-name.

```
%% point(S){6,6}  S = (6, 6)
%% *** Line 15: point(S
%% ***                 ){7,6}
%% ... Warning: Point S has been used already
%% point(S){7,6}  S = (7, 6)
```

The `point*` command allocates parameters to a point-name irrespective of whether that point-name has been previously defined or not. Thus in the above example, the reallocation proceeds without any warning message at all, as follows

```
%% point(S){6,6}  S = (6, 6)
%% point*(S){7,6}  S = (7, 6)
```

- **Examples**

```
point(A){5,5}
point(B2){22,46}[symbol=$\odot$]
point(B2){22,46}[symbol=circle(2),radius=5]
point(B2){22,46}[symbol=square(3),radius=5]
```

```
point(B2){22,46}[radius=5]
point(D2){B2, shift(5,5)}
point(D3){D2, polar(6,32 deg)}
point(D4){D2, polar(6,1.2 rad)}
point(D4){D2, polar(6,direction(AB))}
point(D4){D2, polar(6,directiondeg(AB)deg)}
point(G2){Q, rotate(P, 23 deg)}
point(J4){B2, vector(AB)}
point(D2){midpoint(AB)}
point(D2){intersection(AB,CD)}
point(F){PointOnLine(AB,5.3)}
point(G){perpendicular(P,AB)}
point(H){circumcirclecenter(ABC)}
point(J){incirclecenter(ABC)}
point(K){excirclecenter(ABC,BC)}
point*(A){6,3}
point*(B){B, shift(5,0)}
point*(P){J} %% make J have the same coords as P
point*(P){xcoord(J),ycoord(J)}  %% same as  Point*(P){J}
```

4.3.27 PointSymbol

Sets a particular point-symbol and line-free radius.

- **Syntax**

  `pointSymbol (` ⟨*chars*⟩ `,` ⟨*expr*⟩ `)`

  `pointSymbol (square(`⟨*expr*⟩`)` `,` ⟨*expr*⟩ `)`

  `pointSymbol (circle(`⟨*expr*⟩`)` `,` ⟨*expr*⟩ `)`

- **Notes**

  This command allows the default point-symbol (`$\bullet$`, line-free radius zero) to be changed. The `square` option takes the side-length as argument. The `circle` option takes the radius as argument.

  The PointSymbol command is particularly useful where a set of points uses the same point-symbol, and also when drawing graphs.

  For example, the following command changes the point-symbol to ⊙ having a line-free radius of 0·7 units.

  ```
  PointSymbol($\odot$, 0.7)
  ```

  Note that the `PointSymbol` command only influences subsequent `point` commands. The optional square bracket of the `point` command overrides

the PointSymbol command. The point-symbol can be reset to the default (`$\bullet$`, zero line-free radius) using the command `PointSymbol(default)`.

- **Example**

```
PointSymbol($\odot$, 0.7)
PointSymbol(square(4), 5)
PointSymbol(circle(3), 3)
var r = 1.2
PointSymbol($\triangle$, 0.7)
PointSymbol(circle(r), r)
pointSymbol{default)
```

4.3.28 Skip environment

This is an environment within which commands are not actioned.

- **Syntax**

  `beginSKIP...endSKIP`

- **Notes**

  It is useful in development for by-passing commands (i.e. its function is equivalent to the `\iffalse....\fi` commands in a TEX document).

4.3.29 System

This command allows the user to access the command line and execute system commands. Allows programs to be run from within mathsPIC.

- **Syntax**

  `system ( " ⟨command⟩ " )`

- **Notes**

  The whole command must be delimited by inverted commas. For example, the following command will temporarily stop mathsPIC processing, access the command-line and run LATEX on the file `myfile.tex`, and then seamlessly return and continue mathsPIC processing.

  ```
  system("latex2e myfile.tex")
  ```

  Alternatively, the `system()` command may be used to create a small batch file on-the-fly in order to facilitate some procedure. In mathsPIC a common use is for running a Perl program to write mathsPIC commands to a file which is then input by mathsPIC (see the examples at the end of the Examples chapter).

- **Example**

```
system("dir > mydir-listing.txt")
system("perl drawbox.pl  5  5  temp.txt")
inputFile(temp.txt)
```

4.3.30 Show...

This command makes mathsPIC return the value of a calculation or specified parameter.

- **Syntax**

`ShowLength (` ⟨*two-points*⟩ `)`

`ShowAngle (` ⟨*three-points*⟩ `)`

`ShowArea (` ⟨*three-points*⟩ `)`

`ShowPoints`

`ShowVariables`

- **Notes**

The `showarea()` command is only for triangles. The results of the `Show...` commands are shown in the output-file as a commented line.

- **Example**

```
showLength(AB)
showAngle(ABC)
showArea(ABC)
showPoints
showVariables
```

When the above examples are processed, the results appear as commented lines in the output-file as follows.

```
%% Length(AB) =  25.35746
%% Angle(ABC) =  39.35746 deg (0.68691 rad)
%% Area(ABC)  =  54.54267
%%-----------------------------------------------
%%           L I S T  O F  P O I N T S
%%-----------------------------------------------
%%  q = (8.000, 9.000), LF-radius = 5.000, symbol = $\bigodot$
%%  s = (6.000, 6.000), LF-radius = 0.000, symbol = $\bullet$
%%  p = (5.000, 5.000), LF-radius = 3.000, symbol = $\circle$
%%  t = (5.000, 5.000), LF-radius = 7.000, symbol = $\square$
```

```
%%-----------------------------------------------
%%     E N D  O F  L I S T  O F  P O I N T S
%%-----------------------------------------------
%%-----------------------------------------------
%%      L I S T  O F  V A R I A B L E S
%%-----------------------------------------------
%% a = 4
%% b = 12
%%-----------------------------------------------
%%   E N D  O F  L I S T  O F  V A R I A B L E S
%%-----------------------------------------------
```

4.3.31 Text

Places text at a given location.

- **Syntax**

  `Text (` ⟨*string*⟩ `)` { LOCATION } `[` POSSN [`,` POSSN] `]`

  LOCATION `::=` ⟨*point*⟩

  LOCATION `::=` ⟨*x-expr*⟩ `,` ⟨*y-expr*⟩

  LOCATION `::=` ⟨*point*⟩ `,` POINT-FUNCTION

  POINT-FUNCTION `::= shift(` ⟨*x-expr*⟩ `,` ⟨*y-expr*⟩ `)`

  POINT-FUNCTION `::= polar(` ⟨*r-expr*⟩ `,` ⟨*θ-expr*⟩ `)`

  POSSN `::= l | t | r | R | b`

- **Notes**

  This command puts the given text-string either at the named point, or with a displacement specified by the optional `shift()` or `polar()` or `rotate()` functions. By default the text is centreed vertically and horizontally at the specified location.

  Optionally, text can be placed relative to the specified location using appropriate combinations of the PICTEX *position* options `l t r B b` to align the **l**eft edge, **r**ight edge, **t**op edge, **B**aseline, **b**ottom edge respectively of the text box with the point-location (see the PICTEX Manual, page 5; Wichura, 1992). For example, the text box `This is point P` would be aligned such that the right edge of the text box would be centreed vertically at the point P, using `text(This is point P){P}[r]` (see figure3.3).

  Note that TEX and LATEX macros are very useful for defining blocks of text in this setting, since the macro name can be used in the `text()` command for convenience, as shown in the examples below.

- **Example**

```
text(A){5,6}
text($A_1$){A1, shift(2, 2)}
text($Z2$){Z2, shift(5, -5)}[tr]
text($Z3$){Z2, polar(5, 20 deg)}[Br]
text($Z4$){Z2, rotate(P, 45)}
text(\framebox{$Z5$}){Z3}
\newcommand{\mybox}{\framebox{$Z5$}}
text(\mybox){P421}
```

4.3.32 Var

The `var` command is used to define scalar variables.

- **Syntax**

  `var` ⟨*name*⟩ `=` ⟨*expr*⟩ [`,` ⟨*name*⟩ `=` ⟨*expr*⟩] ...

- **Notes**

  The variable name follows the same naming convention as points and variables (see Section 4.3). The scalar argument can be any numeric expression.

  New values can be re-allocated to existing variable-names; however, when this occurs then mathsPIC does not issue a warning message to hightlight this fact. If it is important to be warned if a potential variable is accidentally reallocated then one should consider using the `const` command instead (since mathsPIC does generate an error message if a constant is reallocated).

  Note that in addition to all the mathematical functions, the following functions can also be used.

  `angle(`⟨*three-points*⟩`)`

  `angledeg(`⟨*three-points*⟩`)`

  `direction(`⟨*two-points*⟩`)`

  `directiondeg(`⟨*two-points*⟩`)`

  `area(`⟨*three-points*⟩`)`

  `xcoord(`⟨*point*⟩`)`

  `ycoord(`⟨*point*⟩`)`

- **Example**

```
var r = 20, r4 = r3*tan(0.3), j = (r*2e3)**2,  r5 = AB
var e = _e_, p1 = _Pi_
var t = _linethickness_
```

```
var L25 = AB             %% gives length of line AB
var g137 = angle(ABC)    %(default: returns in radians)
var g = angledeg(ABC)    % returns in degrees
var d = direction(PQ)       % angular direction of PQ in radians
var d = directiondeg(PQ)    % angular direction of PQ in degrees
var h = area(ABC)
var x2 = xcoord(A), y2 = ycoord(A)
var m5 = 12 rem 3   %% remainder after dividing by 3
var s1 = sgn(h)     % returns the sign (+1, -1, 0) of h
var i = int(k)      % returns the integer value of k
```

4.4 Summary of mathsPIC commands

The following list shows the format and typical usage of all mathsPIC commands. Although mathsPIC commands are *not* case sensitive, in this summary of commands points are represented using upper case letters, and variables and constants are represented using lower case letters. Note that a leading \␣ is used for copying TEX or PICTEX lines verbatim, for example with macros or coordinates of data points etc.

```
\   4.5    6.3
%def loge(n)log(n)%
%def fancydashes() dasharray(1pt,2pt,3pt,4pt)%
%def plaindashes() dasharray(1pt,1pt)%
%def d2r()_pi_/180%
%def r2d()180/_pi_%
ArrowShape(4mm,30,50)
ArrowShape(default)  %% generates arrowshape(2mm,30,40)
beginLoop ... endLoop  5
beginLoop ... endLoop  n
beginNoOutput ... endNoOutput
beginSKIP ... endSKIP
const r40=40
drawAngleArc{angle(ABC), radius(3), internal, clockwise}
drawAngleArrow{angle(ABC), radius(3), internal, clockwise}
drawArrow(AB)          %from A to B
drawArrow(AB,CD)
drawCircle(J,12)
drawCircle(C,r2)
drawCircle(C,AB)       %% the radius is length of line AB
drawCircumcircle(ABC)
drawCurve(ABC)          %% three points only
```

```
drawExcircle(ABC)
drawIncircle(ABC)
drawLine(AB)
drawline*(AB, CDEF)     %% the * option disables use of \putrule
drawLine(ABCDE)
drawPerpendicular(P,AB)
drawPoint(B)
drawPoint(ABP1P2)
drawRightAngle(ABC, 4)
drawSquare(P,2)    %% side = 2
drawThickArrow(AB)
drawThickArrow(AB,CD)
drawThickLine(RS,TU)
inputFile(mathspic.dat)
inputFile(mathspic.dat)[4]
inputfile*(fig2.dat)       %% disables mathsPIC processing of file
linethickness(2pt)
paper{units(1mm,3mm),xrange(-5,50),yrange(-5,50),axes(LR)}
paper{units(2cm),xrange(0,5),yrange(0,9),axes(X*Y),ticks(1,1)}
paper{units(k mm),xrange(0,5),yrange(0,9),axes(X*Y),ticks(1,1)}
point(D1){20,2}
point(D4){6.3,8.9}
point(P){x1,y1}
point(P){Q}   %% make P have same coords as Q
point(P){xcoord(Q),ycoord(Q)}  %% same as  point(P){Q}
point(P){AB,PQ}
point(P){3,4}[symbol=$\odot$,radius=2]
point(P){3,4}[radius=2]
point(D2){20,2}[symbol=square(2),radius=3]
point(D3){20,3}[symbol=circle(r),radius=5]
point(D4){20,4}[symbol=$\Box$]
point(E1){D1, shift(5,6)}
point(E5){D1, shift(r2,6)}
point(E2){D2, polar(8, 1.34)}           %% radians is the default
point(E2){D2, polar(8, 1.34 rad)}
point(E2){D2, polar(8, direction(AB))}  %% radians is the default
point(E2){D2, polar(8,45 deg)}
point(E6){D2, polar(r4,45 deg)}
point(E2){D2, polar(8, directiondeg(AB) deg)}
point(E5){D2, polar(AB,45 deg)}
point(G2){Q, rotate(P, 23 deg)}  %% rotate Q about P by 23 deg
point(P){J, vector(AB)}     %% from J with direction and length AB
```

```
point(D32){midpoint(AB)}
point(D2){intersection(AB,CD)}
point(F){PointOnLine(AB,5)}
point(F){PointOnLine(AB,-d)}
point(G){perpendicular(P,AB)}
point(H){circumcirclecenter(ABC)}
point(J){incirclecenter(ABC)}
point(K){excirclecenter(ABC,BC)}
point*(D1){20,3}
point*(E1){D1, shift(3,0)}
point*(E1){E1}[radius=3] %% change the line-free radius
PointSymbol(circle(r))
PointSymbol(square(1),2)
PointSymbol($\odot$,2)
PointSymbol(default)
PointSymbol(default,0.5)
showAngle()
showArea()
showLength()
showVariables
showPoints
system("dir > mydir-listing.txt")
system("perl myprogram.pl")
text(P){5,7}
text($A$){A}
text($K$){K}[r]
text($B$){B, shift(5,5)}
text($Z3$){Z2, polar(5, 20 deg)}[Br]
text(\framebox{$Z5$}){Z3}
\newcommand{\mybox}{\framebox{$Z5$}}
text(\mybox){P421}
text(\framebox{$C$}){C, polar(5,62 deg)}[Br]
var r3 = 20, r4 = r3 * tan(0.4), r5 = AB, e=_e_, p1 = _Pi_
var g = angle(ABC)% (returns in radians)
var g = angledeg(ABC)% (returns in degrees)
var a = area(ABC)
var d = vector(PQ) % angular direction of PQ in radians
var d = vectordeg(PQ) % angular direction of PQ in degrees
var x2 = xcoord(A), y2 = ycoord(A)
var m5 = 12 rem 3   %% remainder after dividing by 3
```

5

PICTEX commands

Note that PICTEX commands can *only* be used within the `\beginpicture` ... `\endpicture` environment, as described in the PICTEX Manual[1] (Wichura, 1992).

Most PICTEX commands are short one-line commands starting with a leading backslash. Such commands can be used in the normal way as mathsPIC will automatically copy lines starting with a backslash command unchanged through into the output-file (`.mt` file). For example, drawing with dashed lines is enabled using the PICTEX `\setdashes` command, and this would be expressed in the mathsPIC file as follows.

```
\setdashes
```

However, some PICTEX commands are very long. It is therefore sometimes necessary to have the initial part of a PICTEX command on one line, with the rest of the command continuing onto the next line, such that the second and subsequent lines may well not have a leading backslash command. In order to protect such subsequent lines from being processed as mathsPIC commands, they must be protected by a leading backslash *followed by one or more spaces* (e.g. \␣...) as this instruction tells mathsPIC to copy the rest of the line unchanged (*without* the leading backslash) through into the output-file. For example, the PICTEX code for plotting data-points for a curve could be spread across several lines in the mathsPIC file as follows.

```
\setquadratic
\plot  1.15    -0.67
\      1.25     0.02
\      1.35     1.24
\      1.45     3.13 /
\setlinear
```

[1] See Section 9.5 for information regarding the PICTEX manual, and PICTEX files on CTAN.

When these commands are processed by mathsPIC, they will appear in the output TEX file (.mt file) as follows.

```
\setquadratic
\plot  1.15    -0.67
       1.25     0.02
       1.35     1.24
       1.45     3.13 /
\setlinear
```

5.1 Useful PICTEX commands

The following is a list of PICTEX commands which are particularly useful for including in the mathsPIC file, mainly for controlling the thickness of lines and axes, customising dash patterns and symbol spacing, and for plotting and rotation. See also Chapter 9 for details of other PICTEX files and packages available on CTAN.

Note that there is a section on PICTEX in Alan Hoenig's recent book *TEX Unbound*[2] which also includes a brief list of commands.

