Using the `amsthm` Package

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1 Introduction

The `amsthm` package provides an enhanced version of LaTeX's `\newtheorem` command for defining theorem-like environments. The enhanced `\newtheorem` recognizes a `\theoremstyle` specification (as in Mittelbach's `theorem` package) and has a * form for defining unnumbered environments. The `amsthm` package also defines a `proof` environment that automatically adds a QED symbol at the end. AMS document classes incorporate the `amsthm` package, so everything described here applies to them as well.

If the `amsthm` package is used with a non-AMS document class and with the `amsmath` package, `amsthm` must be loaded *after* `amsmath`, not before.

Examples are given in the file `thmtest.tex`. For best understanding, examine the output side-by-side with the input.

2 The `\newtheorem` command

In mathematical research articles and books, theorems and proofs are among the most common elements, but authors also use many others that fall in the same general class: lemmas, propositions, axioms, corollaries, conjectures, definitions, remarks, cases, steps, and so forth. It is natural to handle these elements as LaTeX environments, but document classes do not provide predefined environments for theorem-like elements because (a) that would make it difficult for authors to exercise the necessary control over the automatic numbering, and (b) the variety of such elements is so wide that it's not possible for a document class to provide every one that will ever be needed. Instead there is a command `\newtheorem`, similar in effect to `\newenvironment`, that makes it easy for authors to set up the elements required for a particular document.

The `\newtheorem` command has two mandatory arguments; the first one is the environment name that the author would like to use for this element; the second one is the heading text. For example,

`\newtheorem{lem}{Lemma}`

means that instances in the document of

`\begin{lem} Text text ... \end{lem}`

will produce

> **Lemma 1.** *Text text . . .*

where the heading consists of the specified text "Lemma" and an automatically generated number and punctuation.

If `\newtheorem*` is used instead of `\newtheorem` in this example, numbers will not be generated automatically for any of the lemmas in the document. This form of the command can be useful if you have only one lemma and don't want it to be numbered; more often, though, it is used to produce a special named variant of one of the common theorem types. For example, if you have a lemma that should be labeled "Klein's Lemma", then the statement

```
\newtheorem*{KL}{Klein's Lemma}
```

would allow you to write

```
\begin{KL} Text text ... \end{KL}
```

and get the desired output.

Sometimes additional information is desired in the heading of a theorem or lemma, often because it is cited from another source. An optional argument is used to provide this information:

```
\begin{lem}[Alinhac-Lerner \cite{a-l}]
```

yielding the output

> **Lemma 2.** (Alinhac-Lerner [1]). *Text text . . .*

3   Numbering modifications

In addition to the two mandatory arguments, `\newtheorem` has two mutually exclusive optional arguments. These affect the sequencing and hierarchy of the numbering.

By default each kind of theorem-like environment is numbered independently. Thus if you have three lemmas and two theorems interspersed, they will be numbered something like this: Lemma 1, Lemma 2, Theorem 1, Lemma 3, Theorem 2. If you want lemmas and theorems to share the same numbering sequence—Lemma 1, Lemma 2, Theorem 3, Lemma 4, Theorem 5—then you should indicate the desired relationship as follows:

```
\newtheorem{thm}{Theorem}
\newtheorem{lem}[thm]{Lemma}
```

The optional argument `[thm]` in the second statement means that the `lem` environment should share the `thm` numbering sequence instead of having its own independent sequence.

To have a theorem environment numbered subordinately within a sectional unit—e.g., to get propositions numbered Proposition 2.1, Proposition 2.2, and so on in Section 2—put the name of the parent unit in square brackets in final position:

```
\newtheorem{prop}{Proposition}[section]
```

With the optional argument `[section]`, the `prop` counter will be reset to 0 whenever the parent counter `section` is incremented, and the proposition label will have the section number prepended.

Note that theorem numbering is not accomplished by the same method as the `\numberwithin` facility of `amsmath`, so an attempt to use that to relate theorem numbers to equation numbers will not work in the expected way. A method for accomplishing that, as well as some other variations, is given in the AMS Author FAQ [AF], in the section on "Theorems in AMS-LATEX".

4 Changing styles for theorem-like environments

4.1 The \theoremstyle command

The `amsthm` package supports the notion of a current theorem style, which determines what will be produced by a given `\newtheorem` command. The three theorem styles provided—`plain`, `definition`, and `remark`—specify different degrees of visual emphasis corresponding to their relative importance. The details of this typographical treatment may vary depending on the document class, but typically the `plain` style produces italic body text, while the other two styles produce roman body text.

