Hour 11

Equation Writing I

Mathematical expressions or equations in LaTeX are written in math-mode environments, such as **equation** or **eqnarray**. The math-mode environments are defined in the **amsmath** package, while many mathematical symbols are defined in the **amssymb** package. There exist many more relevant packages, which are stated in Appendix A on page 247.

11.1 Basic Mathematical Notations and Delimiters

Since various mathematical notations are basic tools for writing mathematical expressions, LaTeX commands for some frequently used notations are listed in Table 11.1 on the next page as a quick reference. Note that multi-letter (or multi-digit) superscripts or subscripts must be inserted in **{}**, while a single-letter (or single-digit) can be inserted directly also.

Some basic delimiters, a pair of which acts like parentheses to enclose an expression, are also given in Table 11.2 on the next page (more delimiters are given in Appendix A). To fit automatically around the height of a mathematical expression, the **\left** and **\right** commands may be used before the opening and closing delimiters (**\left** and **\right** are used as a complementary pair). The two delimiters enclosing an expression need not to be similar. For example, **\left(** and **\right]** can be used to enclose an expression in **( ]**. If no delimiter is required in one side of an expression, the **\left.** or **\right.** command, as applicable, may be used. On the other hand, for fixed big-size delimiters (i.e., the size of a delimiter is not auto-adjusted as seen in the right column of Table 11.2), the **\big**, **\Big**, **\bigg** and **\Bigg** commands may be used by appending **l** and **r** for producing opening and closing delimiters respectively, e.g., **\biggl\{** and **\biggr\}** will produce a pair of big-sized curly braces. Note that none of the commands of the forms of **\big**, **\Big**, **\bigg** and **\Bigg** is required to appear in a complementary pair, i.e., either the opening or closing delimiter can also be used alone as shown in the right column of Table 11.2.

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Table 11.1 Frequently used mathematical notations (math-mode)

Function	Command with application	Output
Prime	p'	p'
Dots	\dot{x}, \ddot{x}, \dddot{x}, \ddddot{x}	$\dot{x}, \ddot{x}, \dddot{x}, \ddddot{x}$
Single sub-/super-script	x_i, x^2	x_i, x^2
Multiple sub-/super-scripts	x_{ij}, x^{2k}	x_{ij}, x^{2k}
Subscript and superscript	x^{2k}_{ij} or x_{ij}^{2k}	x_{ij}^{2k}
Summation	\sum, \sum_{i=1}^{20}	$\sum, \sum_{i=1}^{20}$
Product	\prod, \prod_{i=1}^{i=20}	$\prod, \prod_{i=1}^{20}$
Integration	\int x^2\,dx, \int_a^b xy\,dx	$\int x^2\,dx, \int_a^b xy\,dx$
Multiple integration	\iint\limits_s, \iiint\limits_v, \iiiint	$\iint\limits_s, \iiint\limits_v, \iiiint$
Set of integrations	\idotsint	$\int\cdots\int$
Cyclic integration	\oint	$\oint$
Fraction	\frac{x}{y}	$\frac{x}{y}$
Derivative	\nabla{f}, \frac{dx}{dy}	$\nabla f, \frac{dx}{dy}$
Partial derivative	\frac{\partial{y}}{\partial{x}}	$\frac{\partial y}{\partial x}$
Root	\sqrt{x}, \sqrt[5]{xyz}	$\sqrt{x}, \sqrt[5]{xyz}$
Limit	\lim_{x\to 0}, \underset{x\to 0}{\lim}	$\lim_{x\to 0}, \underset{x\to 0}{\lim}$
Exists/not exists	\exists, \nexists	$\exists, \nexists$
Modes	\mod{n^2}, \bmod{n^2}, \pmod{n^2}, \pod{n^2}	$\mod n^2, \bmod n^2, \pmod{n^2}, \pod{n^2}$
Binomial expression	\binom{n}{k}	$\binom{n}{k}$