Note that where small angle brackets are shown (e.g. <...>) then these must be used exactly as shown, including spaces.

```
\grid {cols} {rows}  %% eg \grid {5} {10}
\setdashpattern <4pt, 2pt>
\setdashes <7pt>  %% equivalent to  \setdashpattern <7pt, 7pt>
\setdashes        %% default is  \setdashes <5pt>
\setdots <4pt>
\setdots          %% default is  \setdots <5pt>
\setsolid         %% sets solid-line mode (ie not dashes/dots)
\setlinear        %% sets straight-line plotting mode
                  %% (ie not quadratic)
\setquadratic     %% sets curved plotting for graphs etc
\setplotsymbol({\large .})
\setplotsymbol({\tiny .})   %% default size for curves
                            %% (used by \plot)
\plotsymbolspacing=2pt  %% sets spacing between plot symbols
                        %% (used by \plot)
\plotheading{..}        %% eg \plotheading{This is a quadratic}
\headingtoplotskip=1cm  %% separation between plotheading & graph
\linethickness=2pt      %% for horiz & vert lines: default 0.4pt
\frame <sep> {text}           %% eg  \frame <5pt> {Hello}
```

[2] Hoenig A (1998). *TEX Unbound: LATEX and TEX strategies for fonts, graphics, & more.* (Oxford University Press, UK) pp 580. ISBN: 0-19-509685-1 (hardback), 0-19-509686-X (paperback); see pages 377–389.

```
\rectangle <width> <height>   %% eg  \rectangle <2cm> <1cm>
\putrectangle corners at 5 10 and 30 5   %% corners at Top-left
                                          %% and Bottom-right
\inboundscheckon        %% restricts plotting to plotting area
\inboundscheckoff       %%
\normalgraphs           %% restores default values for
                        %% graph parameters (see Section 4.6.1)
\circulararc 30 degrees from 3.5  4.5 center at 5 5
\ellipticalarc axes ratio 2:1  360 degrees from 3 3 center at 5 5
(axes ratio is  major-axis:minor-axis, i.e.~ a:b)
```

Note that PICTEX also has an excellent rotation facility. PICTEX will rotate about a given point, by a given angle, all picture elements (but not text) which are detailed between its `\startrotation...` and `\stoprotation` commands. However the decimal value of the Sine and Cosine angle must be supplied (see below). If the point is not specified then rotation is performed about the origin. The format is as follows.

```
\startrotation by cos(t) sin(t) [about x y]
...
\stoprotation
```

This command is particularly useful for rotating curves. For example, to rotate an ellipse by 30 degrees about the point (5,5) one would write

```
\startrotation by  0.86602  0.5  about  5  5
\ellipticalarc.....
\stoprotation
```

Note that the `\startrotation` command would be easily amenable to rewriting as a mathsPIC macro (to avoid calculating the radian values etc).

A PICTEX error-bar facility is also available by loading the file `errorbar.tex` (see Section 9.4). Note that PICTEX does allow more sophisticated graph axes and tick-marks to be setup, as well as shading of enclosed areas. However, these are complicated and require access to the PICTEX Manual (see Section 9.5), and are currently outside the scope of mathsPIC.

5.2 Using the $ symbol with PICTEX

Because PICTEX was originally written for Plain TEX there is a difficulty when using the $ symbol in the labels for axes. The 'work-around' fix for this is to re-encode it as, say, `\dollar`, and express $2 as `{\dollar}2`, as shown in the following example which has dollars on the y-axis (note the % at the end of the first line to stop unwanted horizontal space being grabbed by PICTEXand pushing the Y-axis slightly to the right).

```
\newcommand{\dollar}{\char'44}%
\setcoordinatesystem units <1mm, 1mm>
\setplotarea x from 0 to 50, y from 0 to 50
\axis bottom ticks numbered from 0 to 50 by 10 /
\axis left ticks withvalues {\dollar}1  {\dollar}2 / at 10  20 /  /
\plotheading{A nice picture costing \$25}
```

6

TEX and LATEX commands

A mathsPIC file (or script) can contain any appropriate TEX and LATEX commands. Clearly a significant chunk of these commands relate to the preamble, and many of these are described in detail in Section 3.2.

6.1 The \typeout{} command

A very useful command is the `\typeout{}` command, which will make TEX print comments to the screen while the output-file is being processed. For example, the following commands in the mathsPIC file will print a message to the screen just before processing a data-file for a curve.

```
\typeout{processing the data-file now}%
inputfile*(curve.dat)
```

This command is also useful when a file is `input` several times in a loop using the mathsPIC `inputFile{..}[]` command. In such cases it is quite useful to include the line `\typeout{...}%` at the beginning of the file being input, as this results in TEX printing `...` to the screen each time the file is input.

Note the importance of including the comment `%` symbol at the end of the line when the `\typeout{}%` command is used within the PICTEX picture environment.

6.2 The Color package

The Color package can be used to draw parts of a diagram in colour, in much the same way one would when dealing with text (note that the color package must be installed *after* mathspic). One simply inserts the the usual LATEX commands between mathsPIC commands. In practice we have found that it is prudent to

include the `\normalcolor` command immediately following the `\beginpicture` command, and also immediately before the `\endpicture` command, in order to prevent strange colors spreading into any following text (following the diagram).

For example, the following code will draw the line PQ in blue. Note the two instances of the `\normalcolor` command.

```
\usepackage{mathspic, color}
....
\beginpicture
\normalcolor
....
....
\color{blue}
\drawline(PQ)
\color{black}
....
....
\normalcolor
\endpicture
```

The colours will be visible in PostScript (use `dvips`) and PDF (use `ps2pdf`; `pdfLaTeX`) . Note however, that some DVI-viewers do not currently show colour (e.g. XDVI for Linux).

6.3 Other useful LATEX commands

Note that it is important to put a % on the end of these LATEX commands in order to prevent PICTEX from adding spaces to the end. For more details of these useful commands see Knuth (1990) p 272–279; Eijkhout (1992); Salomon (1995).

```
\typeout{drawing circle now}%
\scrollmode  %(forces TeX to display errors but not to stop)
\nonstopmode
\batchmode
\newlength{}
\newcommand{}
\settowidth{}
\settolength{}
\settodepth{}
\newcount       %% \newcount\loopcounter
\advance        %% \advance\loopcounter by 1
\divide         %% \divide\mycounter by 2
\multiply       %% \multiply\mycounter by 2
```

```
\newwrite
\openout
\immediate\write18{...}
\write
\closeout
\the
\number
\showthe
\jobname
```

7

Examples

This section describes some practical examples of figures drawn using mathsPIC, together with the associated code.

When drawing a new figure or diagram, the authors finds it best to start with a graduated coordinate frame (see Figure 7.1) using the `axes` and `ticks` options of the `paper` command. The next step is to define an *anchor point* from which other points can be derived—this has the advantage that the whole figure can then be moved by simply changing the coordinates of the anchor point. If necessary, different parts of a complicated figure can be made having their own separate anchor points, allowing the various parts to be easily adjusted relative to each other. Finally, the frame should be moved close to the edge of the figure by adjusting the `xrange` and `yrange` parameters, in order to remove unnecessary surrounding white space, after which the the `axes` and `ticks` options of the `paper` command can be removed ready for inserting into the document. The code can then be either pasted into the document directly (within a `\beginpicture...\endpicture` environment), or kept as a separate file and then `\input` as required.

As regards scales and units, the authors find it most convenient to use the 1mm units and to keep the x and y scales the same whenever possible (i.e. use `paper{units(1mm)...}`), since this allows easy scaling up and down after the figure has been finished.

7.1 Input- and output-files

The following example mathsPIC file (input-file) illustrates how some of these commands are used to draw Figure 7.1. Note that the dashed line BD is drawn after the PiCTeX `\setdashes` command is invoked; following this `\setsolid` is used before drawing the right-angle symbol. Also, the points A, B, C are defined using the TeX `\odot` symbol $\odot$, in conjunction with a line-free zone of 1·2 mm in order

to make the lines go to the edge of the symbol—the value of the radius of such TEX symbols has to be determined by trial and error—see Table 1.

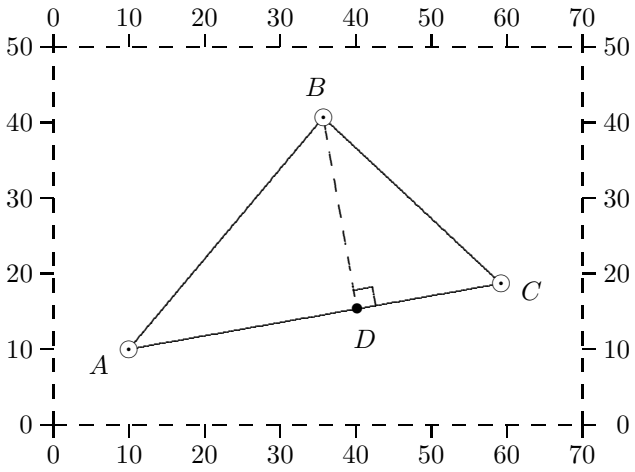


Figure 7.1:

```
%% mpicpm07-1.m  (Figure 7.1)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
\setdashes
paper{units(1mm),xrange(0,70),yrange(0,50),axes(LRTB),ticks(10,10)}
\setsolid
point(A){10,10}[symbol=$\odot$, radius=1.2]     %% anchor point
point(B){A, polar(40, 50 deg)}[symbol=$\odot$, radius=1.2]
point(C){A, polar(50, 10 deg)}[symbol=$\odot$, radius=1.2]
point(D){perpendicular(B,AC)}
drawPoint(ABCD)
drawLine(ABCA)
\setdashes
drawLine(BD)
\setsolid
drawRightangle(BDC,2.5)
text($B$){B, shift(-1,4)}
text($A$){A, shift(-4,-2)}
```

```
text($C$){C, shift(4,-1)}
text($D$){D, shift(1,-4)}
showLength(BD)
showLength(AC)
showArea(ABC)
showAngle(ABC)
\endpicture
\end{document}
```

When the above mathsPIC file is processed by mathsPIC the output-file (`.mt` file) is as follows. Note how the PiCTeX commands are preceded by their mathsPIC commands (commented out), some of which have additional information (e.g. the coordinates of a derived point—see the line `%% point(D)...`). Being able to compare the mathsPIC commands and the resulting PiCTeX commands in the output-file is particularly useful when debugging. Note also how the `show...` commands at the end of the file return the lengths AD, BC, the area ABC, and the angle ABC.

```
%* ------------------------------------------------
%* mathsPIC (Perl version 0.99.22 Dec 29, 2004)
%* A filter program for use with PiCTeX
%* Copyright (c) 2004 A Syropoulos & RWD Nickalls
%* Command line: mpic09922.pl -b mpicpm07-1.m
%* Input filename : mpicpm07-1.m
%* Output filename: mpicpm07-1.mt
%* Date & time: 2005/01/05    10:00:40
%* ------------------------------------------------
%% mpicpm07-1.m  (figure 7.1)
%% mathsPIC  Perl  triangle
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
\setdashes
%% paper{units(1mm),xrange(0,70),yrange(0,50),axes(LRTB),ticks(10,10)}
\setcoordinatesystem units <1mm,1mm>
\setplotarea x from 0.00000 to 70.00000, y from 0.00000 to 50.00000
\axis left ticks numbered from 0 to 50 by 10 /
\axis right ticks numbered from 0 to 50 by 10 /
\axis top ticks numbered from 0 to 70 by 10 /
\axis bottom ticks numbered from 0 to 70 by 10 /
\setsolid
%% point(A){10,10}[symbol=$\odot$, radius=1.2]
```

```
        %% anchor point A = (10.00000, 10.00000)
%% point(B){A, polar(40, 50 deg)}[symbol=$\odot$, radius=1.2]
        B = (35.71150, 40.64178)
%% point(C){A, polar(50, 10 deg)}[symbol=$\odot$, radius=1.2]
  C = (59.24039, 18.68241)
%% point(D){perpendicular(B,AC)}  D = (40.17626, 15.32089)
%% drawPoint(ABCD)
\put {$\odot$} at 10.00000 10.00000 %% A
\put {$\odot$} at 35.71150 40.64178 %% B
\put {$\odot$} at 59.24039 18.68241 %% C
\put {$\bullet$} at 40.17626 15.32089 %% D
%% drawLine(ABCA)
\plot 10.77135 10.91925 34.94015 39.72253 / %% AB
\plot 36.58878 39.82302 58.36311 19.50117 / %% BC
\plot 58.05862 18.47403 11.18177 10.20838 / %% CA
\setdashes
%% drawLine(BD)
\plot 35.91988 39.46001 40.17626 15.32089 / %% BD
\setsolid
%% drawRightangle(BDC,2.5)
\plot  42.63828 15.75501    42.20416 18.21703   /
\plot  39.74214 17.78291    42.20416 18.21703   /
%% text($B$){B, shift(-1,4)}
\put {$B$} at 34.711500 44.641780
%% text($A$){A, shift(-4,-2)}
\put {$A$} at 6.000000 8.000000
%% text($C$){C, shift(4,-1)}
\put {$C$} at 63.240390 17.682410
%% text($D$){D, shift(1,-4)}
\put {$D$} at 41.176260 11.320890
%% length(bd) = 25.7115062228898
%% length(ac) = 50.0000025076019
%% area(abc) = 642.7877063896
%% angle(abc) = 86.97613 deg ( 1.51802 rad)
\endpicture
\end{document}
```

If the above output-file (`.mt` file) is to be included or `\input` into a document (say, into a `figure` environment), it is sometimes useful to reduce the size of the file by disabling the writing of `%%` comment lines (using the command-line `-c` switch), as well as some of the header and footer lines which are not now required, as follows.

```
%* ------------------------------------------------
%* mathsPIC (Perl version 0.99.22 Dec 29, 2004)
%* A filter program for use with PiCTeX
%* Copyright (c) 2004 A Syropoulos & RWD Nickalls
%* Command line: mpic09922.pl -c mpicpm07-1.m
%* Input filename : mpicpm07-1.m
%* Output filename: mpicpm07-1.mt
%* Date & time: 2005/01/05    11:50:14
%* ------------------------------------------------
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
\setdashes
\setcoordinatesystem units <1mm,1mm>
\setplotarea x from 0.00000 to 70.00000, y from 0.00000 to 50.00000
\axis left ticks numbered from 0 to 50 by 10 /
\axis right ticks numbered from 0 to 50 by 10 /
\axis top ticks numbered from 0 to 70 by 10 /
\axis bottom ticks numbered from 0 to 70 by 10 /
\setsolid
\put {$\odot$} at 10.00000 10.00000 %% A
\put {$\odot$} at 35.71150 40.64178 %% B
\put {$\odot$} at 59.24039 18.68241 %% C
\put {$\bullet$} at 40.17626 15.32089 %% D
\plot 10.77135 10.91925 34.94015 39.72253 / %% AB
\plot 36.58878 39.82302 58.36311 19.50117 / %% BC
\plot 58.05862 18.47403 11.18177 10.20838 / %% CA
\setdashes
\plot 35.91988 39.46001 40.17626 15.32089 / %% BD
\setsolid
\plot  42.63828 15.75501    42.20416 18.21703   /
\plot  39.74214 17.78291    42.20416 18.21703   /
\put {$B$} at 34.711500 44.641780
\put {$A$} at 6.000000 8.000000
\put {$C$} at 63.240390 17.682410
\put {$D$} at 41.176260 11.320890
%% length(bd) = 25.7115062228898
%% length(ac) = 50.0000025076019
%% area(abc) = 642.7877063896
%% angle(abc) = 86.97613 deg ( 1.51802 rad)
\endpicture
\end{document}
```

Note that the remaining comments at the end of the `\plot` and `\put` lines are generally sufficient to understand what each line relates to. Note also that the `-c` switch only removes comment lines having a leading `%%` pair of characters (but not the results of the `show()` commands); comment lines prefixed with only a single `%` character remain.

7.2 Line modes

When drawing figures with both solid and dashed lines it is necessary to switch between the PICTEX commands `\setdashes` and `\setsolid`, as in the following code for drawing the rectangular box shown in Figure 7.2. The default `\setdashes` gives alternating lines and spaces, each of width 5pt.

More fancy dash-patterns (see Figure 7.2) can be easily generated using the mathsPIC `dasharray()` command which defines the pattern cycle, and hence takes an even number of parameters. For example the command

```
dasharray(6pt,2pt,1pt,2pt)
```

generates the dash pattern used for lines AH and DE in Figure 7.2.

If several different dash patterns are required then it maybe useful to define them as separate mathsPIC macros, as follows for example.

```
%def fancydashes()  dasharray(6pt,2pt, 1pt, 2pt)
%def simpledashes()  dasharray(4pt,4pt)
```

The separate patterns can then be called as required as follows (see Figure 7.2).

```
...
fancydashes
drawline(AH, DE)
simpledashes
drawline(BG, CF)
...
```

The equivalent PICTEX command is the `\setdashpattern` command which also takes an even number of parameters but has a slightly different syntax as follows.

```
\setdashpattern <6pt,2pt,1pt,2pt>
```

The equivalent LATEX macro would be as follows.

```
\def\fancydashes{\setdashpattern <6pt, 2pt, 1pt, 2pt>}%
...
\fancydashes
```

Note that in Figure 7.2 all the points are defined, directly or indirectly, relative to point A, with the effect that the position of the whole figure can be adjusted simply by altering the coordinates of point A. This can be useful when drawing diagrams having several components since the relative position of each component can then be easily adjusted.

