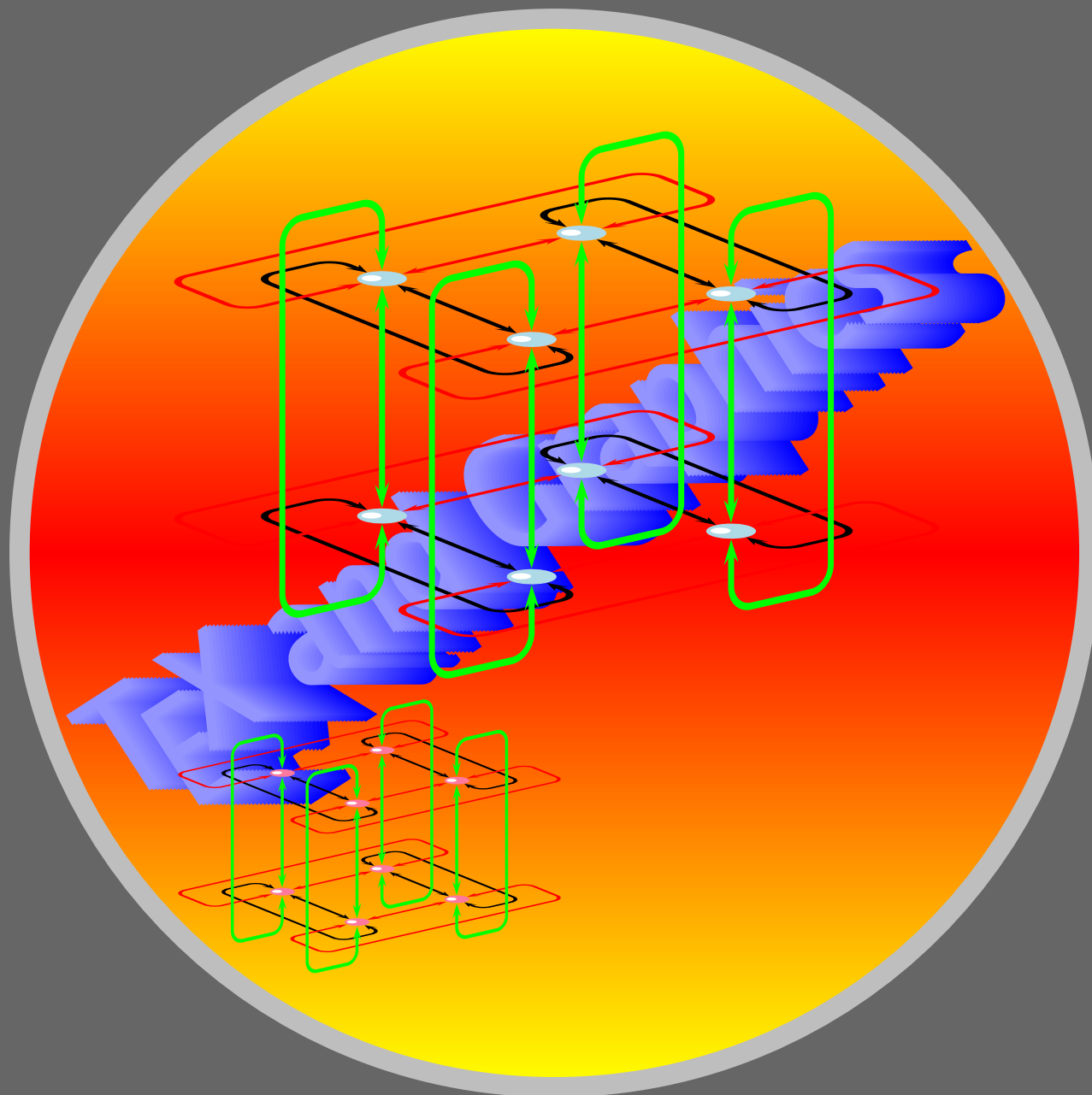


# Tricky Repetitions

*Repeated placing*

*Nesting*

*All-purpose repetition*



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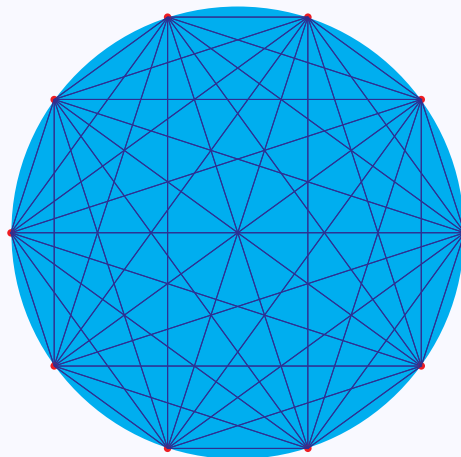
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## 12. Tricky Repetitions

In mathematical (and other kinds of) graphics, we often need to repeat the same thing according to a pattern. It may be a simple thing, such as placing equally spaced points on a line segment:



or slightly more complex, such as joining pairs of equally spaced points on a circle:



These can be done using PSTricks in using the commands we have already seen in earlier chapters; but then, it will be a tedious job, keeping track of the various coordinates.

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We first see how simple repetitions can be done using certain commands available in the generic `pstricks` package itself and then see how all these and much more can be done using an additional package.

# Tricky Repetitions

*Repeated placing*

*Nesting*

*All-purpose repetition*

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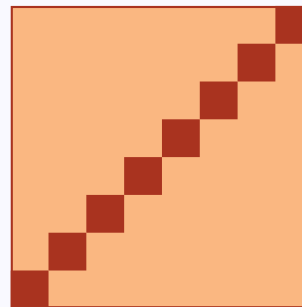
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## 12.1. Repeated placing

We have seen how objects can be placed at specified locations of a PSTricks picture, using the `\rput` command. It has a variant named `\multirput` which places multiple copies of an object at equally spaced points along a line. Look at this example:

```
\begin{center}
\begin{pspicture}(0,0)(4,4)