Table 11.2 Basic delimiters (math-mode)

<table>
<tr><th>Delimiter</th><th>Command</th><th>Delimiter</th><th>Command</th></tr>
<tr><td>$\left(\frac{x}{y}\right)$</td><td>\left(\frac{x}{y} \right)</td><td>$\bigl(\frac{x}{y}\bigr)$</td><td>\bigl(\frac{x}{y} \bigr)</td></tr>
<tr><td>$\left(\frac{x}{y}\right.$</td><td>\left(\frac{x}{y} \right.</td><td>$\Bigl(\frac{x}{y}$</td><td>\Bigl(\frac{x}{y}</td></tr>
<tr><td>$\left.\frac{x}{y}\right)$</td><td>\left. \frac{x}{y} \right)</td><td>$\frac{x}{y}\biggr)$</td><td>\frac{x}{y} \biggr)</td></tr>
<tr><td>$\left\{\frac{x}{y}\right\}$</td><td>\left\{ \frac{x}{y} \right\}</td><td></td><td></td></tr>
<tr><td>$\left\{\frac{x}{y}\right.$</td><td>\left\{ \frac{x}{y} \right.</td><td>$\biggl\{\frac{x}{y}\biggr\}$</td><td>\biggl\{ \frac{x}{y} \biggr\}</td></tr>
<tr><td>$\left.\frac{x}{y}\right\}$</td><td>\left. \frac{x}{y} \right\}</td><td></td><td></td></tr>
<tr><td>$\left[\frac{x}{y}\right]$</td><td>\left[\frac{x}{y} \right]</td><td>$\Biggl(\frac{x}{y}\Biggr)$</td><td>\Biggl(\frac{x}{y} \Biggr)</td></tr>
<tr><td>$\left[\frac{x}{y}\right.$</td><td>\left[\frac{x}{y} \right.</td><td></td><td></td></tr>
<tr><td>$\left.\frac{x}{y}\right]$</td><td>\left. \frac{x}{y} \right]</td><td>$\frac{x}{y}\Biggr\}$</td><td>\frac{x}{y} \Biggr\}</td></tr>
<tr><td>$\left|\frac{x}{y}\right|$</td><td>\left| \frac{x}{y} \right|</td><td></td><td></td></tr>
<tr><td>$\left|\frac{x}{y}\right.$</td><td>\left| \frac{x}{y} \right.</td><td>$\frac{x}{y}\Biggr|$</td><td>\frac{x}{y} \Biggr|</td></tr>
<tr><td>$\left.\frac{x}{y}\right|$</td><td>\left. \frac{x}{y} \right|</td><td></td><td></td></tr>
</table>

11.2 Mathematical Operators

In order to form a mathematical expression, various terms are connected by some operators, which are classified into two categories: binary operators and relation operators. Such basic operators, which are to be obtained in LaTeX through some commands, are given in Tables 11.3 and 11.4 (more operators are given in Appendix A).

Table 11.3 Basic binary operators

Symbol	Command	Symbol	Command	Symbol	Command
$\pm$	\pm	$\diamond$	\diamond	$\wr$	\wr
$\mp$	\mp	$\Diamond$	\Diamond	$\setminus$	\setminus
$\div$	\div	$\triangle$	\triangle	$\amalg$	\amalg
$\times$	\times	$\bigtriangleup$	\bigtriangleup	$\dagger$	\dagger
$\ast$	\ast	$\bigtriangledown$	\bigtriangledown	$\ddagger$	\ddagger
$\star$	\star	$\triangleleft$	\triangleleft	$\bigcirc$	\bigcirc
$\cdot$	\cdot	$\triangleright$	\triangleright	$\bigcap$	\bigcap
$\circ$	\circ	$\lhd$	\lhd	$\bigcup$	\bigcup
$\bullet$	\bullet	$\rhd$	\rhd	$\bigsqcup$	\bigsqcup
$\cap$	\cap	$\unlhd$	\unlhd	$\biguplus$	\biguplus
$\cup$	\cup	$\unrhd$	\unrhd	$\bigvee$	\bigvee
$\sqcap$	\sqcap	$\odot$	\odot	$\bigwedge$	\bigwedge
$\sqcup$	\sqcup	$\oplus$	\oplus	$\bigodot$	\bigodot
$\uplus$	\uplus	$\ominus$	\ominus	$\bigoplus$	\bigoplus
$\vee$	\vee	$\otimes$	\otimes	$\bigotimes$	\bigotimes
$\wedge$	\wedge	$\oslash$	\oslash		