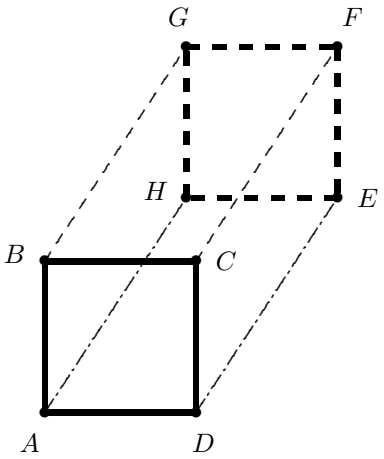


Figure 7.2:

```
%% mpicpm07-2.m (Figure 7.2)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
paper{units(1mm), xrange(0,50), yrange(0,62)}
var s= 20  % Sides front & back
var L = 34  % Length
var a2 = 56.6  % angle degrees
%def fancydashes() dasharray(6pt,2pt, 1pt, 2pt)%
%def simpledashes() dasharray(4pt,4pt)%
point(A){5,7}
point(B){A, polar(s,90 deg)}
point(C){B, polar(s,0  deg)}
point(D){A, polar(s,0  deg)}
point(H){A, polar(L,a2 deg)}
point(G){B, polar(L,a2 deg)}
```

```
point(F){C, polar(L,a2 deg)}
point(E){D, polar(L,a2 deg)}
drawpoint(ABCDEFGH)
linethickness(2pt)
  \setsolid
drawline(ABCDA)
  \setdashes
drawline(HGFEH)
linethickness(default)
&fancydashes
drawline(AH, DE)
&simpledashes
drawline(BG, CF)
text($A$){A, shift(-2,-4)}
text($B$){B, shift(-4,1)}
text($C$){C, shift(4,0)}
text($D$){D, shift(1,-4)}
text($E$){E, shift(4,0)}
text($F$){F, shift(2,4)}
text($G$){G, shift(-1,4)}
text($H$){H, shift(-4,1)}
\endpicture
\end{document}
```

7.3 Arrows

Arrows can be drawn in all possible orientations, will *stretch* between points, and arrow-heads are readily customised using the mathsPIC `Arrowshape` command (see also Salomon, 1992).

Although arrow shape can of course be controlled using the standard PICTEX `\arrow` command, the mathsPIC `Arrowshape` command makes this easier by allowing you to define (in degrees) the angle parameters (B and C) of the arrow-head directly (see box). The default arrowshape is equivalent to the following command

```
Arrowshape(2mm,30,40)
```

and can be invoked using the command

```
ArrowShape(default)
```

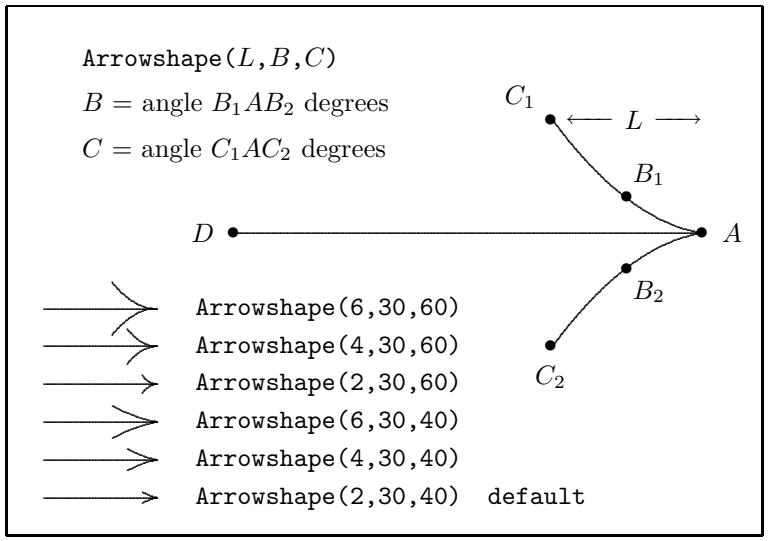


Figure 7.3: The mathsPIC code for this figure is given in the appendix

If the arrowshape has been altered, it can be reset using the `ArrowShape(default)` command. Curved arrows (circular arcs) are drawn using the `drawAngleArrow` command, which takes parameters for the angle, radius of arc, direction, and whether the angle is internal or external (see Figures 7.4 and 7.5).

Arrows can also be used to link elements in a diagram, as shown in Figure 7.5. The right-hand diagram uses the `drawArrow` command; the small gap between

```
%% mpicpm07-4.m (Figure 7-4)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
paper{units(1mm),xrange(5,45),yrange(5,45)}
point(A){30,30}
point(P){10,10}
point(B){30,10}
drawPoint(APB)
drawLine(APBA)
var d = 5
text($A$){A,shift(1,d)}
text($B$){B,shift(d,0)}
text($P$){P,shift(-d,0)}
drawAngleArrow{angle(BPA),radius(11),internal, anticlockwise}
text($\psi$){P,polar(7,22.5 deg)}
drawRightangle(ABP,2.5)
\endpicture
\end{document}
```

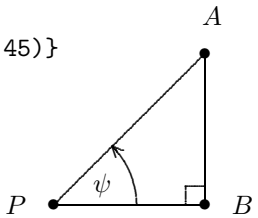
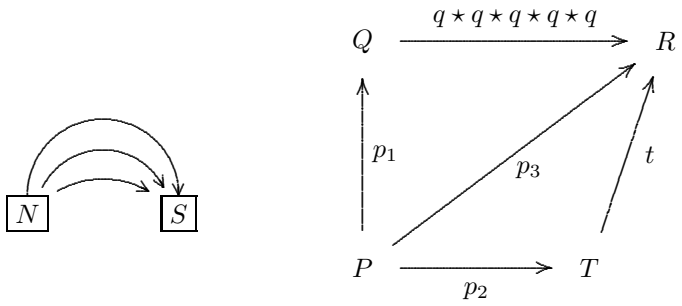


Figure 7.4:

the arrows and the letters P, Q, R, T being due to the 5 unit line-free radius associated with these points (see Figure 7.5b. The arrows are easily 'stretched' to accommodate their labels simply by adjusting the separation of the nodes using the `polar(`r`,`θ`)` commands (see Feruglio, 1994).

```
%% mpicpm07-5a.m (Figure 5a)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
paper{units(1mm),xrange(10,40),yrange(0,45)}%, axes(LB), ticks(10,10)}
point(N){15,20}
point(S){N,shift(20,0)}
text(\framebox{$N$}){N,shift(0,-2.5)}
text(\framebox{$S$}){S,shift(0,-2.5)}
point(Z){midpoint(NS)}
drawAngleArrow{angle(NZS),radius(NZ),internal,clockwise}
point(N1){N,shift(2,1)}
point(S1){S,shift(-2,1)}
point(Z1){Z,shift(0,-3)}
```



a. Circular arrows b. Straight arrows

Figure 7.5:

```
drawAngleArrow{angle(N1Z1S1),radius(N1Z1),internal,clockwise}
point(N2){N1,shift(2,-0.5)}
point(S2){S1,shift(-2,-0.5)}
point(Z2){Z,shift(0,-10)}
drawAngleArrow{angle(N2Z2S2),radius(N2Z2),internal,clockwise}
\endpicture
\end{document}
```

```
%% mpicpm07-5b.m (Figure 7.5b)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
paper{units(1mm),xrange(0,45),yrange(0,45)}%, axes(LB), ticks(10,10)}
point(P){5,10}[symbol=$P$,radius=5]
point(Q){P,polar(30,90 deg)}[symbol=$Q$,radius=5]
point(R){Q,polar(40,0 deg)}[symbol=$R$,radius=5]
point(T){P,polar(30,0 deg)}[symbol=$T$,radius=5]
drawPoint(PQRT)
drawArrow(PQ,QR,PT,TR,PR)
point(P1){midpoint(PQ)}
text($p_1$){P1,shift(3,0)}
point(P2){midpoint(PT)}
text($p_2$){P2,shift(0,-3)}
point(P3){midpoint(PR)}
```

```
text($p_3$){P3,shift(2,-2)}
point(T1){midpoint(TR)}
text($t$){T1,shift(3,0)}
point(Q1){midpoint(QR)}
%% use a LaTeX macro for the label
\newcommand{\q}{$q \star q \star q \star q \star q$}
text(\q){Q1,shift(-1,3)}
\endpicture
\end{document}
```

7.4 Circles & colour

MathsPIC allows the point-symbol to be designated as a circle using the option `[symbol=circle(r),radius=z]` to the `point()` command, which not only gives the circles an internal line-free zone, but also arranges that they are drawn by the `drawPoint` command, as shown in Figure 7.6. This construction greatly simplifies the drawing of directed graphs, trees and equivalent structures. In Figure 7.6 we have also made use of the LaTeX Color package to make the circles red, the lines blue, and the text and labels black, as can be seen from the code in the mathsPIC file. However, the colours will only be visible when viewing the PDF (via pdfLaTeX) or PostScript (via dvips) derivatives of the diagram.

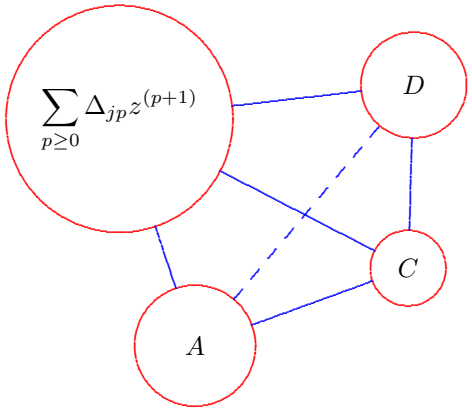


Figure 7.6:

```
%% mpicpm07-6.m  (figure 7.6)
%% 4 circles figure
\documentclass[a4paper]{article}
\usepackage{mathspic,color}
\begin{document}

\beginpicture
\normalcolor%
paper{units(1mm),xrange(0,70),yrange(0,60)}%
point(A){30,11}[symbol=circle(8),radius=8]
point(B){A,shift(-10,30)}[symbol=circle(15),radius=15]
point(C){A,polar(30,20 deg)}[symbol=circle(5),radius=5]
point(D){A,polar(45,50 deg)}[symbol=circle(7),radius=7]
\color{red}%
drawPoint(ABCD)
\color{blue}%
drawLine(AB,AC,BC,BD,CD)
\setdashes
drawLine(AD)
\color{black}%
text($A$){A}
%% use a macro for the formula
\newcommand{\formula}{%
\     $\displaystyle \sum_{p\ge0} \Delta_{jp} z^{(p+1)}$%
\     }%
text(\formula){B}
text($C$){C}
text($D$){D}
\normalcolor%
\endpicture
\end{document}
```

Note that in this particular case it is necessary to define the maths formula using the LaTeX `\displaystyle`, in order to avoid the embedded `\textwidth` white space associated with using `\vbox{\formula}` in the `\text()` command, and hence allow centering of the figure. Note also how the mathsPIC `\␣...` commands make it easy to include multi-line macros in the mathsPIC file.

Points on circles (and their labels) are most easily defined and positioned using the `polar(`r`,`θ`)` option, as shown in the mathsPIC file for Figure 7.7. Notice the use of the variable `r` for the radius of the circle (allocated using the command `var r = 20`), which then allows the use of `r` to define the radius in the `polar` commands for the points P, Q, S.

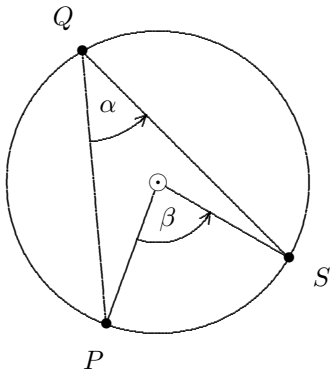


Figure 7.7:

```
%% mpicpm07-7.m (Figure 7.7)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
paper{units(1mm), xrange(5,55), yrange(5,55)}
point(C){30,30}[symbol=$\odot$,radius=1.2]   %% center
var r = 20                       %% radius
drawcircle(C,r)
point(P){C, polar(r,250 deg)}
point(Q){C, polar(r,120 deg)}
point(S){C, polar(r,-30 deg)}
drawpoint(CPQS)
drawline(PCSQP)
text($P$){P, polar(5,250 deg)}
text($Q$){Q, polar(5,120 deg)}
text($S$){S, polar(5,-30 deg)}
drawAngleArrow{angle(PCS), radius(8) internal anticlockwise}
text($\beta$){C, polar(5,285 deg)}
drawAngleArrow{angle(PQS), radius(12) internal anticlockwise}
text($\alpha$){Q, polar(8,-65 deg)}
showangle(PQS)     % alpha
showangle(PCS)     % beta
\endpicture
\end{document}
```

Note that the returned values in the output-file from the `showAngle` commands

(see below) for Figure 7.7 indicate that β is twice α, as one would expect.

```
%% angle(pqs) = 40.00000 deg ( 0.69813 rad)  %alpha
%% angle(pcs) = 80.00000 deg ( 1.39626 rad)  %beta
```

MathsPIC offers a range of other circle commands (`drawIncircle`, `drawExcircle`, `drawCircumcircle`) specifically for geometry diagrams, as shown in Figure 7.8.

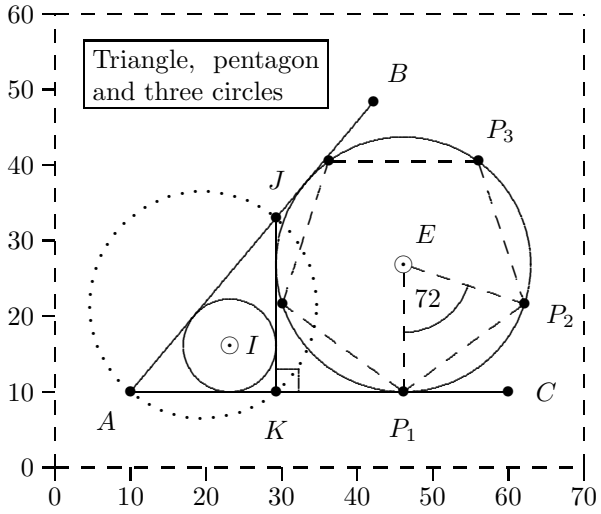


Figure 7.8:

```
%% mpicpm07-8.m  (Figure 7.8)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
\setdashes
paper{units(1mm),xrange(0,70),yrange(0,60),axes(LBT*R*),ticks(10,10)}
\setsolid
point(A){10,10}   %% anchor point
point(B){A, polar(50,50 deg)}
point(C){A,polar(50,0 deg)}
point(J){pointonline(AB,30)}
point(K){perpendicular(J,AC)}
```

```
drawRightangle(JKC,3)
drawLine(AB,AC,JK)
drawIncircle(AJK)
drawExcircle(AJK,JK)
\setplotsymbol({\large .}) \setdots
drawCircumcircle(AJK)
\setplotsymbol({\tiny .})
point(I){IncircleCenter(AJK)}[symbol=$\odot$, radius=1.2]
point(E){ExcircleCenter(AJK,JK)}[symbol=$\odot$, radius=1.2]
point(P1){perpendicular(E,AC)}
var r = EP1  %% radius of excircle
var d = 72   %% angle of pentagon (deg)
var a1 = -90, a2=a1+d, a3=a2+d, a4=a3+d, a5=a4+d
point(P2){E, polar(r,a2 deg)}
point(P3){E, polar(r,a3 deg)}
point(P4){E, polar(r,a4 deg)}
point(P5){E, polar(r,a5 deg)}
drawPoint(ABCJKIEP1P2P3P4P5)
\setdashes
drawLine(P1P2P3P4P5P1,EP1,EP2)
\setsolid
drawAngleArc{angle(P2EP1),radius(9),internal,clockwise}
\newcommand{\figtitle}{%
   \fbox{%
   \begin{minipage}{30mm}%
   \  Triangle, pentagon and three circles%
   \end{minipage}%
   \  }}%
text(\figtitle){20,52}
var s = 5
text($A$){A,polar(s,230 deg)}
text($B$){B,polar(s,50 deg)}
text($C$){C,polar(s,0 deg)}
text($J$){J,polar(s,90 deg)}
text($K$){K,polar(s,270 deg)}
text($E$){E,polar(s,a3 deg)}
text($72$){E,polar(5.5,-54 deg)}
text($I$){I,shift(3, 0)}
text($P_1$){P1,polar(s, a1 deg)}
text($P_2$){P2,polar(s, a2 deg)}
text($P_3$){P3,polar(s, a3 deg)}
\endpicture
```

```
\end{document}
```

7.5 Functionally connected diagrams

When constructing diagrams it is often useful to write the mathsPIC file in such a way that the position of each new point is related to that of earlier points, since then the structure of the diagram is maintained even when points are moved as shown in Figure 7.9. Although the two diagrams appear to be quite different the mathsPIC code for the two diagrams differs *only* in the angle of the line AB (left diagram, 60 degrees; right diagram, 5 degrees) as defined in the `point(B){...}` command as follows.