\psframe[fillstyle=solid,%
fillcolor=Apricot,%
linecolor=Mahogany]%
(0,0)(4,4)
\multirput(0,0)(0.5,0.5){8}{%
\psframe*[linecolor=Mahogany]
(0,0)(0.5,0.5)}
\end{pspicture}
\end{center}
```



In this example, the small dark squares are all drawn with the single command

```
\multirput(0,0)(0.5,0.5){8}{\psframe*[linecolor=Mahogany](0,0)(0.5,0.5)}
```

Here, the small square drawn with the `\psframe*` is the object to be repeatedly placed. The first coordinate  $(0,0)$  is the first point where a copy is to be put. The next pair of numbers,  $(0.5,0.5)$  gives the successive increments to the coordinates; this means, the next copy is to be put at  $(0.5,0.5)$ , the third at  $(1,1)$  and so on. The numbers 8 in the command specifies the number of copies, which also means the final copy would be put at  $(0+8\times0.5,0+8\times0.5) = (4,4)$ .

Thus the first picture at the beginning of the chapter can be easily drawn with the code

# Tricky Repetitions

*Repeated placing*

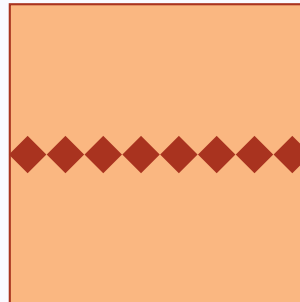
*Nesting*

*All-purpose repetition*

```
\begin{center}
\begin{pspicture}(0,-1)(10,1)
\psline[linecolor=Blue](0,0)(10,0)
\multirput(0,0)(1,0){11}{%
\psdots[linecolor=Red](0,0)}
\end{pspicture}
\end{center}
```

The `\multirput` command has an additional argument to specify rotation, used as in the next example:

```
\begin{center}
\begin{pspicture}(0,0)(4,4)
\psframe[fillstyle=solid,%
fillcolor=Apricot,%
linecolor=Mahogany]%
(0,0)(4,4)
\multirput{45}(0.25,1.75)(0.5,0){8}{%
\psframe*[linecolor=Mahogany]
(0,0)(0.35,0.35)}
\end{pspicture}
\end{center}
```