Table 11.4 Basic relation operators

Symbol	Command	Symbol	Command	Symbol	Command
$\leq$	\leq (or, \le)	$\in$	\in	$\not=$	\not=
$\ll$	\ll	$\notin$	\not\in	$\doteq$	\doteq
$\geq$	\geq (or, \ge)	$\ni$	\ni	$\propto$	\propto
$\gg$	\gg	$\vdash$	\vdash	$\vert$	|
$\gtreqqless$	\gtreqqless	$\dashv$	\dashv	$\models$	\models
$\prec$	\prec	$\equiv$	\equiv	$\perp$	\perp
$\preceq$	\preceq	$\not\equiv$	\not\equiv	$\mid$	\mid
$\succ$	\succ	$\sim$	\sim	$\parallel$	\parallel
$\succeq$	\succeq	$\not\sim$	\not\sim	$\nparallel$	\not\parallel
$\subset$	\subset	$\simeq$	\simeq	$\bowtie$	\bowtie
$\subseteq$	\subseteq	$\asymp$	\asymp	$\Join$	\Join
$\sqsubseteq$	\sqsubseteq	$\approx$	\approx	$\smile$	\smile
$\supset$	\supset	$\not\approx$	\not\approx	$\frown$	\frown
$\supseteq$	\supseteq	$\cong$	\cong	$\not<$	\not<
$\sqsupseteq$	\sqsupseteq	$\neq$	\neq	$\not>$	\not>

11.3 Mathematical Expressions in Text-Mode

A math-mode environment, like **equation** or **enqarray**, prints a mathematical expression in a new line. Sometime a short mathematical notation or expression may need to be printed in running texts also, i.e., in the same line along with texts. For example, in the following statement, one equation and three variables are printed in running texts:

> The equation of an origin-centered circle is $x^2 + y^2 = r^2$, where x and y are the coordinates of a point on the circumference of the circle, and r is its radius.

A mathematical expression, say `amath`, can be inserted in running texts as `$amath$`, `\(amath\)` or `\begin{math}amath\end{math}`, where '`$$`', '`\( \)`' or the **math** environment create math-modes in running texts[1]. A single notation is usually inserted in `$$`, while an expression is inserted in `\( \)` or in the **math** environment (however, all three are applicable in either case). In the above example, accordingly, the equation can be inserted as `\(x^2 + y^2 = r^2\)` or `\begin{math}x^2 + y^2 = r^2\end{math}`, while the variables x, y and r as `$x$`, `$y$` and `$r$` respectively.

11.4 Simple Equations

The very basic math-mode environment for producing an equation is **equation**. Within the environment, an equation can be written as a combination of different mathematical expressions, as shown in Table 11.1, such as summation, power, root or equality. The **equation** environment, an example of which is shown in Table 11.5, is used for

Table 11.5 A simple equation through the **equation** environment

LaTeX input	Output

`\begin{equation}`
`x^2 + y^2 = r^2`
`\label{eq:circ}`
`\end{equation}`
	$x^2 + y^2 = r^2$ (11.1)

inserting a single equation that is printed in a separate center-aligned line. Moreover, the equation is assigned a serial number printed in `( )` on its right hand side. As shown in Table 11.5, an equation can be assigned a unique label-word through the `\label{}` command, which can be used for referring the equation through the `\ref{}` command (similar to `\ref{}`, the `\eqref{}` command may also be used for referring an equation, which automatically puts the serial number of the equation in a pair of parentheses).