- Left-hand diagram: `point(B){A,polar(45,60 deg)}`
- Right-hand diagram: `point(B){A,polar(45,5 deg)}`

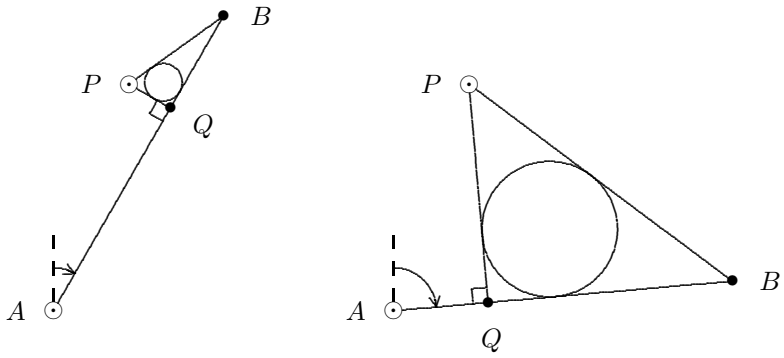


Figure 7.9: The mathsPIC code for the two diagrams differs *only* in the angle of the line AB as defined in the `point(B){...}` command (see `mpicpm07-9.m`).

```
%% mpicpm07-9.m (Figure 7.9)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
paper{units(1mm), xrange(5,110), yrange(0,45)}
point(A){15,5}[symbol=$\odot$, radius=1.2]
point(P){A, shift(10,30)}[symbol=$\odot$, radius=1.2]
```

```
point(B){A, polar(45,60 deg)}
point(Q){perpendicular(P,AB)}
drawRightangle(PQA,2)
drawPoint(ABPQ)
drawLine(ABPQ)
drawIncircle(PQB)
var d = 5
text($A$){A,shift(-d, 0)}
text($B$){B,shift(d, 0)}
text($P$){P,shift(-d, 0)}
point(S){pointOnLine(QP,-5)}
text($Q$){S}
point(N){A,shift(0,10)}
\setdashes
drawline(AN)
\setsolid
drawAngleArrow{angle(NAB), radius(5.7), internal, clockwise}
%%---------  second figure --------------------
point*(A){60,5}[symbol=$\odot$, radius=1.2]
point*(P){A, shift(10,30)}[symbol=$\odot$, radius=1.2]
point*(B){A, polar(45,5 deg)} %%5 60 deg
point*(Q){perpendicular(P,AB)}
drawRightangle(PQA,2)
drawPoint(ABPQ)
drawLine(ABPQ)
drawIncircle(PQB)
text($A$){A,shift(-5, 0)}
text($B$){B,shift(5, 0)}
text($P$){P,shift(-5, 0)}
point*(S){pointOnLine(QP,-5)}
text($Q$){S}
point*(N){A,shift(0,10)}
\setdashes
drawline(AN)
\setsolid
drawAngleArrow{angle(NAB), radius(5.7), internal, clockwise}
\endpicture
\end{document}
```

Note that in Figure 7.9 the location of the label 'Q' is made to lie outside the figure by placing the label at point S, which is defined as being 5 mm to the right of the line AB and in-line with the points PQ, using the command `point(S){pointOnLine(QP,-5)}`.

7.6 Inputting the same data-file repeatedly

There are two methods:

- use the `beginloop [n] ... endloop` environment

  The file `myfile.dat` is input six times sequentially using the commands

  ```
  beginLOOP 6
      inputfile(myfile.dat)
  endLOOP
  ```

- use the `inputfile [n]` command

  The file `myfile.dat` is input six times sequentially using the single command `inputfile(myfile.dat)[6]`.

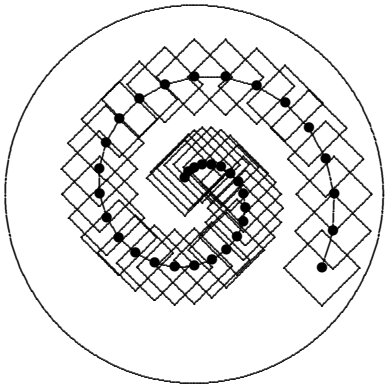


Figure 7.10:

Figure 7.10 was produced by the following code which inputs a small file of mathsPIC code (`mpicpm07-10.dat`) repeatedly 35 times using the command `inputfile(mpicpm07-10.dat)[35]`. Note the use of the `point*` commands in the data-file to re-allocate points.

```
%% mpicpm07-10.m  (figure 7-10)
%% mathsPIC  small spiral by recursion
%%  (requires datafile mpicpm07-10.dat)
\documentclass[a4paper]{article}
```

```
\usepackage{mathspic}
\begin{document}
\beginpicture
paper{units(1mm), xrange(0,60), yrange(0,60)}% axes(LB), ticks(10,10)}
point(C){30,30}   % circle center
drawcircle(C,25)
%% initialise the reusable points and variables
var a=315  % angle degrees
var r=20   % start radius
var s=5    % square semi-diagonal (see datafile)
point(T){C,polar(r,330 deg)}
%% cycle datafile 35 times
inputfile(mpicpm07-10.dat)[35]
\endpicture
\end{document}
```

```
%% mpicpm07-10.dat --------first line----------------
%% mathsPIC  (spiral data)  input by file mpicpm07-10.m
var a = a+15, r = r-0.5   %% increment angle and radius
point*(P){C,polar(r,a deg)} % increment point P
drawpoint(P)
drawline(TP)        %% draw line from OLD T to NEW P
point*(T){P}        %% reallocate T <-- P
%% make a rotated square centered on P with side/2=s
point*(Q1){P,polar(s,0 deg)}
point*(Q2){P,polar(s,90 deg)}
point*(Q3){P,polar(s,180 deg)}
point*(Q4){P,polar(s,270 deg)}
drawline(Q1Q2Q3Q4Q1)
%% eof ---------------------------------------------
```

When the `inputfile` command is used mathsPIC writes the iteration number to the output file, prefixed using three `%` symbols (to make sure they are not deleted when using the `-c` switch, as follows.

```
%%% Iteration number: 26
```

For example, the following extract shows the resulting output `.mt` file showing how mathsPIC writes the iteration number of each data-file input to the output file just before it inputs the data-file. This example includes the whole of the 26th cycle of data-file input. It also demonstrates the value of labeling the beginning and the end of the data-file differently in order to make it easy to see the cycling of the input file. This is very helpful as it allows you to check whether the data-file is working correctly.

```
...
...
\plot 31.49519 26.25000 36.49519 21.25000 / %% Q3Q4
\plot 36.49519 21.25000 41.49519 26.25000 / %% Q4Q1
%% eof ========================================
%%% Iteration number: 26
%% mpicpm07-10.dat --------first line----------------
%% mathsPIC  (spiral data)  input by file mpicpm07-10.m
%% var a = a+15, r = r-0.5   %% increment angle and radius
%% a = 705
%% r = 7
%% point*(P){C,polar(r,a deg)} %increment P, P=(36.76148, 28.18827)
%% drawpoint(P)
\put {$\bullet$} at 36.76148 28.18827 %% P
%% drawline(TP)        %% draw line from OLD T to NEW P
\plot 36.49519 26.25000 36.76148 28.18827 / %% TP
%% point*(T){P} %% reallocate T <-- P  T = (36.76148, 28.18827)
%% make a square on P  with side/2=s (s is defined in mpicpm07-10.m)
%% point*(Q1){P,polar(s,0 deg)}  Q1 = (41.76148, 28.18827)
%% point*(Q2){P,polar(s,90 deg)}  Q2 = (36.76148, 33.18827)
%% point*(Q3){P,polar(s,180 deg)}  Q3 = (31.76148, 28.18827)
%% point*(Q4){P,polar(s,270 deg)}  Q4 = (36.76148, 23.18827)
%% drawline(Q1Q2Q3Q4Q1)
\plot 41.76148 28.18827 36.76148 33.18827 / %% Q1Q2
\plot 36.76148 33.18827 31.76148 28.18827 / %% Q2Q3
\plot 31.76148 28.18827 36.76148 23.18827 / %% Q3Q4
\plot 36.76148 23.18827 41.76148 28.18827 / %% Q4Q1
%% eof ========================================
%%% Iteration number: 27
%% mpicpm07-10.dat --------first line----------------
...
...
```

Because mathsPIC prefixes the iteration number comment with %%% these comments remain even when the -c switch is used, as the following extract of the same data shows.

```
...
...
\plot 31.49519 26.25000 36.49519 21.25000 / %% Q3Q4
\plot 36.49519 21.25000 41.49519 26.25000 / %% Q4Q1
%%% Iteration number: 26
\put {$\bullet$} at 36.76148 28.18827 %% P
```

```
\plot 36.49519 26.25000 36.76148 28.18827 / %% TP
\plot 41.76148 28.18827 36.76148 33.18827 / %% Q1Q2
\plot 36.76148 33.18827 31.76148 28.18827 / %% Q2Q3
\plot 31.76148 28.18827 36.76148 23.18827 / %% Q3Q4
\plot 36.76148 23.18827 41.76148 28.18827 / %% Q4Q1
%%% Iteration number: 27
\put {$\bullet$} at 36.50000 30.00000 %% P
...
...
```

Using the `beginloop...endloop` environment

The script for the previous spiral figure of squares can be written more simply (i.e. without repeatedly inputing a separate file) using the `beginloop...endloop` environment as shown in the following example. Some care needs to be taken in initialising (before the loop) all those quantities which get changed or incremented with each cycle of the loop. Note also that (a) since we are not using the `inputfile` command it is useful to create a loop counter (n) so we can see which loop is which when we read the output `.mt` file, (b) the squares will not be rotated in this particular example as we are using the `[symbol=square(s)]` option with the point command in order to generate the square, and (c) since all mathsPIC commands are case-insensitive we have chosen to capitalise the 'loop' of the commands for clarity.

```
\beginpicture
paper{units(1mm), xrange(0,60), yrange(0,60) axes(LB), ticks(10,10)}
point(C){30,30}   % circle center
drawcircle(C,25)
%% initialise loop counter (n), angle (a), radius (r), side (s)
var n=0, a=315, r=20, s=7
point(T){C,polar(r,330 deg)}
beginLOOP 35       % loop 35 times
    %% increment loop counter (n), angle (a) and radius (r)
    var n=n+1, a = a+15, r = r-0.5
    %% increment position of new square with side s
    point*(P){C,polar(r,a deg)}[symbol=square(s)]
    drawpoint(P)         % draw new square
    text($\bullet$){P}   % draw bullet in center of new square
    drawline(TP)         % draw line from OLD T to NEW P
    point*(T){P}         % reallocate T <-- P
endLOOP
\endpicture
```

Using LaTeX to cycle a loopcounter

A slightly irritating problem associated with processing diagrams which involve repeated loops is that while the `.mt` file is being processed by LaTeX there is no screen activity to show how things are proceeding.

In this example program we therefore illustrate a simple way of using some LaTeX register commands (Knuth (1990) p 118–121; 272-273; Eijkhout (1992) p 242–244) in order to make LaTeX indicate the loop status on the screen while it is processing the `.mt` file. This can be useful for debugging especially if the loop is cycled many times.

We first allocate a suitable name to an unused TeX integer register (a so-called `count` register) using the TeX `\newcount` command (here we have used the name `\loopcounter`), and then we initialise it to zero, as follows (all in the main calling program).

```
\newcount\loopcounter
\loopcounter=0
```

Then in the loop (or in the data file itself) we increment the counter and also print the result to the screen using the `\typeout{...}%` command, remembering to include a `%` symbol at the end.

```
\advance\loopcounter by 1
\typeout{loop = \the\loopcounter}%
```

A typical use might therefore be as follows:-

```
\beginpicture
\newcount\loopcounter  %% allocate a TeX rigester
\loopcounter=0         %% initialise the register
%% create a convenient macro
\newcommand{\showloopnumber}{%
   \advance\loopcounter by 1           %increment TeX loop counter
   \typeout{loop = \the\loopcounter}%  %print loop no to screen
   \ }%
...
beginLOOP 26
    \showloopnumber%
    ....
endLOOP
\endpicture
```

The screen output during the LaTeX processing (with respect to the the command `latex mpicpm07-10.mt`) for this example then appears as the following.

```
This is TeX, Version 3.14159 (Web2C 7.4.5)
(./mpicpm07-10.mt
LaTeX2e <2001/06/01>
Babel <v3.7h> and hyphenation patterns for american, french, german,
basque, italian, portuges, russian, spanish, nohyphenation, loaded.
(/usr/share/texmf/tex/latex/base/article.cls
Document Class: article 2001/04/21 v1.4e Standard LaTeX document class
(/usr/share/texmf/tex/latex/base/size10.clo))
(/usr/share/texmf/tex/latex/base/mathspic.sty
Loading mathsPIC package (c) RWD Nickalls & A Syropoulos 08/08/2004
(/usr/share/texmf/tex/generic/pictex/prepictex.tex)
(/usr/share/texmf/tex/generic/pictex/pictexwd.tex)
(/usr/share/texmf/tex/generic/pictex/postpictex.tex)) (./mpicpm07-10.aux)
loop = 1
loop = 2
loop = 3
loop = 4
...
...
loop = 33
loop = 34
loop = 35
[1] (./mpicpm07-10.aux) )
Output written on mpicpm07-10.dvi (1 page, 106560 bytes).
Transcript written on mpicpm07-10.log.
```

7.7 Plotting graphs

Data-files which do *not* contain mathsPIC commands can be input using the `inputfile*()` command. This command inputs files *verbatim*, and so can be used for inputting files containing, for example, only PiCTeX commands and/or points for plotting curves. For example, the following mathsPIC code (`mpicpm07-11.m`) draws the quartic curve shown in Figure 7.11, by inputting in *verbatim* a datafile containing some PiCTeX commands and a set of data points for plotting. Note that in this example the x-axis is stretched by using `units(3cm,cm)` in the `paper{}` command.

```
%% mpicpm07-11.m  (Figure 7-11)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
```

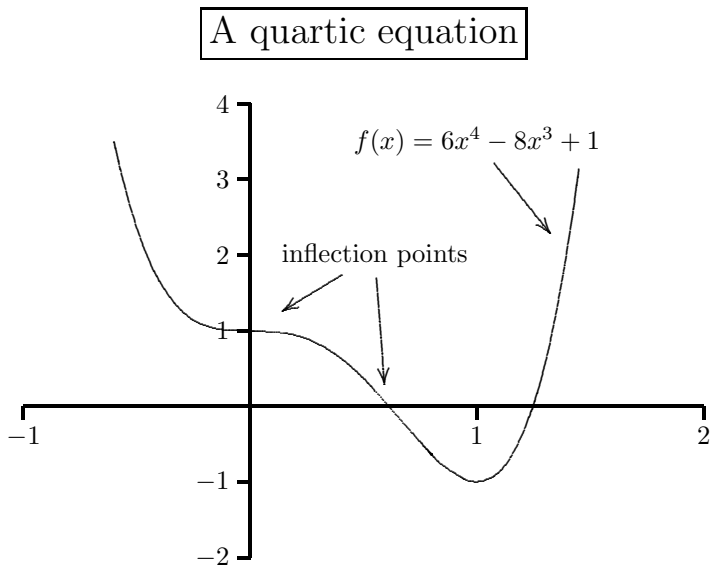


Figure 7.11:

```
\beginpicture
\linethickness=1pt  %% make a thick line for the axes
paper{units(3cm,1cm),xrange(-1,2),yrange(-2,4),axes(XY),ticks(1,1)}
\linethickness=0.4pt       %% reset to default value
\headingtoplotskip=8mm
\plotheading{\fbox{\Large A quartic equation}}
%% now load file containing data points for curve
inputfile*(mpicpm07-11.dat)
pointsymbol(default,0.3)  % define line-free-radius
point(E1){1,3.5}
text($f(x)=6x^4 - 8x^3 + 1$){E1}  % center the equation at E1
point(E2){1.4,2}
drawarrow(E1E2)
point(J1){0.55,2}
text(inflection points){J1}  % center inflection text at J1
point(J2){0,1}
point(J3){0.6,0}
drawarrow(J1J2,J1J3)
\endpicture
\end{document}
```

The datafile for the curve is as follows. Note that PICTEX requires an *odd* number of pairs of data points to satisfy its curve-drawing algorithm.[1]

```
%% mpicm07-11.dat  (Figure 7.11)
%% quartic curve data (use an odd number of data points)
\setquadratic
\plot
-0.6      3.50
-0.5      2.37
-0.4      1.66
-0.35     1.43
...
...
 1.15    -0.67
 1.25     0.02
 1.35     1.24
 1.45     3.13 /
\setlinear
%%EOF
```

However, when there are only a few data points, it is sometimes more convenient just to plot the points separately and then draw connecting lines, as shown in Figure 7.12.

```
%% mpicpm07-12.m  (Figure 7.12)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\usepackage{amssymb}
\begin{document}
\beginpicture
paper{units(1cm),xrange(0,6),yrange(73,77),axes(LBT*R*),ticks(1,1)}
pointsymbol($\odot$,0.2)
point(d1){1, 76.2}
point(d2){2, 76.2}
point(d3){3, 75.5}
point(d4){4, 75.7}
point(d5){5, 74.6}
drawpoint(d1d2d3d4d5)
drawline(d1d2d3d4d5)
%
```

[1] See the PICTEX manual (Wichura, 1992).