This command comes in handy, for example, in drawing periodic extensions of functions:

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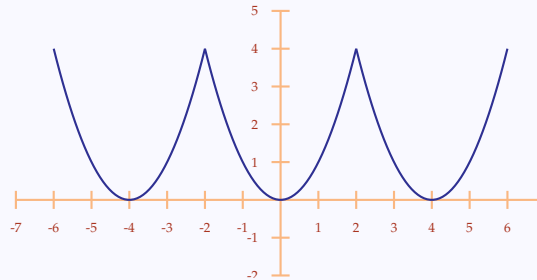
# Tricky Repetitions

Repeated placing

Nesting

All-purpose repetition

```
\renewcommand{\pshlabel}[1]{%
  \tiny\color{Mahogany}\#1}
\renewcommand{\psvlabel}[1]{%
  \tiny\color{Mahogany}\#1}
\newcommand{\pbarc}{%
  \psplot[linecolor=Blue]%
    {-2}{2}{x^2 exp}}
\begin{center}
  \psset{unit=0.8cm}
  \begin{pspicture}(-7,-2)(7,5)
    \psaxes[linecolor=Apricot]%
      (0,0)(-7,-2)(7,5)
    \multirput(-4,0)(4,0){3}{%
      \pbarc}
  \end{pspicture}
\end{center}
```



We can `\multirput` pieces of text also:

```
\DeclareFixedFont{\bigsf}{T1}{phv}{b}{n}{1.5cm}
\begin{center}
  \begin{pspicture}(-0.2,-0.2)(6.2,1)
    \psset{fillstyle=solid,%
      fillcolor=Cyan,%
      linecolor=Blue}
    \multirput[b1](0,0)(-0.02,-0.02){10}{%
      \pscharpath{\bigsf PSTricks}}
  \end{pspicture}
\end{center}
```

**PSTricks**

Note the use `[b1]` in this example, which refers to the bottom left of the (T<sub>E</sub>X) box containing the text. As has been mentioned earlier, the pure graphic objects produced by PSTricks are zero-dimensional T<sub>E</sub>X boxes, and so such a specification is redundant for placing these objects.

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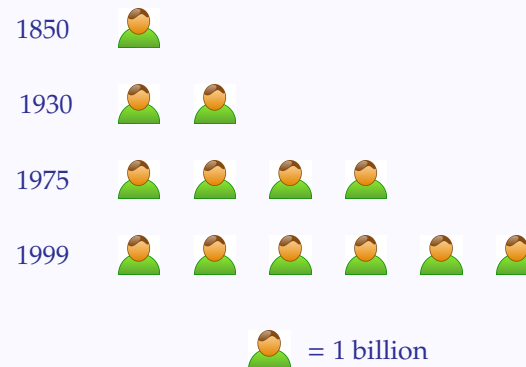
Repeated placing

Nesting

All-purpose repetition

We can also `\multirput` external graphics, which is useful, for example, in drawing pictographs:

```
\newcommand{\includeman}{%
  \includegraphics[scale=0.075]{%
    iconman.eps}}
\begin{center}
  \color{Blue}
  \begin{pspicture}(0,-1.5)(8,4)
    \rput(1,0.25){1999}
    \multirput[b1](2,0)(1,0){6}{%
      \includeman}
    \rput(1,1.25){1975}
    \multirput[b1](2,1)(1,0){4}{%
      \includeman}
    \rput(1,2.25){1930}
    \multirput[b1](2,2)(1,0){2}{%
      \includeman}
    \rput(1,3.25){1850}
    \rput[b1](2,3){\includeman}
    \rput(4,-1){\includeman}
    \rput[l](4.5,-1){$=1$ billion}
  \end{pspicture}
\end{center}
```