If no `\theoremstyle` command is given, the style used will be `plain`. To specify different styles, divide your `\newtheorem` commands into groups and preface each group with the appropriate `\theoremstyle`. Some examples:

```
\theoremstyle{plain}% default
\newtheorem{thm}{Theorem}[section]
\newtheorem{lem}[thm]{Lemma}
\newtheorem{prop}[thm]{Proposition}
\newtheorem*{cor}{Corollary}
\newtheorem*{KL}{Klein's Lemma}

\theoremstyle{definition}
\newtheorem{defn}{Definition}[section]
\newtheorem{conj}{Conjecture}[section]
\newtheorem{exmp}{Example}[section]

\theoremstyle{remark}
\newtheorem*{rem}{Remark}
\newtheorem*{note}{Note}
\newtheorem{case}{Case}
```

The following list summarizes the types of structures which are normally associated with each theorem style.

`plain`	Theorem, Lemma, Corollary, Proposition, Conjecture, Criterion, Algorithm
`definition`	Definition, Condition, Problem, Example
`remark`	Remark, Note, Notation, Claim, Summary, Acknowledgment, Case, Conclusion

4.2   Number swapping

A common style variation is to have the theorem number at the beginning of the heading instead of at the end, for example "1.4 Theorem" instead of "Theorem 1.4". As this variation is usually applied to all `\theoremstyle`s, it is done by placing a `\swapnumbers` command at the beginning of the list of `\newtheorem` statements that should be affected. For example:

```
\swapnumbers
\theoremstyle{plain}
\newtheorem{thm}{Theorem}
\theoremstyle{remark}
\newtheorem{rem}{Remark}
```

In AMS document classes, when numbers are swapped, the style of the numbers matches that of section headings; this may not be the same style as the rest of the theorem heading.

4.3   New theorem styles

The `amsthm` package provides a `\newtheoremstyle` command to aid in the creation of custom styles, should the three predefined styles prove insufficient. The following example illustrates the use of the `\newtheoremstyle` command.

```
\newtheoremstyle{note}%    ⟨name⟩
  {3pt}%         ⟨Space above⟩
  {3pt}%         ⟨Space below⟩
  {}%            ⟨Body font⟩
  {}%            ⟨Indent amount⟩¹
  {\itshape}%    ⟨Theorem head font⟩
  {:}%           ⟨Punctuation after theorem head⟩
  {.5em}%        ⟨Space after theorem head⟩²
  {}%            ⟨Theorem head spec (can be left empty, meaning 'normal')⟩
```

[1] Indent amount: empty = no indent, `\parindent` = normal paragraph indent
[2] Space after theorem head: `{ }` = normal interword space; `\newline` = linebreak

Apply the new theorem style in the same manner as the predefined ones. For examples, see the file `thmtest.tex`.

5   Proofs

A predefined `proof` environment provided by the `amsthm` package produces the heading "Proof" with appropriate spacing and punctuation. The proof environment is primarily intended for short proofs, no more than a page or two in length; longer proofs are usually better done as a separate `\section` or `\subsection` in your document.

An optional argument of the proof environment allows you to substitute a different name for the standard "Proof". If you want the proof heading to be, say, "Proof of the Main Theorem", then write

```
\begin{proof}[Proof of the Main Theorem]
```

A QED symbol, □, is automatically appended at the end of a `proof` environment. To substitute a different end-of-proof symbol, use `\renewcommand` to redefine the command `\qedsymbol`. For a long proof done as a subsection or section instead of with the `proof` environment, you can obtain the symbol and the usual amount of preceding space by using `\qed`.

Placement of the QED symbol can be problematic if the last part of a `proof` environment is a displayed equation or list environment or something of that nature. In that case put a `\qedhere` command at the place where the QED symbol should appear, for example,

```
\begin{proof}
...
\begin{equation}
G(t)=L\gamma!\,t^{-\gamma}+t^{-\delta}\eta(t) \qedhere
\end{equation}
\end{proof}
```

When used with the `amsmath` package, version 2 or later, `\qedhere` will position the QED symbol flush right; with earlier versions, the symbol will be spaced a quad away from the end of the text or display.

If `\qedhere` produces an error message in an equation, try using `\mbox{\qedhere}` instead.

References

[AF]   AMS Author FAQ, `http://www.ams.org/authors/author-faq.html`