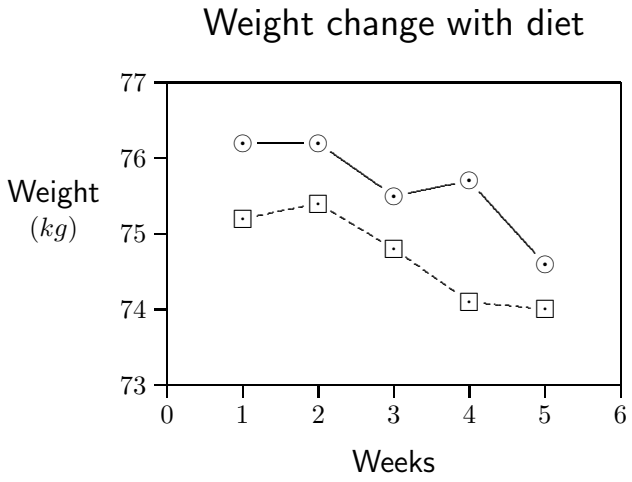


Figure 7.12:

```
pointsymbol($\boxdot$, 0.2)
point(k1){1, 75.2}
point(k2){2, 75.4}
point(k3){3, 74.8}
point(k4){4, 74.1}
point(k5){5, 74.0}
drawpoint(k1k2k3k4k5)
\setdashpattern <2pt, 2pt>
drawline(k1k2k3k4k5)
%
\plotheading{\textsf{\Large Weight change with diet}}
text(\shortstack{\textsf{\large Weight}\\($kg$)}){-1.5,75.3}
text(\textsf{\large Weeks}){3,72}
\endpicture
\end{document}
```

7.8 Drawing other curves

The `drawcurve` command can also be used for drawing smooth curves linking a number of points or touching lines. For example, Figure 7.13 shows a smooth curve touching a piecewise linear closed line[2], some of the points being constructed using

[2]Figure 7.13 was constructed and drawn by František Chvála.

a Bézier technique[3]. The smooth curve is drawn using the `drawcurve()` command for successive three-point sequences.

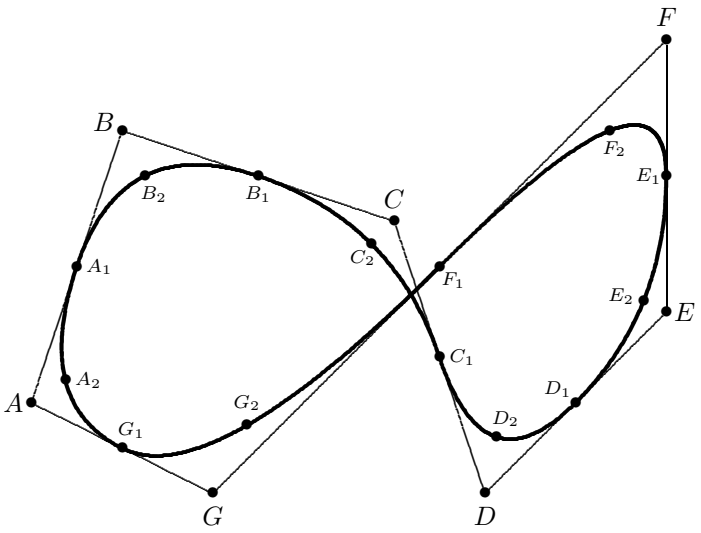


Figure 7.13: A smooth curve inscribed in the intersecting closed line $ABCDEFGA$

```
%% mpicpm07-13.m  (Figure 7.13)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
var u = 12    %%  units = 12 mm
paper{units(Umm),xRange(0.5,8.5),yRange(-0.5,5.5)}
var r = 0.7  %% line-free radius of \circ (0.7mm)
var r = r/u  %% line free radius scaled for U mm
pointsymbol($\circ$,r)
Point(A){1,1}
Point(B){2,4}
Point(C){5,3}
Point(D){6,0}
Point(E){8,2}
Point(F){8,5}
Point(G){3,0}
```

[3]see *The Metafont book* by DE Knuth, chapter 3 for details regarding Bézier curves.

```
pointsymbol(default)  %% restore $\bullet$
%
Point(A1){midpoint(AB)}
Point(B1){midpoint(BC)}
Point(C1){midpoint(CD)}
Point(D1){midpoint(DE)}
Point(E1){midpoint(EF)}
Point(F1){midpoint(FG)}
Point(G1){midpoint(GA)}
%
Point(A2){midpoint(G1A1)}
Point*(A2){midpoint(AA2)}
Point(B2){midpoint(A1B1)}
Point*(B2){midpoint(BB2)}
Point(C2){midpoint(B1C1)}
Point*(C2){midpoint(CC2)}
Point(D2){midpoint(C1D1)}
Point*(D2){midpoint(DD2)}
Point(E2){midpoint(D1E1)}
Point*(E2){midpoint(EE2)}
Point(F2){midpoint(E1F1)}
Point*(F2){midpoint(FF2)}
Point(G2){midpoint(F1G1)}
Point*(G2){midpoint(GG2)}
%
DrawPoint(ABCDEFG)
DrawPoint(A1B1C1D1E1F1G1)
DrawPoint(A2B2C2D2E2F2G2)
%
DrawLine(ABCDEFGA)
\setplotsymbol ({\Large.})
DrawCurve(A1B2B1)
DrawCurve(B1C2C1)
DrawCurve(C1D2D1)
DrawCurve(D1E2E1)
DrawCurve(E1F2F1)
DrawCurve(F1G2G1)
DrawCurve(G1A2A1)
%
Text($A$){A,shift(-0.2,0)}
Text($B$){B,shift(-0.2,0.1)}
Text($C$){C,shift(0,0.25)}
```

```
Text($D$){D,shift(0,-0.25)}
Text($E$){E,shift(0.2,0)}
Text($F$){F,shift(0,0.25)}
Text($G$){G,shift(0,-0.25)}
\scriptsize
Text($A_1$){A1,shift(0.25,0)}
Text($B_1$){B1,shift(0,-0.2)}
Text($C_1$){C1,shift(0.25,0)}
Text($D_1$){D1,shift(-0.2,0.15)} %
Text($E_1$){E1,shift(-0.2,0)}
Text($F_1$){F1,shift(0.15,-0.15)}
Text($G_1$){G1,shift(0.1,0.2)}
Text($A_2$){A2,shift(0.25,0)}
Text($B_2$){B2,shift(0.1,-0.2)}
Text($C_2$){C2,shift(-0.1,-0.15)}
Text($D_2$){D2,shift(0.1,0.2)}
Text($E_2$){E2,shift(-0.25,0.05)} %
Text($F_2$){F2,shift(0.05,-0.2)}  %
Text($G_2$){G2,shift(0,0.25)}    %
\endpicture
\end{document}
```

Note the technique used in the code for Figure 7.13 above, for making the *physical* line-free radius (r) invariant with respect to the scaling value (u) (i.e. does not change when the figure is enlarged or reduced by varying the value of the variable u), as follows.

```
....
var u = 12              %%  units = 12 mm
paper{units(u mm),xRange(0,9),yRange(-1,6)}
var r = 0.7             %% line-free radius of \circ = 0.7mm
var r = r/u    %% scaled linefree radius for u mm
pointsymbol($\circ$, r)
point(A){1,1}
....
```

This technique can be very useful when it is necessary to scale the figure after having designed the figure in order, say, to make it fit into a particular space in a document.

7.9 Using Perl programs & the system() command

Since mathsPIC allows access to the command-line via the system() command, users can write Perl programs which can then be used as a powerful aid for drawing complicated mathsPIC diagrams. In other words, components of a diagram (particularly those components which are frequently used) can be encoded as a small Perl program which can then be invoked via the mathsPIC system() command. Particularly useful is the fact that Perl programs can have parameters passed to them, which greatly increases their value and utility with regard to mathsPIC. Indeed, a mathsPIC file for drawing a particularly complicated diagram could usefully input several Perl programs, each drawing separate elements of the diagram.

In view of the interplay between the mathsPIC file and the Perl program it calls, we now describe two typical examples in some detail. In the following some familiarity with the Perl programming language is assumed.

7.9.1 Example-1

This example (see Figure 7.14) uses the small Perl program drawcurvedarrow.pl (see below) to generate the mathsPIC commands for drawing a curved arrow (note that there is no mathsPIC command for doing this at the moment), and place them in a temporary file which can then be accessed by the mathsPIC file.

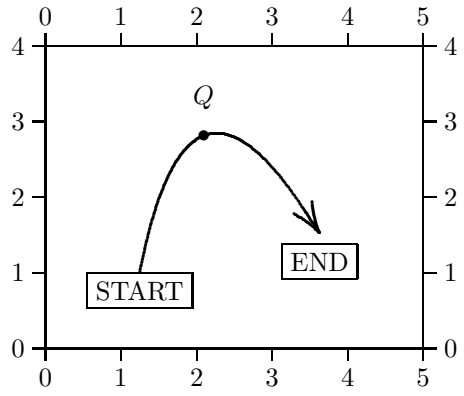


Figure 7.14:
A curved arrow drawn using the Perl program drawcurvedarrow.pl

Perl program (drawcurvedarrow.pl)

```
#!/usr/bin/perl
## drawcurvedarrow.pl
```

```
# 5 command-line parameters A B C h filename
my ($A, $B, $C, $h, $filename)=@ARGV;
open (outfile, ">$filename")|| die "ERROR can't create file $filename\n";
print (outfile  "Point*(P999){pointonline($B$A, -($A$B)/3)}\n");
print (outfile  "Point*(H999){pointonline($C P999,$h)}\n");
print (outfile  "Drawcurve($A$B H999)\n");
print (outfile  "drawArrow(H999 $C)\n");
close (outfile);
```

The above Perl program accepts five parameters and writes the mathsPIC commands required for drawing a curved arrow through the three points A, B, C (from A to C). The program places an arrowhead (length h) at the end pointing at point C, and places all the necessary mathsPIC commands into the temporary file `filename`.

Note that in this example all new points defined in the Perl program are defined using the `point*()` command, since this allows the program to be reused without needing to know which points have been defined before. The point names `P999` and `H999` have been chosen in order to try and avoid clashing with any point names likely to be used in the mathsPIC file. Indeed, the authors suggest that point numbers ≥ 900 be reserved for use in Perl programs in this way. Note also that these particular point names (e.g. H999) need to be separated by a space from a previous string name (e.g. `$A$B H999`) since they are not Perl variable names (Perl variable names are prefixed with a $ symbol).

`System()` command

mathsPIC 'calls' a Perl program (with appropriate parameters) via the `system()` command. For example, the following mathsPIC commands (a) call the Perl program `drawcurvedarrow.pl` to draw the curved arrow PQR with an arrowhead length 0·4 units, and places the commands in the file `temp.txt`, and (b) inputs the temporary file which then contains the commands.

```
....
system("perl drawcurvedarrow.pl P Q R 0.4 temp.txt")
inputfile(temp.txt)
....
```

It is useful to include the filename as one of the parameters, since this allows us to write the mathsPIC command to input the same file immediately afterwards. Note also that since we are, in effect, using the command-line here then the parameters following the program name must be separated by spaces, as required by Perl syntax.

The mathsPIC file

The following example mathsPIC file uses the above commands to draw a curved arrow from a START box (just below the first point P) to an END box (below the last point R) as shown in Figure 7.14. Note the use of the `[t]` option at the end of two of the `text()` commands which places the point at the [t]op of the `\fbox{}`.

```
%% mpicpm07-14.m  (Figure 7.14)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
paper{units(1cm) xrange(0,5)  yrange(0,4), axis(LRTB),ticks(1,1)}
point(P){1.25,1}
point(Q){P, polar(2, 65 deg)}
point(R){Q, polar(2,-40 deg)}
drawpoint(Q)
text(\fbox{START}){P}[t]
text($Q$){Q, shift(0,0.5)}
text(\raisebox{-5mm}{\fbox{END}}){R}[t]
linethickness(1pt)
arrowshape(0.4cm, 30,40)
system("perl drawcurvedarrow.pl P Q R 0.4 temp.txt")
inputfile(temp.txt)
\endpicture
\end{document}
```

The temporary file

When the above mathsPIC file is run it creates (in the same directory) the following four-line temporary ASCII text-file (named `temp.txt`) containing the mathsPIC commands which actually draw the curve, and then inputs the file `temp.txt` into the mathsPIC file for processing.

```
Point*(P999){pointonline(QP, -(PQ)/3)}
Point*(H999){pointonline(R P999,0.4)}
Drawcurve(PQ H999)
drawArrow(H999 R)
```

Output file

The output TEX file which is generated by running the file `mpicpm07-14.m` through mathsPIC is as follows. Towards the end of the file you can see the temporary file

code and the results after processing by mathsPIC located between the following two lines

```
%% ... start of file <temp.txt> loop [1]
...
%% ... end of file <temp.txt> loop [1]
```

The full output file is as follows.

```
%* ------------------------------------------------
%* mathsPIC (Perl version 0.99.22 Dec 29, 2004)
%* A filter program for use with PiCTeX
%* Copyright (c) 2004 A Syropoulos & RWD Nickalls
%* Command line: mpic09922.pl mpicpm07-14.m
%* Input filename : mpicpm07-14.m
%* Output filename: mpicpm07-14.mt
%* Date & time: 2005/01/05    09:30:55
%* ------------------------------------------------
%% mpicpm07-14.m  (Figure 7.14)
%% curved arrow
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
%% paper{units(1cm) xrange(0,5)  yrange(0,4), axis(LRTB),ticks(1,1)}
\setcoordinatesystem units <1cm,1cm>
\setplotarea x from 0.00000 to 5.00000, y from 0.00000 to 4.00000
\axis left ticks numbered from 0 to 4 by 1 /
\axis right ticks numbered from 0 to 4 by 1 /
\axis top ticks numbered from 0 to 5 by 1 /
\axis bottom ticks numbered from 0 to 5 by 1 /
%% point(P){1.25,1}  P = (1.25000, 1.00000)
%% point(Q){P, polar(2, 65 deg)}  Q = (2.09524, 2.81262)
%% point(R){Q, polar(2,-40 deg)}  R = (3.62733, 1.52704)
%% drawpoint(Q)
\put {$\bullet$} at 2.09524 2.81262 %% Q
%% text(\fbox{START}){P}[t]
\put {\fbox{START}} [t] at 1.250000 1.000000
%% text($Q$){Q, shift(0,0.5)}
\put {$Q$} at 2.095240 3.312620
%% text(\raisebox{-5mm}{\fbox{END}}){R}[t]
\put {\raisebox{-5mm}{\fbox{END}}} [t] at 3.627330 1.527040
%% linethickness(1pt)
\linethickness=1.00000pt\Linethickness{1.00000pt}%
```

```
\font\CM=cmr10 at 9.97226pt%
\setplotsymbol  ({\CM .})%
%% arrowshape(0.4cm, 30,40)
%% arrowLength = 0.4cm, arrowAngleB = 30 and arrowAngleC = 40
%% system("perl drawcurvedarrow.pl P Q R 0.4 temp.txt")
%% inputfile(temp.txt)
%% ... start of file <temp.txt> loop [1]
%%% Iteration number: 1
%% point*(P999){pointonline(QP, -(PQ)/3)}  P999 = (2.37699, 3.41683)
%% point*(H999){pointonline(R P999,0.4)}  H999 = (3.40661, 1.86063)
%% Drawcurve(PQ H999)
\setquadratic
\plot
1.25000  1.00000 %P
2.09524  2.81262 %Q
3.40661  1.86063 / %H999
\setlinear
%% drawArrow(H999 R)
\arrow <0.40000cm> [0.2679,0.7279] from 3.4066 1.8606 to 3.6273 1.5270
%% ... end of file <temp.txt> loop [1]
\endpicture
\end{document}
```

LaTeXing this file then generates the DVI file for Figure 7.14.