We now look at a similar command with slightly different functionality. The command `\multips` is similar to `\multirput`, so that we can get the same output as in the first example above by replacing the line

```
\multirput(0,0)(0.5,0.5){8}{\psframe*[linecolor=Mahogany](0,0)(0.5,0.5)}
```

with

```
\multips(0,0)(0.5,0.5){8}{\psframe*[linecolor=Mahogany](0,0)(0.5,0.5)}
```

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# Tricky Repetitions

*Repeated placing*

*Nesting*

*All-purpose repetition*

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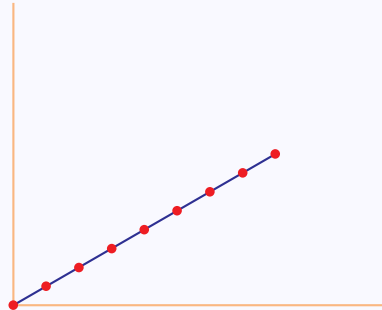


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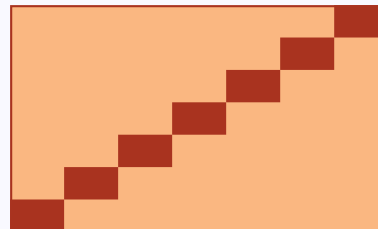
<http://www.tug.org.in>

But `\multips` can handle only pure graphic objects produced by PSTricks. On the other hand, with this command, we can use other kinds of coordinates (remember `\SpecialCoor`?) as increments. Look at these examples:

```
\begin{center}
\begin{pspicture}(0,0)(5,4)
\SpecialCoor
\coloraxes(0,0)(5,4)
\psline[linecolor=Blue](0,0)(4;30)
\multips(0,0)(0.5;30){9}{%
\psdots[linecolor=Red](0,0)}
\end{pspicture}
\end{center}
```



```
\begin{center}
\begin{pspicture}(0,0)(5,3)
\SpecialCoor
\psframe[fillstyle=solid,%
fillcolor=Apricot,%
linecolor=Mahogany]%
(0,0)(5,3)
\multips(0,0)(!5 7 div 3 7 div){7}{%
\psframe*[linecolor=Mahogany]%
(0,0)(!5 7 div 3 7 div)}
\end{pspicture}
\end{center}
```





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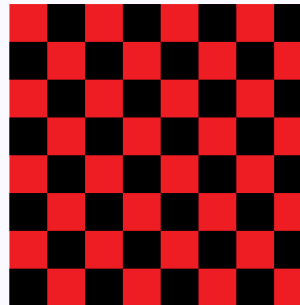
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## 12.2. Nesting

The command `\multirput` can be nested, to produce two-dimensional arrays as below:

```
\begin{center}
\psset{unit=0.5cm}
\begin{pspicture}(0,0)(8,8)
\psframe*[linecolor=Red](0,0)(8,8)
\multirput(0,0)(0,2){4}{%
\multirput(0,0)(2,0){4}{%
\psframe*(0,0)(1,1)
\psframe*(1,1)(2,2)}}
\end{pspicture}
\end{center}
```



To understand why this works, look at the output produced by the inner `\multirput` alone:

```
\begin{center}
\psset{unit=0.5cm}
\begin{pspicture}(0,0)(8,8)
\psframe*[linecolor=Red](0,0)(8,8)
\multirput(0,0)(2,0){4}{%
\psframe*(0,0)(1,1)
\psframe*(1,1)(2,2)}
\end{pspicture}
\end{center}
```



The outer `\multirput` repeats these *two rows* of small black squares four times to fill the large red square.

With deeper nesting, we can produce three-dimensional arrays as well: As an example, We first draw a small cube like this:

# Tricky Repetitions

*Repeated placing*

*Nesting*

*All-purpose repetition*

```
\newcommand{\smallcube}{%  
  \psset{fillstyle=solid,%  
    linestyle=none}  
  \pspolygon[fillcolor=Mahogany]%  
    (0,0)(0,1.2)(1,1)(1,-0.2)  
  \pspolygon[fillcolor=Apricot]%  
    (1,-0.2)(1,1)(2,1.2)(2,0)  
  \pspolygon[fillcolor=Tan]%  
    (0,1.2)(1,1)(2,1.2)(1,1.4)}
```



```
\begin{center}  
  \psset{unit=0.5cm}  
  \begin{pspicture}(0,-0.2)(2,1.4)  
    \smallcube  
  \end{pspicture}  
\end{center}
```