[1]A mathematical notation or expression, say `amath`, can be inserted in running texts as `$amath$`, `\(amath\)`, or `\begin{math}amath\end{math}`.

11.4.1 Eliminating Equation Numbering

If an equation is not to be numbered, either the **equation*** environment, or one of the **\nonumber** and **\notag** commands after the equation, may be used. There exist the **displaymath** environment and the **\[\]** mode, which also allow to produce an equation without numbering it. The applications of these provisions are shown in Table 11.6. When an equation is prevented from numbering by any of these approaches, the equation is not counted during numbering its following equations.

Table 11.6 Different approaches for producing equations without numbering

LaTeX input	Output
`\begin{equation}` `x^2 + y^2 = r^2 \nonumber` `\end{equation}`	$x^2 + y^2 = r^2$
`\begin{equation}` `x^2 + y^2 = r^2 \notag` `\end{equation}`	$x^2 + y^2 = r^2$
`\begin{equation*}` `x^2 + y^2 = r^2` `\end{equation*}`	$x^2 + y^2 = r^2$
`\begin{displaymath}` `x^2 + y^2 = r^2` `\end{displaymath}`	$x^2 + y^2 = r^2$
`\[x^2 + y^2 = r^2\]`	$x^2 + y^2 = r^2$

11.4.2 Overwriting Equation Numbering

Opposite to **\notag**, there are **\tag{**`anum`**}** and **\tag*{**`anum`**}** commands allowing to overwrite the numbering of an equation by `anum`, where **\tag{}** prints `anum` in a pair of parentheses and **\tag*{}** prints it without any parenthesis. An example is shown in Table 11.7, where **\tag*{}** is used to refer a label-word by **\ref{}**[2].

Table 11.7 Overwriting equation numbering by the **\tag*{}** command

LaTeX input	Output
`\begin{equation}` `x^2+y^2=r^2 \tag*{Repeat Eq.~(\ref{eq:circ})}` `\end{equation}`	$x^2 + y^2 = r^2$ Repeat Eq. (11.1)

11.4.3 Changing Printing Format of Equations*

As seen in Table 11.5, by default an equation is printed in a center-aligned new line and it is assigned a serial number in `()` on its right side. All the equations of a doc-

[2]The **\eqref{}** command works in the **\tag{}** command, but not in the **\tag*{}** command.

ument can be made globally left aligned, with some predefined indentation, using **fleqn** as an option to **\documentclass[ ]{ }** (§11.6 on page 110 discusses left alignment of a particular equation only). The predefined indentation under the **fleqn** option can be changed by altering the value of **\mathindent**, e.g., **\setlength{\mathindent}{5mm}** or **\mathindent=0mm**. Such a change may be made in the preamble for global effect, or prior to an equation for local effect. Further, **leqno** may be used as another option to **\documentclass[ ]{ }** for printing equation number on left side. Another noticeable thing in Table 11.5 is that the serial number of the equation is preceded by the chapter number and a period mark. That is, equations in the document-class **book** are numbered chapter-wise. In contrast, an equation in the document-class **article** is assigned its serial number only, i.e., not section-wise (the document-class **article** does not support a chapter). To get the equation numbering section-wise, the following four lines of commands may be included in the preamble (§19.2.5 on page 189 discusses the commands in detail):

```
\makeatletter
\@addtoreset{equation}{section}
\makeatother
\renewcommand{\theequation}{\thesection.\arabic{equation}}
```

Applications of the above mentioned provisions are shown in Table 11.8. In the document-class **article**, tables and figures, which are also by default numbered by their serial numbers only, can be numbered section-wise as above. In that case, **equation** and **\theequation** in **\@addtoreset{ }{ }** and **\renewcommand{ }{ }** are to be replaced by **table** and **\thetable** (or, **figure** and **\thefigure**) respectively.