7.9.2 Example-2

Once the main working part of a Perl program has been debugged, then some finishing touches can be added. In the following example, therefore, we have 'upgraded' the previous program by including (a) error messages, (b) made it delete the temporary file automatically, (c) useful macros, (d) added colour.

Note also how the one-line `system()` command in the mathsPIC file calling the `drawcube.pl` program is processed into the large output file necessary for drawing the cube. This illustrates the value of being able to encode certain elements of a diagram as a separate Perl program capable of receiving parameters, and so making it possible for them to be used as and when necessary.

Delete temporary file

We can automatically delete the temporary file by writing the mathsPIC command

```
system("rm temp.txt")
```

(where `rm` is the Linux command for 'remove').

Now, this can be done by the Perl program itself (providing the temporary file is not to be input more than once), in which case it would have to output the above command. However, in order for it to do this, the Perl command would have to be as follows:-

```
print (outfile  qq(system("rm $filename")\n));
```

where the `qq()` command exports the argument in inverted commas, as required.

Useful macros

In addition, we have improved the mathsPIC file (made it more readable) by creating the macros `&center()`, `&side()` and `&filename()` to hold the three parameters, namely center point, the sidelength and the temporary filename. In this way we can pass P, s and `temp.txt` as `&center(P)`, `&side(s)` and `&filename(temp.txt)` (note that when the macros are used then they need to be prefixed with the `&` symbol).

```
%def center(j)j%     %%center point
%def side(j)j%       %%sidelength
%def filename(j)j%   %% temporary file name
point(P){5,5}[symbol=$\bigodot$]
var s=4  %% sidelength
system("perl drawcube.pl  &center(P)  &side(s)  &filename(temp.txt)")
inputfile(temp.txt)
```

Added colour

We have also made use of the LaTeX Color package and coloured the sides of the cube blue, the diagonals red, and the points and labels black. Always load the color package *after* the mathsPIC package.

MathsPIC program

All these improvements are implemented in the following example mathsPIC script & Perl program `drawcube.pl` which draws a simple cube (side s) about a central point P (see Figure 7.15).

```
%% mpicpm07-15.m  (Figure 7.15)
\documentclass[a4paper]{article}
\usepackage{mathspic,color}
\begin{document}
\beginpicture
\normalcolor%
paper{units(1cm) xrange(0,6)  yrange(0,6), axis(LB),ticks(1,1)}
```

```
point(P){3,3}[symbol=$\bigodot$]  %center of the cube
%def center(j)j%     %% center point
%def side(j)j%       %% sidelength
%def filename(j)j%   %% temp filename
var s=3  %% sidelength
system("perl drawcube.pl &center(P) &side(s) &filename(temp.txt)")
inputfile(temp.txt)
\normalcolor%
\endpicture
\end{document}
```

Note that the point-name P, side-length s, and filename `temp.txt` are all passed to the Perl program as parameters using the `system()` command. The code of the Perl program `drawcube.pl` is listed below.

Perl program (`drawcube.pl`)

```
#!/usr/bin/perl
## drawcube.pl
# pickup command line parameters P,s,filename
# use: system("perl drawcube.pl P s3 temp.txt")
#============================
my ($argnumber) = $#ARGV +1;
if ($argnumber != 3){
  print "============================\n";
  print "ERROR: drawcube.pl requires 3 arguments\n";
  print "USE:   drawcube.pl  <pointname> <sidelength> <filename> \n";
  print "============================\n";
  exit(1);
}
my ($point, $side, $filename)=@ARGV;
open (outfile, ">$filename")|| die "ERROR can't create file $filename\n";
print (outfile  <<EOF);
\%\%------mathsPIC code----------------
var r=$side*sqrt(2)/2
var a=30 %% angle degrees
Point*(P990){$point, polar(r/2, (a-180) deg)}
Point*(P991){P990, polar(r, 45 deg)}
Point*(P992){P991, rotate(P990, 90)}
Point*(P993){P991, rotate(P990, 180)}
Point*(P994){P991, rotate(P990, 270)}
Point*(P995){P991, polar(r, a deg)}
Point*(P996){P992, polar(r, a deg)}
```

```
Point*(P997){P993, polar(r, a deg)}
Point*(P998){P994, polar(r, a deg)}
%% draw the sides
\\color{blue}
drawline(P991 P992 P993 P994 P991, P994 P998 P995 P996 P992, P991 P995)
\\setdashes
drawline(P993 P997 P998, P997 P996)
%% draw the diagonals
\\color{red}
drawline(P991 P997, P992 P998, P996 P994, P995 P993)
%% draw the points and labels
\\setsolid\\color{black}
drawpoint($point P991 P992 P993 P994 P995 P996 P997 P998)
text(\$$point\$){$point, shift(-0.5,-0.1)}
text(\$P991\$){P991, shift(-0.3,0.3)}
text(\$P995\$){P995, shift(-0.3,0.3)}
%%------end of mathspic code----------------------
EOF
# now delete the temp file
print (outfile  qq(system("rm $filename")\n));
close outfile
__END__
```

Note the use of the `<<EOF...EOF` environment to contain the chunk of mathsPIC code which is written to text file `temp.txt` Note also that where you want $ and \ characters written to the output file (temporary file—for use by mathsPIC) by the Perl program, it is important to remember that these characters need to be 'escaped' using a preceding backslash. In the above example the point name P is held in the Perl variable `$point`; consequently since we need the Perl program to write the mathsPIC command `text($P$){P,shift(-0.5, -0.1)}` to the temporary file the Perl code needs to be `text(\$$point\$){$point, shift(-0.5,-0.1)}`

The temporary file

```
%%------mathsPIC code----------------
var r=s*sqrt(2)/2
var a=30 %% angle degrees
Point*(P990){P, polar(r/2, (a-180) deg)}
Point*(P991){P990, polar(r, 45 deg)}
Point*(P992){P991, rotate(P990, 90)}
Point*(P993){P991, rotate(P990, 180)}
Point*(P994){P991, rotate(P990, 270)}
Point*(P995){P991, polar(r, a deg)}
```

```
Point*(P996){P992, polar(r, a deg)}
Point*(P997){P993, polar(r, a deg)}
Point*(P998){P994, polar(r, a deg)}
%% draw the sides
\color{blue}
drawline(P991 P992 P993 P994 P991, P994 P998 P995 P996 P992, P991 P995)
\setdashes
drawline(P993 P997 P998, P997 P996)
%% draw the diagonals
\color{red}
drawline(P991 P997, P992 P998, P996 P994, P995 P993)
%% draw the points and labels
\setsolid\color{black}
drawpoint(P P991 P992 P993 P994 P995 P996 P997 P998)
text($P$){P, shift(-0.5,-0.1)}
text($P991$){P991, shift(-0.3,0.3)}
text($P995$){P995, shift(-0.3,0.3)}
system("rm $filename")
%%---------------------------
```

Output file

When the mathsPIC script is run the output file is as follows.

```
%* ---------------------------------------------
%* mathsPIC (Perl version 0.99.22 Dec 29, 2004)
%* A filter program for use with PiCTeX
%* Copyright (c) 2004 A Syropoulos & RWD Nickalls
%* Command line: mpic09922.pl mpicpm07-15.m
%* Input filename : mpicpm07-15.m
%* Output filename: mpicpm07-15.mt
%* Date & time: 2005/01/05    09:46:22
%* ---------------------------------------------
%% mpicpm07-15.m  (Figure 7.15)
\documentclass[a4paper]{article}
\usepackage{mathspic,color}
\begin{document}
\beginpicture
\normalcolor
%% paper{units(1cm) xrange(0,6)  yrange(0,6), axis(LB),ticks(1,1)}
\setcoordinatesystem units <1cm,1cm>
\setplotarea x from 0.00000 to 6.00000, y from 0.00000 to 6.00000
\axis left ticks numbered from 0 to 6 by 1 /
```

```
\axis bottom ticks numbered from 0 to 6 by 1 /
%% point(P){3,3}[symbol=$\bigodot$]  %center P = (3.00000, 3.00000)
%def center(j)j%     %% center point
%def filename(j)j%   %% temp filename
%def side(j)j%       %% sidelength
%% var s=3  %% sidelength
%% s = 3
%% system("perl drawcube.pl P s temp.txt")
%% ... start of file <temp.txt> loop [1]
%%% Iteration number: 1
%%------mathsPIC code----------------
%% var r=s*sqrt(2)/2
%% r = 2.12132034355964
%% var a=30 %% angle degrees
%% a = 30
%% point*(P990){P, polar(r/2, (a-180) deg)}  P990 = (2.08144, 2.46967)
%% point*(P991){P990, polar(r, 45 deg)}  P991 = (3.58144, 3.96967)
%% point*(P992){P991, rotate(P990, 90)}  P992 = (0.58144, 3.96967)
%% point*(P993){P991, rotate(P990, 180)}  P993 = (0.58144, 0.96967)
%% point*(P994){P991, rotate(P990, 270)}  P994 = (3.58144, 0.96967)
%% point*(P995){P991, polar(r, a deg)}  P995 = (5.41856, 5.03033)
%% point*(P996){P992, polar(r, a deg)}  P996 = (2.41856, 5.03033)
%% point*(P997){P993, polar(r, a deg)}  P997 = (2.41856, 2.03033)
%% point*(P998){P994, polar(r, a deg)}  P998 = (5.41856, 2.03033)
%% draw the sides
\color{blue}
%% drawline(P991 P992 P993 P994 P991, P994 P998 P995 P996 P992, P991 P995)
\putrule from 3.58144 3.96967 to 0.58144 3.96967 %% P991P992
\putrule from 0.58144 3.96967 to 0.58144 0.96967 %% P992P993
\putrule from 0.58144 0.96967 to 3.58144 0.96967 %% P993P994
\putrule from 3.58144 0.96967 to 3.58144 3.96967 %% P994P991
\plot 3.58144 0.96967 5.41856 2.03033 / %% P994P998
\putrule from 5.41856 2.03033 to 5.41856 5.03033 %% P998P995
\putrule from 5.41856 5.03033 to 2.41856 5.03033 %% P995P996
\plot 2.41856 5.03033 0.58144 3.96967 / %% P996P992
\plot 3.58144 3.96967 5.41856 5.03033 / %% P991P995
\setdashes
%% drawline(P993 P997 P998, P997 P996)
\plot 0.58144 0.96967 2.41856 2.03033 / %% P993P997
\putrule from 2.41856 2.03033 to 5.41856 2.03033 %% P997P998
\putrule from 2.41856 2.03033 to 2.41856 5.03033 %% P997P996
%% draw the diagonals
```

```
\color{red}
%% drawline(P991 P997, P992 P998, P996 P994, P995 P993)
\plot 3.58144 3.96967 2.41856 2.03033 / %% P991P997
\plot 0.58144 3.96967 5.41856 2.03033 / %% P992P998
\plot 2.41856 5.03033 3.58144 0.96967 / %% P996P994
\plot 5.41856 5.03033 0.58144 0.96967 / %% P995P993
%% draw the points and labels
\setsolid\color{black}
%% drawpoint(P P991 P992 P993 P994 P995 P996 P997 P998)
\put {$\bigodot$} at 3.00000 3.00000 %% P
\put {$\bullet$} at 3.58144 3.96967 %% P991
\put {$\bullet$} at 0.58144 3.96967 %% P992
\put {$\bullet$} at 0.58144 0.96967 %% P993
\put {$\bullet$} at 3.58144 0.96967 %% P994
\put {$\bullet$} at 5.41856 5.03033 %% P995
\put {$\bullet$} at 2.41856 5.03033 %% P996
\put {$\bullet$} at 2.41856 2.03033 %% P997
\put {$\bullet$} at 5.41856 2.03033 %% P998
%% text($P$){P, shift(-0.4,-0.1)}
\put {$P$} at 2.600000 2.900000
%% text($P991$){P991, shift(-0.3,0.3)}
\put {$P991$} at 3.281440 4.269670
%% text($P995$){P995, shift(-0.3,0.3)}
\put {$P995$} at 5.118560 5.330330
%%----------------------------
%% system("rm temp.txt")
%% ... end of file <temp.txt> loop [1]
\normalcolor%
\endpicture
\end{document}
```

and the diagram is shown in Figure 7.15.

7.9.3 Commands for processing the files

In Linux the command-line commands used to generate and print figure 7.15 were as follows:

```
perl mpic09922.pl mpicpm07-15.m
latex mpicpm07-15.mt
xdvi mpicpm07-15.dvi   %% to view dvi file
dvips -o  mpicpm07-15.ps mpicpm07-15.dvi %% generate the .ps version
gv mpicpm07-15.ps      %% view the .ps version
```

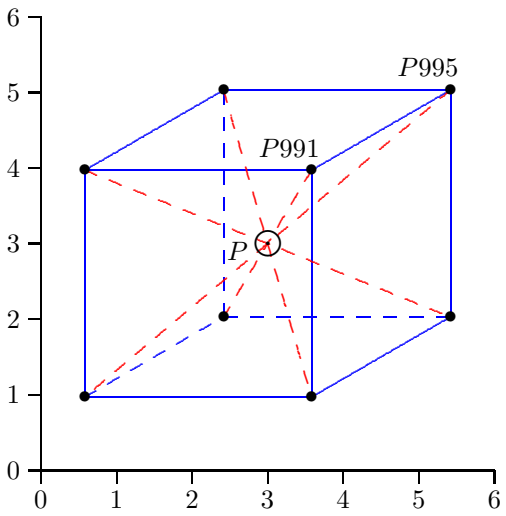


Figure 7.15:
3-D cube drawn about a central point P $(3, 3)$ and with sidelength s $(s = 3)$. The PDF and PostScript versions of the output show the sides coloured blue, the diagonals red, and the points and labels black. The mathsPIC command used was:-
`system("perl drawcube.pl &center(P) &side(s) &filename(temp.txt)")`.

```
lpr mpicpm07-15.ps     %% print the .ps version
```

8

Accessing TEX parameter values

It is sometimes useful for mathsPIC to be able to access TEX parameter values. For example, mathsPIC could be made to automatically scale the height and width of a graph to the as yet unknown page size of the TEX document. Knowledge of the TEX parameters `\textheight` and `\textwidth` during processing would allow the height and width of a graph to be defined as a function of these page parameters.

One way of doing this is to include in the TEX file some code to write the required parameter values to a temporary data file, in the form of mathsPIC `var` commands or macros. Using the mathsPIC `system()` command mathsPIC can run the TEX file, and then access the parameter values by inputting the data-file.

8.1 Useful TEX commands

```
\settowidth{\variablename}{text}
\settoheight{\variablename}{text}
\settodepth{\variablename}{text}
```

For example, the following code would put the length of the word January into the variable `\janlength`. Note that `\the` gives the value in points, while `\number` returns the value as an integer in scaled points (see Table 8.1).

```
\newlength{\janlength}
\settowidth{\janlength}{January}
The length of the word January in points is \the\janlength
The length of the word January in 'scaled' points is \number\janlength
```

The output is as follows (note that `\the\janlength` returns the numeric points but includes the characters `pt` on the end).

```
The length of the word January in points is 35.16676pt
The length of the word January in 'scaled' points is 2304689
```

TEX has a number of parameters which are classified according to type, e.g. integers, dimensions, glue, muglue, token lists. For a full list of all the TEX parameters which have values which can be accessed see Knuth (1990; page 272–275).

The token list `\jobname` is very useful as it holds the filename (but not the filename extension) which TEX is currently working on, and can be used for generating derivative temporary files, e.g. `\jobname`.dvi, `\jobname`.toc etc.

8.2 Outputting data to a file

TEX requires a file-number as a handle to identify an 'open' file, and has the command `\newfile` specifically for allocating an unused file-number to a variable name. We then use the commands `\openout`, `\write`, and `\closeout` to open, write to, and close the file. For example, the following code will write `...blah blah blah ..` to the file `texfiledata.dat` using the file handle `\outfile`.

```
\newwrite\outfile
\openout\outfile=texfiledata.dat
\write\outfile{...blah blah blah....}
\closeout\outfile
```

Note that the `\write` command only writes the data to the file when the `.dvi` file is created, so if these commands are in a file which may not actually create a `.dvi` file, then we may need to force output (`dvi` file creation) by including something writable like `\strut` on a line.