By nesting `\multirput`, we can repeatedly stack such cubes as below:

```
\begin{center}  
  \psset{unit=0.5cm}  
  \begin{pspicture}(-4.2,-0.8)(2,1.4)  
    \multirput(0,0)(-1.4,-0.28){4}{%  
      \smallcube  
    }  
  \end{pspicture}  
\end{center}
```



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# Tricky Repetitions

*Repeated placing*

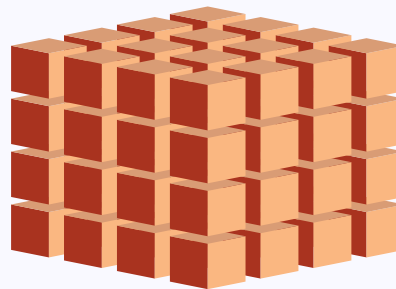
*Nesting*

*All-purpose repetition*

```
\begin{center}
\psset{unit=0.5cm}
\begin{pspicture}(-4.2,-2.2)(6.2,1.4)
\multirput(0,0)(1.4,-0.28){4}{%
\multirput(0,0)(-1.4,-0.28){4}{%
\smallcube}}
\end{pspicture}
\end{center}
```



```
\begin{center}
\psset{unit=0.5cm}
\begin{pspicture}(-4.2,-2.2)(6.2,5.6)
\multirput(0,0)(0,1.4){4}{%
\multirput(0,0)(1.4,-0.28){4}{%
\multirput(0,0)(-1.4,-0.28){4}{%
\smallcube}}}
\end{pspicture}
\end{center}
```



The `\multirput` can also be nested as in the next example. (Yes, the red lines are indeed parallel.)

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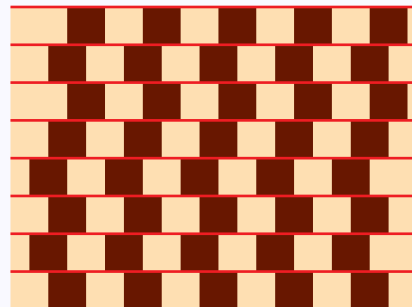
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```

\definecolor{LightApricot}{cmyk}{0,0.12,0.32,0}
\begin{center}
  \psset{unit=0.5cm}
  \begin{pspicture}(-1,0)(10,8)
    \psset{linecolor=Sepia}
    \psframe*[linecolor=LightApricot](-1,0)(10,8)
    \multips(0,0)(0,2){4}{%
      \multips(0,0)(2,0){5}{%
        \psframe*(0,0)(1,1)}%
    }
    \multips(0,0)(0,4){2}{%
      \multips(0.5,1)(2,0){5}{%
        \psframe*(0,0)(1,1)}%
    }
    \multips(-0.5,3)(2,0){5}{%
      \psframe*(0,0)(1,1)}%
    }
    \multips(0,0)(0,1){9}{%
      \psline[linecolor=Red,%
        linewidth=1pt]%
        (-1,0)(10,0)}
  \end{pspicture}
\end{center}

```



# Tricky Repetitions

*Repeated placing*

*Nesting*

*All-purpose repetition*

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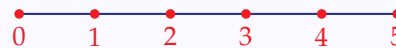
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### 12.3. All-purpose repetition

The commands `\multirput` and `\multips` can only place the *same object* repeatedly at different places in a picture. We cannot use them, for example, to place circles of different radii at different points. The package `multido` contains the command `\multido`, which is admirably suited for such purposes. It was written by Timothy von Zandt, the author of `pstricks`, as a general purpose loop macro for T<sub>E</sub>X. (So, `multido` can be used independent of PSTricks.)

Let's see it in action in a simple example, our own first picture, but with the points labeled:

```
\begin{center}
\begin{pspicture}(0,-1)(5,1)
\psline[linecolor=Blue](0,0)(5,0)
\multido{\i=0+1}{6}{%
\psdots[linecolor=Red](\i,0)
\uput[d](\i,0){\color{Red}\i}}
\end{pspicture}
\end{center}
```



Unlike `\multirput` or `\multips`, the first value and increment are single numbers instead of pairs of coordinates; also both these numbers are given as values to the single variable `\i`, with the initial value and the increment specified in one stroke, by `\i=0+1`. We next specify the number of repetitions as 11. Finally the (variable) objects to be drawn (or placed) by the `\psdots` and `\uput`, using the variable `\i`.

Suppose, we want to number the same points, starting with 1 instead of 0? The obvious solution of specifying `\i+1` for the `\psdots` won't work. We will have to define different variables for the points and the labels, as in the example below:

# Tricky Repetitions

Repeated placing

Nesting

All-purpose repetition

```
\begin{center}
\begin{pspicture}(0,-1)(5,1)
\psline[linecolor=Blue](0,0)(5,0)
\multido{\ai=0+1,\ib=1+1}{6}{%
\psdots[linecolor=Red](\ia,0)
\uput[d](\i,0){\color{Red}\ib}}
\end{pspicture}
\end{center}
```



Note that we have named the two variables `\ia` and `\ib`. Thus `\i` is actually a prefix, specifying the *type* of the variable (i for integer). Also, if there is only one variable, we need not name it, as seen in the first example.

If we want to use a variable with decimal values, we can use the `\n` type, as in the next example:

```
\begin{center}
\begin{pspicture}(0,-1)(5,1)
\psline[linecolor=Blue](0,0)(5,0)
\multido{\i=0+1}{6}{%
\psdots[linecolor=Red](\i,0)
\uput[d](\i,0){\color{Red}\i}}
\multido{\n=0.5+1.0}{5}{%
\psdots[linecolor=Red](\n,0)
\uput[d](\n,0){%
\color{Red}\footnotesize\n}}
\end{pspicture}
\end{center}
```



A more colorful example is given below:

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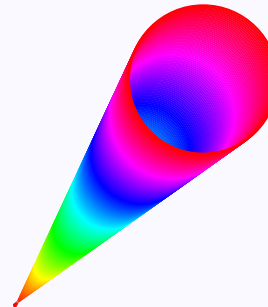
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```

\begin{center}
\psset{unit=0.5cm}
\begin{pspicture}(0,0)(7,8)
\psset{linecolor=Blue}
\multido{\nx=0+0.025,\ny=0+0.03,\nr=0+0.01,\nc=0+0.005}%
{200}%
{\definecolor{varblue}{hsb}{\nc,1,1}
\pscircle[linecolor=varblue](\nx,\ny){\nr}}
\end{pspicture}
\end{center}

```



The type `\n` can handle integers also; but if we use it with decimal values, both the initial number and the increment should have the same number of decimal places after the decimal point. (Actually, if the initial number is an integer, then we can use it without any decimal point.)

The `\multido` command also has a variable type of variable for  $\text{\TeX}$  dimensions, specified as `\d`. As an illustration, here's the code for a generic command, which draws a line joining two specified points and divides into a specified number of equal parts:

# Tricky Repetitions

*Repeated placing*

*Nesting*

*All-purpose repetition*

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# Tricky Repetitions

Repeated placing

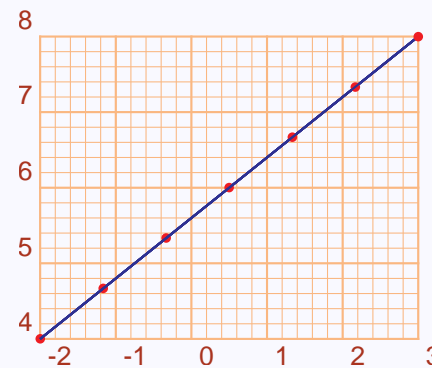
Nesting

All-purpose repetition

```
\newlength{\RunBegin}
\newlength{\RunEnd}
\newlength{\RiseBegin}
\newlength{\RiseEnd}
\newlength{\RunPart}
\newlength{\RisePart}
\newcounter{PartNo}

\def\LineDivide(#1,#2)(#3,#4)#5{%
  \setlength{\RunBegin}{#1cm}
  \setlength{\RunEnd}{#3cm}
  \setlength{\RiseBegin}{#2cm}
  \setlength{\RiseEnd}{#4cm}
  \setlength{\RunPart}{(\RunEnd-\RunBegin)/#5}
  \setlength{\RisePart}{(\RiseEnd-\RiseBegin)/#5}
  \setcounter{PartNo}{#5}
  \addtocounter{PartNo}{1}
  \multido{\dx=\RunBegin+\RunPart,%
    \dy=\RiseBegin+\RisePart}%
    {\value{PartNo}}%
    {\psline[linecolor=Blue]%
      (#1,#2)(#3,#4)%
      \psdots[linecolor=Red]%
        (\dx,\dy)}}

\begin{center}
  \begin{pspicture}(-2,4)(3,8)
    \colgrid
    \LineDivide(-2,4)(3,8){6}
  \end{pspicture}
\end{center}
```



Note that the command `\colgrid` is just a customized `\psgrid`, as explained in an earlier chapter. Also, we have to load the package `calc` for the computations with the  $\text{\TeX}$  dimensions. Here we use the  $\text{\TeX}$  command `\def` for defining the macro, instead of the  $\text{\LaTeX}$  command `\newcommand`, since the

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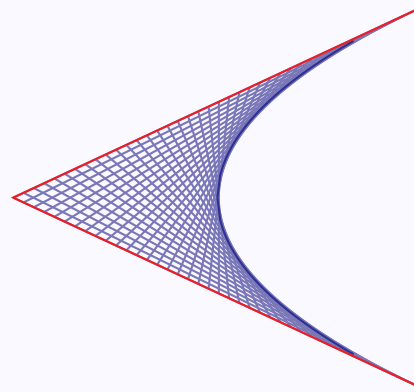
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former can accommodate general delimiters for arguments.

Increments can also be negative, but has to be specified using `+-`, as in the next example:

```
\begin{center}
\psset{unit=0.3cm}
\begin{pspicture}(0,-9)(20,9)
\SpecialCoor
\multido{\nx=0+0.5,\ny=20+-0.5}{41}{%
\psline[linecolor=Periwinkle]%
(\nx;25)(\ny;-25)}
\psplot[linecolor=Blue]%
{9}{15}{x 9 sub sqrt 2.82 mul}
\psplot[linecolor=Blue]%
{9}{15}{x 9 sub sqrt 2.82 mul neg}
\psline[linecolor=Red](20;25)(0,0)(20;-25)
\end{pspicture}
\end{center}
```



Like the other loop commands, `\multido` can also be nested, as in the example below:

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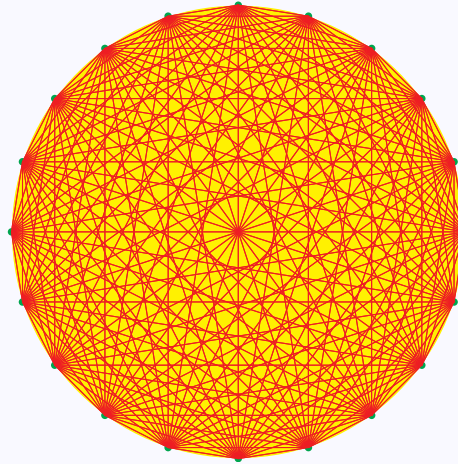
# Tricky Repetitions

*Repeated placing*

*Nesting*

*All-purpose repetition*

```
\begin{center}
\psset{unit=0.75cm}
\begin{pspicture}(-4,-4)(4,4)
\psset{linewidth=0.4pt}
\SpecialCoor
\pscircle[linestyle=none,%
          fillstyle=solid,%
          fillcolor=Yellow]%
          (0,0){4}
\multido{\nx=0+18}{20}{%
\psdots[linecolor=Green](4;\nx)
\multido{\ny=0+18}{20}{%
\psline[linecolor=Red]%
(4;\nx)(4;\ny)}}
\end{pspicture}
\end{center}
```



The second picture at the beginning of the chapter is produced by the same code as above, with 10 iterations instead of 20 (and of course, with a change of color.)