Table 11.8 Changing the standard format for printing and numbering equations

LaTeX input	Output
\documentclass[fleqn,leqno]{article} \usepackage{amsmath, amssymb} \makeatletter \@addtoreset{equation}{section} \makeatother \renewcommand{\theequation}% {\thesection.\arabic{equation}} % \begin{document} \section{First section} \begin{equation} x^2+y^2=r^2 \end{equation} % \section{Second section} \mathindent=0mm \begin{equation} x^3+y^3=r^3 \end{equation} \end{document}	**1 First section** (1.1) $x^2 + y^2 = r^2$ **2 Second section** (2.1) $x^3 + y^3 = r^3$

11.5 Array of Equations

The **equation** or **displaymath** environment, or the **\[\]** mode, is used for producing a single equation in a separate line. Sometime a set of simultaneous equations may need to be produced in an array form (one below another). LaTeX provides a number of special environments for producing an array of equations together, instead of producing each equation by a separate **equation** or **displaymath** environment, or **\[\]** mode. Some of such environments, along with their alignment structures, are given in Table 11.9. In these environments, an equation, except the last one of an array, is

Table 11.9 Array of equations producing environments and their alignment structures

Environment	Alignment structure
gather and **gather***	Gather equations without alignment.
eqnarray and **eqnarray***	Allow alignment about a single place only.
align and **align***	Allow alignment about a single place only.
alignat and **alignat***	Allow alignment about multiple places.
xalignat and **xxalignat**	Allow alignment about multiple places. Columns and margins are equally spaced in **xalignat**, while margin spacing is ignored in **xxalignat**.
array	Allows alignment at multiple places. It is to be nested in a math-mode, say the **equation** or **displaymath** environment or the **\[\]**-mode.

terminated by ****. The **\\[**vsize**]** command can also be used for providing extra vsize vertical space between two equations. The **\displaybreak[**adigit**]** command may also be used just before **** as the page breaking instruction after the current equation, with optional adigit value of 0–4, where 0 means the provision for breaking and 4 means the must breaking. On the other hand, the **\intertext{**atext**}** command after **** allows to insert a few lines of texts (i.e., atext) in between two equations maintaining their alignments.

The patterns of aligning the equations of an array differ from environment to environment. The **eqnarray** and **eqnarray*** environments enclose the aligning place by a pair of **&** sign, e.g., **&**=**&** for aligning about the '=' sign, or simply **&&** for aligning about an empty space. The **align** and **align*** environments use a single **&** on the left side of the aligning place, e.g., **&**= for aligning about the '=' sign. Similarly, the **alignat**, **alignat***, **xalignat** and **xxalignat** environments (which allow alignment at multiple places) also use a single **&** on the left side of an aligning place, but with a provision for ending the current aligning place by another **&** before starting the alignment at the next place, e.g., in x**&**+**&**y**&**=z, the first **&** makes an alignment about the '+' sign, which is ended by the next **&** before starting the second alignment about the '=' sign. The **alignat**, **alignat***, **xalignat** and **xxalignat** environments take the number of aligning places as a mandatory argument, e.g., **\begin{alignat}{**m**}** with $m = \frac{n}{2} + 1$ if n is even and $m = \frac{n+1}{2}$ if n is odd, where n is the number of **&** to be used in an equation. Note that the alignment about a place, under these environments, internally splits an equation at this place into two parts of **rl**-alignment, i.e., the left side part is right aligned and the right side part is left aligned. On the other hand, the aligning process in the **array** environment is quite different. Similar to the **tabular** environment used for preparing a table (refer §7.1 on page 59), the **array** environment creates aligning places through mandatory options of **l** for left alignment, **c** for centered and **r** for right alignment, e.g., **\begin{array}{rl}** for right aligning the left portion (due to **r**) and left aligning the right portion (due to **l**).