Alternatively, we can force TEX to write to the file immediately (i.e. without waiting until it gets to the end of file processing) by using the `\immediate` command, remembering to include it with *all* the commands `\openout`, `\write`, and `\closeout`, as follows.

```
\newwrite\outfile
\immediate\openout\outfile=texfiledata.dat
\immediate\write\outfile{...blah blah blah....}
\immediate\closeout\outfile
```

Since we are interested in accessing the values of TEX parameters, we need to explore some of the TEX commands for accessing such values. For example, the commands `\the`, `\number` and `\showthe` all reveal the numeric value, but in slightly different formats and location, as follows.

```
\the\textwidth      ---> 400.0pt       includes the characters pt
\number\textwidth   ---> 26214400      scaled points (see Table)
\showthe\textwidth  ---> only writes to the log file
```

For the purposes of mathsPIC accessing the numeric value as a variable or macro, it is most convenient to use the `\number` command (yields an integer value in the 'scaled points' used internally by TEX)[1] and to incorporate it into a mathsPIC variable or macro so it is ready to be used once the temporary file it is written to has been input by mathsPIC. For example, the following code allocates the scaled point value of `\textwidth` to the mathsPIC variable `w555`.

```
\immediate\write\outfile{var w555 = \number\textwidth}
```

If the `\textwidth` was 400pt (14.058 cm), then the output of the above line would be as follows (65536 scaled points = 1 printers point pt).

```
var w555 = 26214400
```

In practice, it is useful to have this line commented to indicate which TEX parameter the value relates to, as follows.

```
var w555 = 26214400%  \textwidth (scaled points)
```

However, since what came after the `%` symbol would be ignored in this setting, we need to define the `%` as a character we can print to a file, by allocating it the catcode 12 (instead of the catcode of 14 which it normally has), and calling it by a different name (`\percentchar`), and delimiting the whole line by a curley brace (to keep it local), as follows.[2]

```
{\catcode`\%=12   \global\def\percentchar{%}}%
```

So now, the following code will also include a trailing comment indicating the TEX name of the parameter.

```
\newcommand{\comment}{\percentchar\space}
\immediate\write\outfile{var w555 = \number\textwidth
         \comment\textwidth is \the\textwidth}
```

For example, the resulting line in the output file is as follows.

```
var w555 = 29368707% \textwidth is 448.1309pt
```

[1] 65536 scaled points = 1 printers point (pt).
[2] From: Abrahams, Berry and Hargreaves (1990), p 292.

Table 8.1: Note that for accurate working always use scaled points (sp) and convert in a single step using the following convertion factors (modified from: Beccari C, 1991)

	sp
mm	186467·98
cm	1864679·8
pt	65536
in	4736286·70

8.3 The final code

So now we can put all this code together into one chunk within the target TEX file, or more usefully, keep it as a separate file which can then just be `\input` whenever it is required. For example inputting the following file (and LATEXing it) will output a data file containing appropriate mathsPIC commands with the embedded values of `\textwidth` and `\textheight`. Note that in the following example we have defined two mathsPIC macros called `textwidthcms` and `textheightcms` which will contain the relevant values in cms (see Table 8.1 for conversion factors).

```
%% grabtexdata.tex
%-----------------
\scrollmode  % prevent LaTeX stopping if there are errors
%---------------------
% make a print command  macro
\newcommand{\print}[1]{\immediate\write\outfile{#1}}
%---------------------
% make a comment % command  macro
% first need to define percentchar for the write statement
% (From "TeX for the Impatient" (1990), p 292)
{\catcode`\%=12   \global\def\percentchar{%}}%
\newcommand{\comment}{\percentchar\space}
%
% make a \macro command --> %def<space>
\newcommand{\mydef}{def}
\newcommand{\macro}{\percentchar\mydef\space}
%----------------------
% create and open a new file with filename = textfiledata.dat
\newwrite\outfile
\immediate\openout\outfile=texfiledata.dat
```

```
%----------------------
%% write file header & general info
\print{\percentchar\percentchar\space file: texfiledata.dat}
\print{\percentchar\percentchar\space accessing TeX parameter values}
%---------------------
%% now get \textwidth and \textheight values from the tex file
\print{var w555 = \number\textwidth\comment\textwidth=scaled points}
\print{var w556 = \number\textwidth\comment\textwidth=\the\textwidth}
\print{var w557 = \number\textwidth/1864679.8\comment (\textwidth in cms)}
\print{\comment ============}
\print{\macro textwidthcms()\number\textwidth/1864679.8\comment}
\print{\macro textheightcms()\number\textheight/1864679.8\comment}
\print{\comment ============}
%-------------------
% close the file
\immediate\closeout\outfile
```

In practice one would simply include the following line

```
\input{grabtexdata.tex}
```

in the TEX file we want data from (say, `myfile.tex`), and then LATEX the file to generate the output data file. Alternatively we could LATEX the file from within mathsPIC using the `system` command, and then input the resulting data file as follows.

```
system(``latex2e myfile.tex'')
input(texfiledata.dat)
```

Either way, the resulting output data file `texfiledata.dat` for a file having a standard `{article}` format is as follows

```
%% texfiledata.dat
%% accessing TeX parameter values
var w555 = 22609920% \textwidth =scaled points
var w556 = 22609920% \textwidth =345.0pt
var w557 = 22609920/1864679.8% (\textwidth in cms)
% ============
%def textwidthcms()22609920/1864679.8%
%def textheightcms()39190528/1864679.8%
% ============
```

Once the above file (`texfiledata.dat`) is input into a mathsPIC file we can then use mathsPIC commands to manipulate the textwidth and textheight values, as shown in the following example mathsPIC file.

```
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
.....
system(``latex2e myfile.tex'')
inputfile(texfiledata.dat)
var w=&textwidthcms, w2= &textwidthcms/2
var h=&textheightcms, h2=&textheightcms/2
...
\end{document}
```

Processing the mathsPIC file gives the folllowing output. Notice how useful it is to have the accompanying comments.

```
%% inputfile(texfiledata.dat)
%% ... start of file <texfiledata.dat> loop [1]
%%% Iteration number: 1
%% texfiledata.dat
%% accessing TeX parameter values
%% var w555 = 22609920% \textwidth =scaled points
%% w555 = 22609920
%% var w556 = 22609920% \textwidth =345.0pt
%% w556 = 22609920
%% var w557 = 22609920/1864679.8% (\textwidth in cms)
%% w557 = 12.1253632929364
% ============
%def textwidthcms()22609920/1864679.8%
%def textheightcms()39190528/1864679.8%
% ============
%% ... end of file <texfiledata.dat> loop [1]
%% var w=22609920/1864679.8, w2= 22609920/1864679.8/2
%% w = 12.1253632929364
%% w2 = 6.0626816464682
%% var h=39190528/1864679.8, h2=39190528/1864679.8/2
%% h = 21.0172963744231
%% h2 = 10.5086481872116
```

9

Installing PICTEX

PICTEX is an excellent small graphics package, freely available from CTAN and the usual TEX CD-ROM discs[1].

If you are using Perl within Linux then all the relevant PICTEX files are already installed as part of teTEX. If you are using a MS-Windows version of Perl then it is just possible you may have to download and install the relevant PICTEX files (I am not sure of the current status regarding MiKTEX and VPTEX).

Download all the files in the following two directories, and place them where your TEX system can find them[2].

- `CTAN/tex-archive/graphics/pictex/`
- `CTAN/tex-archive/graphics/pictex/addon/`

If you are a LATEX user, then use `\usepackage{pictexwd}`. If you are a plain TEX user, then use `\input pictexwd.tex` (see Section 4.2.1 and Section 9.2 for details).

Unfortunately, the PICTEX documentation is not available from CTAN—the PICTEX manual has to be purchased separately (see Section 9.5). However, mathsPIC users will mostly find this unnecessary, since those PICTEX commands which are particularly useful in conjunction with mathsPIC are described in the mathsPIC manual (Section 6.3), together with examples in the code for the various Figures.

9.1 The original files (1986)

`CTAN/tex-archive/graphics/pictex/`

[1] Available from TEX user groups. Note that a particularly good 3-disk CTAN archive is published annually by the German TEX users group DANTE (*dante@dante.de*, `http://www.dante.de`).

[2] For EmTeX, this would be the directory `c:\emtex\texinput\pictex\`

The original PICTEX package by Michael Wichura (21/09/1987) originally consisted of the 4 files listed below. On the left is the MS-DOS name (truncated to 8 characters), and on the right is the full UNIX name).

The file `latexpic.tex` gives Plain TEX users the option of using the LATEX Picture macros `\line`, `\vector`, `\circle`, `\oval`, `\thicklines` and `\thinlines` (for syntax and use with PICTEX see Wichura, 1992).

Note that only two of the files are required for using with plain TEX, while three files are required when running LATEX.

```
latexpic.tex  11243 bytes (latexpicobjs.tex - for plain TeX only)
prepicte.tex   1293 bytes (prepictex.tex    - for LaTeX)
pictex.tex   133388 bytes (pictex.tex       - for LaTeX & plain TeX)
postpict.tex   1614 bytes (postpictex.tex   - for LaTeX)
```

The three files required for use with LATEX need to be loaded (input) *in the order shown above*. Note that when using PICTEX with LATEX 2_ε it is necessary to redefine the LATEX 2.09 command `\fiverm` (because PICTEX was originally written for LATEX 2.09). This is most easily done as follows.

```
\newcommand{\fiverm}{\rmfamily\tiny}
```

Alternatively you can use the more robust method (i.e. for *wizards*) suggested by Michael J Downes as follows (I believe Michael Downes suggested this originally on the *comp.text.tex* usenet group—see also the file `fntguide.tex` among the LATEX 2_ε documents).

```
\declarefixedfont{\fiverm}{\encodingdefault}{\rmdefault}{m}{n}{5}
```

A significant problem with the original PICTEX package was that it was very memory hungry. However, in 1994 this problem was overcome by a significant rewrite by Andreas Schrell (see Section 9.2).

9.2 The new updated files (1994)

`CTAN/tex-archive/graphics/pictex/addon/`

In 1994 Andreas Schrell uploaded a set of updated PICTEX files into the `CTAN: .../pictex/addon/` directory. One of these additional files (`pictexwd.tex`) is a replacement for the original (`pictex.tex`), and is extremely economic in its use of TEX's dimension registers, allowing significantly better memory usage with exactly the same functionality. The other files correct some errors (`piccorr.sty`), and add new functionality (`picmore.tex`).

```
pictexwd.sty          416 bytes
pictexwd.tex       133232 bytes
picmore.tex          2952 bytes
piccorr.sty          4608 bytes
pictex.sty            311 bytes
```

- `pictexwd.sty`

  For LaTeX users. This replaces `pictex.sty`. It inputs `prepictex.tex`, `pictexwd.tex`, and `postpictex.tex`, as well as inputting `piccorr.sty` and `picmore.tex` if these are available.

- `pictexwd.tex`

  For TeX users.

- `picmore.tex`

  An extension for drawing impulse diagrams.

- `piccorr.sty`

  A correction for the original PiCTeX `\betweenarrows` command.

- `pictex.sty`

  The LaTeX style-option for loading the *original* PiCTeX files. Note that it also inputs `piccorr.sty` and `picmore.tex` if these are available.

All the necessary files required for running PiCTeX are automatically input in the correct order by `pictexwd.sty` (LaTeX users), or by `pictexwd.tex` (TeX users). Users of LaTeX 2_ε should include the following command in the preamble.

```
\usepackage{pictexwd}
```

Users of plain TeX need to include the following.

```
\input latexpic.tex
\input pictexwd.tex
```

Note that it is still necessary to download all the original PiCTeX files even when using Andreas Schrell's new files, as some of the original files are still required.

9.3 Pictex2.sty

```
CTAN/tex-archive/macros/latex/contrib/supported/pictex2.sty
16418 bytes 09/05/1999
```

William Park[3] has written a style option (`pictex2.sty`) which adds two useful commands to standard PICTEX, which force the use of the `\putrule` command where lines are either horizontal or vertical, thus saving on memory (note that mathsPIC automatically implements the use of `\putrule` in these circumstances). These two commands are as follows.

- `\putanyline`

  This command invokes the PICTEX `\putrule` command (instead of `\plot`) in cases where lines are either vertical or horizontal.

- `\setanyline`

  This is a line-drawing mode (similar to `\setlinear`) which forces subsequent `\plot` commands to invoke `\putrule` whenever the line is either horizontal or vertical.

9.4 Errorbar.tex

```
CTAN/tex-archive/graphics/pictex/errorbar.tex
3041 bytes 20/04/1988
```

In 1988 Dirk Grunwald implemented a new PICTEX command for drawing error bars using a modified `\plot` command, as follows.

- `\plotWithErrorBars`

  This command, which is case sensitive, has the format

  ```
  \plotWithErrorBars mark M at
     x1 y1 e1
     ...
     xn yn en /
  ```

  where `M` is a TEX character (e.g. `$\bullet$`), and `e` is the size of vertical error bars which are plotted above and below the point. The default cross-bar length is 5pt, but can be changed, say to 7pt, using the command `\crossbarlength=7pt`.

  To use this command, input the file `errorbar.tex` after all the PICTEX files.

[3] `parkw@better.net`

9.5 DCpic

DCpic (by Pedro Quaresma) is a package of TEX macros for drawing commutative diagrams in a LATEX or ConTEX document. It uses PICTEX. to implement commands which manipulate its various 'objects' and arrows. This package (February 2002) is available on CTAN at `CTAN:tex-archive/macros/generic/diagrams/dcpic/`

9.6 The PICTEX Manual

You may wish to purchase *The PICTEX Manual* by Michael J. Wichura (The University of Chicago, Chicago, Illinois, USA).This excellent booklet (version 1.1, third printing, March 1992; 85 pages) used to be available from TUG as Publication No. 6 in the TUG TEXniques series. Unfortunately, TUG (`http://www.tug.org/`) has now stopped publishing the manual, and *The PICTEX Manual* is currently only available from *Personal TEX Inc.* (*texsales@pctex.com*, `http://www.pctex.com/`) at approximately $59 plus postage a year or so back.

When you buy a copy of the manual you also receive a floppy disk containing some PICTEX files. Unfortunately the disk which came with the manual one of the author's bought (RWDN) contained only the original 1986 files; i.e. the disk did *not* include the all-important 1994 files of Andreas Schrell.

10

Miscellaneous

10.1 Acknowledgements

The authors are grateful to Mikael Möller for extensive testing of mathsPIC$_{Perl}$ with the ActiveState Win32 implementation of Perl (known as ActivePerl).

We are also grateful to a large number of people for testing the earlier MS-DOS version of the program. In particular we thank František Chvála, Bob Schumacher, Orlando Rodriguez, Glen Ritchie, Boris Kuselj, Raj Chandra, Ju-myoung Kim, Munpyung O, Rex Shudde and Tobias Wahl for their many helpful ideas and suggestions;

10.2 Feedback

The authors would be grateful for feedback regarding bugs and platform specific issues, as well as comments and ideas for improving this program.

10.3 Development history

- p1.00 (Perl) (February 2005): First Perl-version release
- 2.1 (MS-DOS) (November, 2000):
- 1.7u (MS-DOS) (September 1999): First MS-DOS-version release.