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## Non-linear repetitions

All the three loop macros we have discussed can handle only linear increments directly. However, we can use non-linear variables depending on a linear variable, by doing the computation in PostScript, wrapping it in a  $\text{\TeX}$  macro and then putting the macro in `\multido`. The example below illustrates a simple implementation of this idea.

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# Tricky Repetitions

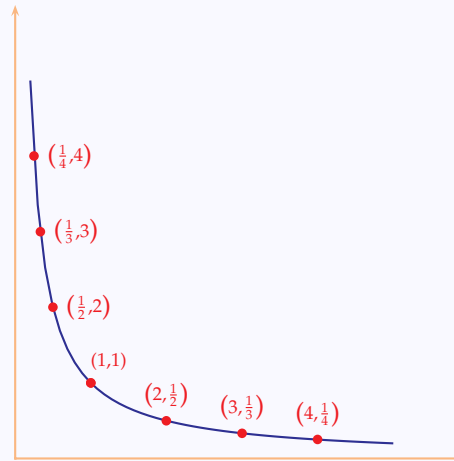
Repeated placing

Nesting

All-purpose repetition

```
\newcommand{\Reciprocal}[1]{%
  !#1 1 #1 div}

\begin{center}
  \begin{pspicture}(0,0)(6,6)
    \psaxes[linecolor=Apricot,%
      ticks=none,%
      labels=none,%
      arrows=->](6,6)
    \psplot[linecolor=Blue]{0.2}{5}{1 x div}
    \SpecialCoor
    \multido{\n=1+1}{4}{%
      \psset{linecolor=Red}
      \psdots(\Reciprocal{\n})
      \psdots(\Reciprocal{\n} exch)}
    \multido{\n=2+1}{3}{%
      \uput[u](\Reciprocal{\n}){%
        \color{Red}
        $\scriptstyle\%
        \left(\n,\frac{1}{\n}\right)$}}
      \multido{\n=2+1}{3}{%
        \uput[r](\Reciprocal{\n} exch){%
          \color{Red}
          $\scriptstyle\%
          \left(\frac{1}{\n},\n\right)$}}
        \uput[60](1,1){%
          \color{Red}$\scriptstyle{(1,1)}$}
      \end{pspicture}
    \end{center}
```



Here, we want to locate and label some points on the curve  $xy = 1$ . The  $\text{\LaTeX}$  macro `\Reciprocal` converts a specified number to PostScript code for the number and its reciprocal. This is then used in `\multido` to produce the `\psdots` at points like  $(2, \frac{1}{2})$ . To produce dots at points like  $(\frac{1}{2}, 2)$  we use the PostScript operator `exch`, to interchange the coordinates. The same trick is

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# Tricky Repetitions

*Repeated placing*

*Nesting*

*All-purpose repetition*

used to produce the labels, except at (1, 1).

We conclude with another example of this trick:

```
\newcommand{\rotsq}[3]{%
  \rput{!#2 #1 mul}{%
    \psframe*[linecolor=#3]%
      (!1 2 sqrt 135 #1 sub sin mul div #2 exp neg dup)
      (!1 2 sqrt 135 #1 sub sin mul div #2 exp dup)}}

\begin{center}
  \psset{unit=2cm}
  \begin{pspicture}(-1,-1)(1,1)
    \psframe*[linecolor=Red](-1,-1)(1,1)
    \SpecialCoor
    \multido{\na=1+2,\nb=2+2}{50}{%
      \rotsq{5}{\na}{Black}
      \rotsq{5}{\nb}{Red}}
  \end{pspicture}
\end{center}
```



The picture is conceived (and produced) as a sequence of shrinking squares, rotated more and more, and painted alternately red and black.

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