The starred forms of the environments (including **xxalignat** which acts like the starred form of **xalignat**) ignore the numbering to any equation, while their non-starred forms (including **xalignat**) assign an individual serial number to each equation. If required, numbering to any equation of an array can be eliminated using the **\nonumber** or **\notag** command as explained in §11.4.1 on page 105. On the other hand, the **array** environment also ignores the numbering, but the entire array of equations will be assigned a single serial number if the **array** environment is nested inside an **equation** environment.

Table 11.10 shows, through the same array of three equations, some applications of the environments given in Table 11.9, along with those of other commands discussed above (except **\displaybreak**). Since the **gather** environment just gathers an array of equations without any alignment, no **&** is used in this environment. The

Table 11.10 Array of equations in different forms

LaTeX input	Output

\begin{gather}
  5x+ 2y = x+ 2z+ 3\\
130x+ 4z = y+ 2\\
  43y+ 57z = 20x+ 99
\end{gather}
	$5x+2y=x+2z+3$ (11.2)
	$130x+4z=y+2$ (11.3)
	$43y+57z=20x+99$ (11.4)

\begin{eqnarray} 5x+2y &=& x+2z+3 \label{eqn1}\\ 130x+4z &=& y+2 \nonumber \\ 43y+57z &=& 20x+99 \label{eqn3} \end{eqnarray}	$5x+2y \; = \; x+2z+3$ (11.5) $130x+4z \; = \; y+2$ $43y+57z \; = \; 20x+99$ (11.6)
\begin{align} 5x+2y &= x+2z+3 \tag{See \eqref{eqn1}}\\ 130x+4z &= y+2 \label{align2}\\[3mm] 43y+57z &= 20x+99 \notag \end{align}	$5x+2y=x+2z+3$ (See (11.5)) $130x+4z=y+2$ (11.7) $43y+57z=20x+99$

\begin{alignat*}{7}
  5x&+& 2y&& &=& x&+& &&2z&+& 3\\
 \intertext{Please notice the alignment ...}
130x&+& && 4z &=& &&y&+& && 2\\
  &&43y&+&57z &=&20x&+& && &&99
\end{alignat*}
	$5x+\;\; 2y \quad = \quad x+ \quad 2z+\;\; 3$
	
	Please notice the alignment made about each '+' and '=' signs of these equations.
	
	$130x+ \quad 4z= \quad y+ \quad 2$
	$43y{+}57z=20x+ \quad 99$

\begin{xxalignat}{7}
  5x&+& 2y&& &=& x&+& &&2z&+& 3\\
130x&+& && 4z &=& &&y&+& && 2\\
  &&43y&+&57z &=&20x&+& && &&99
\end{xxalignat}
	$5x+ \quad 2y \quad = \quad x+ \quad 2z+ \quad 3$
	$130x+ \quad 4z= \quad y+ \quad 2$
	$43y+ \quad 57z= \quad 20x+ \quad 99$

\begin{equation}
\left.\begin{array}{*{13}{@{}r@{}}}
  5x&+& 2y&& &=& x&+& &&2z&+& 3\\
130x&+& && 4z &=& &&y&+& && 2\\
  &&43y&+&57z &=&20x&+& && &&99
\end{array}\right\}
\end{equation}
	$\left.\begin{array}{rrrrrrr} 5x+ & 2y & = & x+ & 2z+ & 3 \\ 130x+ & 4z= & & y+ & & 2 \\ 43y+57z=20x & & & & & 99 \end{array}\right\}$ (11.8)

second equation of the **eqnarray** environment is prevented from numbering by using **\nonumber** before terminating it by ****. For the same purpose, **\notag** is used before terminating the last equation of the **align** environment. Moreover, the first equation of the **align** environment is not numbered but referred to another equation through **\tag{}**, while a gap of 3 mm is created above its last equation by terminating the previous equation by **\\[**3 **mm]**. On the other hand, a note is produced, through **\intertext{}**, after the first equation of the **alignat*** environment (**\intertext{}** cannot be used in the **array** environment).