A

Tables

Table A.1: Equivalent PiCTeX commands for a 10-point font

rules (horizontal/vertical)	all other lines
`\linethickness=1.35pt`	`\setplotsymbol({\Large .})`
`\linethickness=1.1pt`	`\setplotsymbol({\large .})`
`\linethickness=0.9pt`	`\setplotsymbol({\normalsize .})`
`\linethickness=0.4pt`	`\setplotsymbol({\tiny .})`

Table A.2: Useful point-symbols and their radii for 10–12pt fonts.

symbol		radius mm	symbol package
		10pt / 11pt / 12pt	
`$\circ$`	$\circ$	0.70 / 0.75 / 0.80	standard
`$\odot$`	$\odot$	1.20 / 1.35 / 1.50	standard
`$\oplus$`	$\oplus$	1.20 / 1.35 / 1.50	standard
`$\ominus$`	$\ominus$	1.20 / 1.35 / 1.50	standard
`$\oslash$`	$\oslash$	1.20 / 1.35 / 1.50	standard
`$\otimes$`	$\otimes$	1.20 / 1.35 / 1.50	standard
`$\bigcirc$`	$\bigcirc$	1.70 / 1.85 / 2.05	standard
`$\bigodot$`	$\bigodot$	1.70 / 1.85 / 2.05	standard
`$\bigoplus$`	$\bigoplus$	1.70 / 1.85 / 2.05	standard
`$\bigotimes$`	$\bigotimes$	1.70 / 1.85 / 2.05	standard
`$\star$`	$\star$	—	standard
`$\triangle$`	$\triangle$	—	standard
`$\square$`	$\square$	—	amssymb.sty
`$\blacksquare$`	$\blacksquare$	—	amssymb.sty
`$\lozenge$`	$\lozenge$	—	amssymb.sty
`$\blacklozenge$`	$\blacklozenge$	—	amssymb.sty
`$\bigstar$`	$\bigstar$	—	amssymb.sty
`$\boxdot$`	$\boxdot$	—	amssymb.sty
`$\boxtimes$`	$\boxtimes$	—	amssymb.sty
`$\boxminus$`	$\boxminus$	—	amssymb.sty
`$\boxplus$`	$\boxplus$	—	amssymb.sty
`$\divideontimes$`	$\divideontimes$	—	amssymb.sty

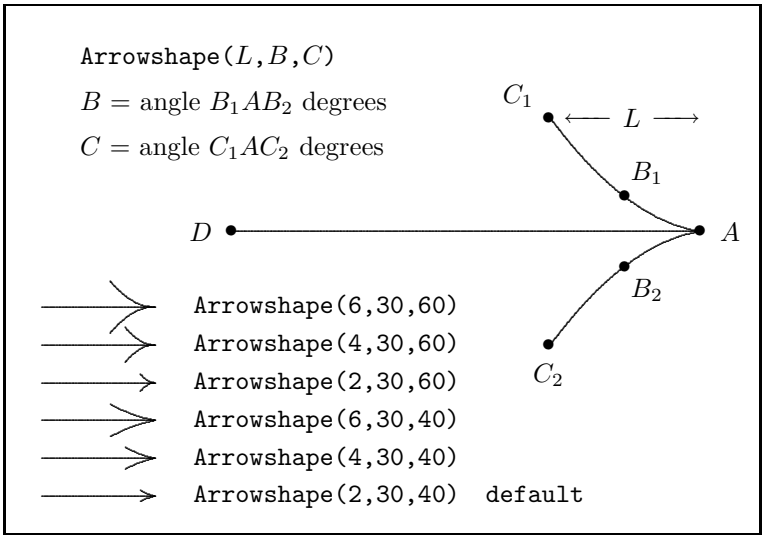
Table A.3: Conversion factors for the units used by LaTeX.
(From Beccari (1991) with permission)

	mm	cm	pt	bp	pc	in	dd	cc	sp
1 mm	1,000	0,100	2,845	2,835	0,2371	0,03937	2,659	0,2216	186 467,98
1 cm	10,00	1,000	28,45	28,35	2,371	0,3937	26,59	2,216	1 864 679,8
1 pt	0,3515	0,03515	1,000	0,9963	0,08333	0,01384	0,9346	0,07788	65 536
1 bp	0,3528	0,03528	1,004	1,000	0,08365	0,01389	0,9381	0,07817	65 781,76
1 pc	4,218	0,4218	12,00	11,96	1,000	0,1660	11,21	0,9346	786 432
1 in	25,40	2,540	72,27	72,00	6,023	1,000	67,54	5,628	4 736 286,7
1 dd	0,3760	0,03760	1,070	1,066	0,08917	0,01481	1,000	0,08333	70 124,086
1 cc	4,513	0,4513	12,84	12,79	1,070	0,1777	12,00	1,000	841 489,04

B

Arrows

The mathsPIC code for drawing the following figure is given below.




```
%% mpicpm07-3.m  (Figure 7.3)
\documentclass[a4paper]{article}
\usepackage{mathspic}
\begin{document}
\beginpicture
paper{units(1mm), xrange(0,100), yrange(0,70), axes(LBTR)}
```

```
%% first do all the small arrows (from top down)
point(J11){5,30}
 point(J12){20,30}
point(J9){5,25}
 point(J10){20,25}
point(J7){5,20}
 point(J8){20,20}
point(J5){5,15}
 point(J6){20,15}
point(J3){5,10}
 point(J4){20,10}
point(J1){5,5}
 point(J2){20,5}
%%
arrowshape(6,30,60)
  drawArrow(J11J12)
arrowshape(4,30,60)
  drawArrow(J9J10)
arrowshape(2,30,60)
  drawArrow(J7J8)
arrowshape(6,30,40)
  drawArrow(J5J6)
arrowshape(4,30,40)
  drawArrow(J3J4)
arrowshape(2,30,40)
  drawArrow(J1J2)
%%
text(\texttt{Arrowshape(2,30,40) \ default}){J2,shift(5,0)}[l]
text(\texttt{Arrowshape(4,30,40)}){J4,shift(5,0)}[l]
text(\texttt{Arrowshape(6,30,40)}){J6,shift(5,0)}[l]
text(\texttt{Arrowshape(2,30,60)}){J8,shift(5,0)}[l]
text(\texttt{Arrowshape(4,30,60)}){J10,shift(5,0)}[l]
text(\texttt{Arrowshape(6,30,60)}){J12,shift(5,0)}[l]
%%
%% now draw big arrow
point(D){30,40}
point(A){D,shift(62,0)}
arrowshape(20,50,75)
drawArrow(DA)
point(B1){82,44.75}
point(B2){82,35.25}
point(C1){72,55}
```

```
point(C2){72,25}
drawpoint(DAB1B2C1C2)
text($A$){A, shift(4,0)}
text($B_1$){B1, shift(3,3)}
text($B_2$){B2, shift(3,-3)}
text($C_1$){C1, shift(-4,3)}
text($C_2$){C2, shift(0,-4)}
text($D$){D, shift(-4,0)}
%%
point(T1){10,63}
point(T2){10,57}
point(T3){10,51}
text(\texttt{Arrowshape($L$,$B$,$C$)}){T1}[l]
text($B$ = \mbox{angle $B_1AB_2$ degrees}){T2}[l]
text($C$ = \mbox{angle $C_1AC_2$ degrees}){T3}[l]
%%
\betweenarrows  {$L$} from 74 55  to  92 55
\endpicture
\end{document}
```

C

Positioning figures in a document

Once a diagram or figure has been finished it can be easily placed in a document either by including the PICTEX code directly in the main document within the `\begin{figure}...\end{figure}` environment, or by `\input`ting the code as a separate file. For example, if the mathsPIC file was called `myPIC.m` and this generated the output-file `myPIC.mt`, then one would comment-out the LATEX headers and footers from the `.mt` file, keeping just the part of the file within the `\beginpicture...\endpicture` environment (renaming it, say, `myPIC.pic`) as follows.

```
%% this is file myPIC.pic
\beginpicture
...
...
\endpicture
```

The `myPIC.pic` file can then be `\input` into a document as a centered Figure as follows. Always use the `\centering` command as this avoids the additional vertical space added by the `\begin{center}...\end{center}` environment.

```
\begin{figure}[hbt]
\centering
   \strut\input{mypic.pic}
   \caption{...}
   \label{...}
\end{figure}
```

It is often useful when adjusting the position of a Figure on the page to initially place the Figure inside a frame in order to see the exact extent of the Figure. To do this just replace the `\input` line above with the following:

```
\strut\framebox{\input{mypic.pic}}
```

Sometimes more flexibility is needed regarding positioning the `\caption`, in which case a `\parbox` or a `minipage` is useful, as follows:

```
\begin{figure}[hbt]
\centering
   \strut\input{mypic.pic}
   \begin{minipage}{8cm}
      \caption{\label{}......}
   \end{minipage}
\end{figure}
```

Note that the general convention is that Tables have the caption at the top while Figures have the caption underneath the Figure.

Getting the vertical position and horizontal width of the caption just right can be awkward. However, using a minipage gives a lot more flexibility as in the following example, which defines the `\captionwidth` in terms of the `\textwidth`. Note also that here the `\caption{}` is empty—it is here just to trigger the Figure counter—we place the actual caption in the minipage.

```
\newcommand{\captionwidth}{0.8\textwidth}
%%
\begin{figure}[hbt]
\centering
   %\framebox{
   \strut \input{mypic.pic}
    %}
            [empty line]
   \vspace\baselineskip
   \begin{minipage}{\captionwidth}
      \caption{\label{fig:fcubic}}%
      {blah blah...}
    \end{minipage}
\end{figure}
```

When typesetting text and a figure side-by-side the following format for using two adjacent minipages works well—this was the construction used for displaying the program code and the associated Figure 7.

```
\begin{figure}[hbt]
\noindent
\begin{minipage}{4cm}
%% put some text or a figure here
...
...
\end{minipage}
%%-----------
\hspace{3cm}   %% controls the horizontal space between Figures
%%-----------
\begin{minipage}{4cm}
  \vspace{3mm}
  \strut\hspace*{...}\input{circle.pic}
  \vspace{...}  % adjusts vertical position of caption
  \caption{\label{}...}
\end{minipage}
%-----
\hfill
\end{figure}
```

Finally, it is often necessary to have two figures side-by-side, each with separate sub-captions, in which case the following rather similar format is useful—this was the construction used for displaying the two figures of Figure 8. Note the commented-out `\framebox{}` commands; these are very useful for revealing the full extent of any white-space surrounding the separate figures, since such unwanted white-space is probably the most common cause of difficulty when trying to position and center figures in a document. Note that while the `\centering` command can be used inside a Figure, the `\begin{center}...\end{center}` environment has to be used within a minipage.

```
\begin{figure}[hbt]
\centering
    %-------
    \noindent %\framebox{
    \begin{minipage}{3cm}
       \begin{center}
       %\vspace{...}  %% controls space above picture
       \input{mpicm08a.pic}
       %\vspace{...}  %% controls space between picture and caption
       a. Circular arrows
       \end{center}
    \end{minipage}
    %} %end of framebox
```

```
    %-----------------------
    \hspace{12mm} %% controls horiz space between figs
    % \bigskip\bigskip  %% use this to adjust vertical space
    %-----------------------
    %\framebox{
    \begin{minipage}{5cm}
       \begin{center}
       %\vspace{...}  %% controls space between picture and caption
       \input{mpicm08b.pic}
       %\vspace{...}  %% controls space between pict and caption
       b. Straight arrows
       \end{center}
    \end{minipage}
    %} %end of framebox
    %---------
    \caption{\label{}....}
\end{figure}
```

D

Installing Perl in MS-Windows

Perl is available for all MS-Windows platforms, and there are several Perl implementations to choose from. A good choice (which we describe here) would seem to be the free ActiveState implementation of Perl in view of their excellent web site, documentation and other resources.

D.1 Perl

The free ActivePerl implementation is a well regarded choice of Perl for the Win32 platform, and is easy to download and install. The current version for download at the time of writing is Perl 5.8.6. There is excellent web support (e.g. documentation etc) via their ASPN website (ActiveState Programming Network).

- `http://www.activestate.com/Products/ActivePerl/`
- `http://aspn.activestate.com/ASPN/docs/ActivePerl/`

The complete ActivePerl package consists of the following:-

- Perl (binary core Perl distribution)
- An installer package
- Perl Package Manager (PPM—a Perl extension installer and manager)
- Documentation
- Perl ISAPI (IIS plug-in that enhances the speed of standard Perl)

- PerlScript (ActiveX scripting engine)
- PerlEz (embedded Perl)

Installation

In addition to the Perl system itself Windows 9x/ME/2000/NT also require you to download a special 'installer' package to implement the installation (see below). About 36 MB of hard-drive space is required. Note that the filename and sizes indicated below are those at the time of writing. A useful installation guide can be found at `http://www.activestate.com/ASPN/docs/ActivePerl/install.html`.

Step 1:

First, create a temporary directory for files which need to be downloaded. Then go to the ActiveState web-site (`http://www.activestate.com/`) and click on the Language/ActivePerl link which will take you to the ActivePerl page. Follow the 'download' links until you reach the 'download' page (you can skip the 'contact-info' section by clicking the 'next' button), and then read the Windows section for the latest version of ActivePerl (version 5.8.6).

Step 2:

Download the latest ActivePerl `.msi` file (12·6 MB).
`ActivePerl-5.8.6.811-MSWin32-x86-122208.msi`

Step 3:

Installation: the exact proceedure depends on your particular Windows system as detailed below. The default installation is the recommended 'complete' installation.

- Windows 9x/Me:

  Download the 'installer' file `instMsiA.exe` into the same directory. To install double click on the `instMsiA.exe` file and follow the instructions.

- Windows 2000/NT:

  Download the 'installer' file `instMsiW.exe` into the same directory. To install double click on the `instMsiW.exe` file and follow the instructions.

- Windows XP/2003:

  To install simply double click on the ActivePerl `.msi` file and follow the instructions (these systems do *not* require a separate installer file).

Running Perl

Now that Perl is installed, we can progress to creating and running a Perl program. To create a Perl program, simply open your favorite text-editor (see below for information on some suitable text-editors) and write the program (as an ASCII text file), and finally save it with a `.pl` extension.

For example, open a new file and type the following into it, and then save it with the file-name `test.pl` (note that in Perl the # sign is the 'comment' symbol; the `\n` starts a new line; variable names start with a `\$`).

```
#!/usr/bin/perl
# test.pl
print "hello world\n";
$a=3, $b=7;
$sum=$a + $b;
print "sum = $sum\n";
```

When this is run it will show the following output

```
hello world
sum = 10
```

We can run this Perl program several ways, as follows.

- Use the command-line:

  Open a DOS box, move to the required directory, and at the command-line prompt type the following command, and then press `<enter>`

  ```
  perl test.pl
  ```

  The output generated by the program will be written to the screen in the usual way. If you want the output written to a file (say. `test.txt`) then instead type `perl test.pl > test.txt`

- Click on the filename

  If you just click on the filename in the directory listing (provided it has the `.pl` filename extension) then ActivePerl will automatically open a DOS box, run the program, and then close the DOS box. This is fine if the program output is directed to a file, but if the output is simply directed to the screen (the default) then you need to add the `<>` command at the end of the file, as this will keep the screen open (so you can read the screen) until you hit a key.

```
#!/usr/bin/perl
# test.pl
print "hello world\n";
$a=3, $b=7;
$sum=$a + $b;
print "sum = $sum\n";
# -------------------
print "press any key to exit\n";
<>
```

- Using a batch file:

  Create a separate batch file with the name, say, `test.bat` containing the following lines:

  ```
  perl test.pl %1 %2
  ```

  This batch file now has to be run at the command-line as shown above. Note that ActivePerl can create a batch file from an ordinary perl program by using the command utility `pl2bat.bat`. Simply access the command-line and type

  ```
  pl2bat test.pl
  ```

  which will then generate the file `test.bat` which can then be run at the command-line by just typing `test`.

Perl modules

Additional modules can be downloaded from the huge Perl archives available on the internet. These Perl modules can be installed either automatically (via the internet using the PPM utility), or manually (download the module and then use the `nmake` utility). The `nmake` utility is a Microsoft port of the Unix `make` utiity, and can be downloaded from the Microsoft internet archive at `ftp://ftp.microsoft.com/Softlib/MSLFILES/`. The current version is bundled in the self-extracting package `nmake15.exe`

Useful Perl links

- *Introduction to Perl on Windows.*
  `http://www.wdvl.com/Authoring/Languages/Perl/Windows/`
- CPAN Perl Ports (binary distributions).
  `http://www.cpan.org/ports/index.html`

- How to install Perl modules.
  `http://www.cpan.org/modules/INSTALL.html`

- Perl documentation.
  `http://www.perldoc.com`

D.2 Text editors

A good text editor offers an excellent environment for both writing and processing Perl programs and, we assume that (La)TEX users are already using one. However, although WinEdt is designed with TEX users in mind, other excellent text editors are available, each with their own strengths and weaknesses. Consequently it is useful to have several installed, and then specific ones can be used for specific tasks. We therefore here simply mention a few which are available for MS-Win32 platforms, namely WinEdt, WinEDIT, GNU Emacs, and PFE32.

WinEdt (shareware)

This is an excellent 'all-purpose' text editor designed for use with TEX and LATEX; it has syntax highlighting and can be tailored for use with Perl. It is available fro download from `http://www.winedt.com/`. Note that a free licence for this editor is provided as a membership benefit by many TEX User Groups (e.g. ukTUG). Note that two 32-bit versions are currently available for download as follows (the most recent version is Winedt-54):

- Windows XP/2000 systems:

  Winedt-54 (5.4 MB; year 2005)

  Winedt-53 (4 MB; year 2002))

- Windows 95/98/ME/NT systems

  Winedt-32 (2.1 MB; year 1998)

WinEDIT ($ 63)

The WinEDIT PowerPack is an excellent (commercial) general purpose text editor available for download (21-day free trial; 5·3 MB) from `http://www.winedit.com/`. It is essentially very similar to the new (2005) WinEdt-5.4, and has the useful facility for column copying/pasting, and also an optional vertical window holding the directory tree.

GNU Emacs (free)

This is a public domain (free) text editor. It is available from the GNU distribution page as follows `http://www.gnu.org/software/emacs/windows/`. See also Harry Halpin's excellent web page entitled *How to install Perl and Emacs on a Windows machine* which can be found at `http://lcb.unc.edu/software/perl/perl.html`.

Programmer's free editor (PFE32)

This is a public domain (free) text editor (`pfe101i.zip`) for Win32 systems, which can be tailored to facilitate the writing and running of Perl programs. PFE32 can be downloaded from the following website `http://www.lancs.ac.uk/people/cpaap/pfe/`.

Unfortunately this editor is rather old now; it lacks context-sensitive highlighting of text, and is not being supported anymore. That said, it is easy to install and does work well.

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