In the **array** environment in Table 11.10, each term and operator, totaling 13 in number, is right aligned separately, which are done by creating 13 number of right aligned places (columns) through **\begin{array}{*{**13**}{r}}** (refer §7.6 on page 64 for detail). The **array** environment allows to enclose an array by a pair of delimiters, which is demonstrated in Table 11.10, where the entire environment is enclosed by **\left.** and **\right\}** for producing a curly brace on the right side of the array. Alternatively, the same effect can be produced by enclosing the mandatory argument of the environment by a pair of delimiters (this provision is defined in the **delarray** package), e.g., it could be created in Table 11.10 as **\begin{array}.{*{**13**}{r}}\}** instead of enclosing the entire environment by **\left.** and **\right\}**. On the other hand, the **array** environment has optional provision for vertical alignment also, which is executed as **\begin{array}[**valign**]{}**, where the permissible values of valign are **t** for top alignment, **c** for center alignment and **b** for bottom alignment. Further, as adjusting column width in tables discussed in §7.5 on page 63, the blank space between two columns in the **array** environment can be changed either by using **@{}** (as shown in the last example in Table 11.10) or by changing the value of **\arraycolsep** (default is 5 pt), e.g., **\setlength{\arraycolsep}{**1**mm}**. Moreover, any row, column or entry in the **array** environment can be colored in the same way discussed in §7.9 on page 68 for those of a table.

Notice in Table 11.10 that the **eqnarray** environment leaves excess blank space around an aligned place, while other environments of Table 11.9 maintain comparatively better spacing. Further, alignment at a single place may not always be preferred, e.g., the case of the array of equations considered in Table 11.10, where all the variables (x, y and z) may need to be aligned. However, the choice of an environment is up to a user.

Each of the equations of a numbered array, produced by a non-starred environment given in Table 11.9 (excluding **xxalignat** and **array**), can be labeled and referred individually through **\label{}** and **\ref{}**, respectively. As shown in Table 11.10, an equation of an array is to be labeled before terminating it, i.e., before the line-break command ****.

11.6 Left Aligning an Equation*

By default an equation is printed in a center-aligned new line. The **fleqn** option to **\documentclass[]{}** acts globally to make all equations of a document left aligned. In contrast, the **flalign** environment (or the **flalign*** form for unnumbered equations) can be used for left aligning a particular equation only.

The **flalign** environment allows the use of two **&** for internally aligning an array of equations about a particular place, out of which one **&** must be at the end of an equation (refer §11.5 on page 107 for detail of using **&** in an array of equations). If no internal alignment of an array of equations is required about any particular place (or in the case of a single equation), the first **&** may be inserted either at the start or at the end (together with the second **&**) of an equation as per requirement.

Some applications of the **flalign** and **flalign*** environments are shown in Table 11.11, where the locational effect of the first **&** is noticeable. In the case of a single

Table 11.11 Left aligned equations through the **flalign** and **flalign*** environments

LaTeX input	Output

`\begin{flalign*}`
`& x^2+y^2 = r^2 &`
`\end{flalign*}`
	$x^2+y^2=r^2$

`\begin{flalign*}`
`x^2+y^2 = r^2 &&`
`\end{flalign*}`
	$x^2+y^2=r^2$

`\begin{flalign}`
` & 2x+3y  =  6-z  & \\`
` &       z  =  1    &`
`\end{flalign}`
	$2x+3y=6-z$ (11.9)
	$z=1$ (11.10)

`\begin{flalign}`
` 2x+3y  =  6-z  && \\`
`     z  =  1    &&`
`\end{flalign}`
	$2x+3y=6-z$ (11.11)
	$z=1$ (11.12)

`\begin{flalign}`
` 2x+3y  &=  6-z  & \\`
`     z  &=  1    &`
`\end{flalign}`
	$2x+3y=6-z$ (11.13)
	$z=1$ (11.14)

`\begin{flalign}`
`\left.\begin{array}{*{13}{@{}r@{}}}`
`   5x&+&   2y&&      &=&   x&+&   &&2z&+&  3\\`
` 130x&+&      &&  4z &=&       &&y&+&      &&  2\\`
`       &&43y&+&57z &=&20x&+&   &&      &&99`
`\end{array}\right}`
`&&`
`\end{flalign}`
	$\left.\begin{array}{rrrrr} 5x+ & 2y & = & x+ & 2z+\ 3 \\ 130x+ & 4z= & & y+ & 2 \\ & 43y+57z=20x & & & 99 \end{array}\right\}$ (11.15)

equation, as shown in the first two examples, the location of the first **&** does not effect the presentation of the equation. However, the location of the first **&** matters in an array of equations, which can be noticed in the third, fourth and fifth examples in Table 11.11. The last example in Table 11.11 is an interesting one (it is the last example of Table 11.10). Since internal alignment of the array of equations is required about more than one place, the array is first produced through an **array** environment. Then the **array** environment, followed by **&&**, is put in a **flalign** environment for left aligning the entire array.

11.7 Sub-numbering a Set of Equations*

It is seen in §11.5 that the non-starred environments of Table 11.9 (excluding **xxalignat** and **array**) assign an individual serial number to each of a set of equations. Instead of such individual numbering, sometime a set of equations may be preferred to be sub-numbered under a main number, e.g., (3a), (3b), (3c), etc. Such sub-numbering can be obtained by nesting the equation generating environments (like **equation**, **eqnarray** or **align**) in the **subequations** environment. Such an example is shown in Table 11.12,

Table 11.12 Sub-numbering a set of equations

LaTeX input	Output

`\begin{subequations}`
`%`
`\begin{equation}`
`5x+2y = 2z+3 \label{eq1}`
`\end{equation}`
`\begin{equation}`
`13x = y+z+2 \label{eq2}`
`\end{equation}`
`Eqs.~\eqref{eq1} and \eqref{eq2} ...`
	$$5x + 2y = 2z + 3 \quad (11.16a)$$ $$13x = y + z + 2 \quad (11.16b)$$ Eqs. (11.16a) and (11.16b) are produced by two separate **equation** environments.

`%`
`\begin{eqnarray}`
` 5x+2y &=& 2z+3 \label{arr1}\\`
` 13x &=& y+z+2 \label{arr2}`
`\end{eqnarray}`
`The same equations are arranged ...`
	$$5x + 2y = 2z + 3 \quad (11.16c)$$ $$13x = y + z + 2 \quad (11.16d)$$ The same equations are arranged in Eqs. (11.16c) and (11.16d) through an **eqnarray** environment.

`%`
`\begin{align}`
` 5x+2y &= 2z+3 \label{algn1}\\`
` 13x &= y+z+2 \label{algn2}`
`\end{align}`
`The equations are reproduced in ...`
	$$5x + 2y = 2z + 3 \quad (11.16e)$$ $$13x = y + 3z + 2 \quad (11.16f)$$ The equations are reproduced in another way in Eqs. (11.16e) and (11.16f) through an **align** environment.

`%`
`\label{sub_arrys}`
`\end{subequations}`
`%`
`Eq.~\eqref{sub_arrys} illustrates ...`
	Eq. (11.16) illustrates the sub-numbering of a set of equations produced by different environments.

where a set of two equations is produced in three different ways under a single **subequations** environment. In the first case, the two equations are produced through two **equation** environments. In the second and third cases, these are produced through **eqnarray** and **align** environments, respectively. Each equation under the **subequations** environment can be labeled by a unique label-word, as well as the entire set of equations by a single label-word, which can be used for independently referring any or the entire set of equations as shown in Table 11.12. It is also shown in Table 11.12 that normal texts can also be inserted between two equation generating environments under the same **subequations** environment.