

Sample title

## Sample Title: with Forced Linebreak

A. Author,<sup>1, a)</sup> B. Author,<sup>1</sup> and C. Author<sup>2, b)</sup>

<sup>1)</sup>*Authors' institution and/or address*

<sup>2)</sup>*Second institution and/or address*

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An article usually includes an abstract, a concise summary of the work covered at length in the main body of the article. It is used for secondary publications and for information retrieval purposes.

### I. FIRST-LEVEL HEADING: THE LINE BREAK WAS FORCED via \\

This sample document demonstrates proper use of REV<sub>TEX</sub> 4.1 (and L<sup>A</sup><sub>TEX</sub> 2<sub>ε</sub>) in manuscripts prepared for submission to AIP journals. Further information can be found in the documentation included in the distribution or available at <http://authors.aip.org> and in the documentation for REV<sub>TEX</sub> 4.1 itself.

When commands are referred to in this example file, they are always shown with their required arguments, using normal <sub>TEX</sub> format. In this format, #1, #2, etc. stand for required author-supplied arguments to commands. For example, in `\section{#1}` the #1 stands for the title text of the author's section heading, and in `\title{#1}` the #1 stands for the title text of the paper.

Line breaks in section headings at all levels can be introduced using `\\`. A blank input line tells <sub>TEX</sub> that the paragraph has ended.

#### A. Second-level heading: Formatting

This file may be formatted in both the `preprint` (the default) and `reprint` styles; the latter format may be used to mimic final journal output. Either format may be used for submission purposes; however, for peer review and production, AIP will format the article using the `preprint` class option. Hence, it is essential that authors check that their manuscripts format acceptably under `preprint`. Manuscripts submitted to AIP that do not format correctly under the `preprint` option may be delayed in both the editorial and production processes.

The `widetext` environment will make the text the width of the full page, as on page 3. (Note the use the `\pageref{#1}` to get the page number right automatically.) The width-changing commands only take effect in `twocolumn` formatting. It has no effect if `preprint` formatting is chosen instead.

#### 1. Third-level heading: Citations and Footnotes

Citations in text refer to entries in the Bibliography; they use the commands `\cite{#1}` or `\onlincite{#1}`. Because REV<sub>TEX</sub> uses the `natbib` package of Patrick Daly, its entire repertoire of commands are available in your document; see the `natbib` documentation for further details. The argument of `\cite` is a comma-separated list of *keys*; a key may consist of letters and numerals.

By default, citations are numerical;<sup>1</sup> author-year citations are an option. To give a textual citation, use `\onlincite{#1}`: (Refs. 2–4). REV<sub>TEX</sub> “collapses” lists of consecutive numerical citations when appropriate. REV<sub>TEX</sub> provides the ability to properly punctuate textual citations in author-year style; this facility works correctly with numerical citations only with `natbib`'s `compress` option turned off. To illustrate, we cite several together<sup>1–3,5</sup>, and once again (Refs. 1, 3–5). Note that, when numerical citations are used, the references were sorted into the same order they appear in the bibliography.

A reference within the bibliography is specified with a `\bibitem{#1}` command, where the argument is the citation key mentioned above. `\bibitem{#1}` commands may be crafted by hand or, preferably, generated by using Bib<sub>TEX</sub>. The AIP styles for REV<sub>TEX</sub> 4 include Bib<sub>TEX</sub> style files `aipnum.bst` and `aipauth.bst`, appropriate for numbered and author-year

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<sup>a)</sup>Also at Physics Department, XYZ University.

<sup>b)</sup><http://www.Second.institution.edu/~Charlie.Author>.

bibliographies, respectively. REVTeX 4 will automatically choose the style appropriate for the document's selected class options: the default is numerical, and you obtain the author-year style by specifying a class option of `author-year`.

This sample file demonstrates a simple use of BibTeX via a `\bibliography` command referencing the `aipsamp.bib` file. Running BibTeX (in this case `bibtex aipsamp`) after the first pass of L<sup>A</sup>T<sub>E</sub>X produces the file `aipsamp.bbl` which contains the automatically formatted `\bibitem` commands (including extra markup information via `\bibinfo` commands). If not using BibTeX, the `thebibliography` environment should be used instead.

*a. Fourth-level heading is run in.* Footnotes are produced using the `\footnote{#1}` command. Numerical style citations put footnotes into the bibliography<sup>6</sup>. Author-year and numerical author-year citation styles (each for its own reason) cannot use this method. Note: due to the method used to place footnotes in the bibliography, *you must re-run BibTeX every time you change any of your document's footnotes.*

## II. MATH AND EQUATIONS

Inline math may be typeset using the `$` delimiters. Bold math symbols may be achieved using the `bm` package and the `\bm{#1}` command it supplies. For instance, a bold  $\alpha$  can be typeset as `$$\bm{\alpha}$$` giving  $\alpha$ . Fraktur and Blackboard (or open face or double struck) characters should be typeset using the `\mathfrak{#1}` and `\mathbb{#1}` commands respectively. Both are supplied by the `amssymb` package. For example, `$$\mathbb{R}$$` gives  $\mathbb{R}$  and `$$\mathfrak{G}$$` gives  $\mathfrak{G}$ .

In L<sup>A</sup>T<sub>E</sub>X there are many different ways to display equations, and a few preferred ways are noted below. Displayed math will center by default. Use the class option `fleqn` to flush equations left.

Below we have numbered single-line equations, the most common kind:

$$\chi_+(p) \lesssim [2|\mathbf{p}|(|\mathbf{p}| + p_z)]^{-1/2} \left( \frac{|\mathbf{p}| + p_z}{px + ip_y} \right), \quad (1)$$

$$\left\{ 1234567890abc123\alpha\beta\gamma\delta1234556\alpha\beta \frac{1\sum_b^a}{A^2} \right\}. \quad (2)$$

Note the open one in Eq. (2).

Not all numbered equations will fit within a narrow column this way. The equation number will move down automatically if it cannot fit on the same line with a one-line equation:

$$\left\{ ab12345678abc123456abcdef\alpha\beta\gamma\delta1234556\alpha\beta \frac{1\sum_b^a}{A^2} \right\}. \quad (3)$$

When the `\label{#1}` command is used [cf. input for Eq. (2)], the equation can be referred to in text without knowing the equation number that T<sub>E</sub>X will assign to it. Just use `\ref{#1}`, where `#1` is the same name that used in the `\label{#1}` command.

Unnumbered single-line equations can be typeset using the `\[, \]` format:

$$g^+g^+ \rightarrow g^+g^+g^+g^+ \dots, \quad q^+q^+ \rightarrow q^+g^+g^+ \dots$$

### A. Multiline equations

Multiline equations are obtained by using the `eqnarray` environment. Use the `\nonumber` command at the end of each line to avoid assigning a number:

$$\begin{aligned} \mathcal{M} = & \quad ig_Z^2(4E_1E_2)^{1/2}(l_i^2)^{-1}\delta_{\sigma_1,-\sigma_2}(g_{\sigma_2}^e)^2\chi_{-\sigma_2}(p_2) \\ & \times [\varepsilon_j l_i \varepsilon_i]_{\sigma_1} \chi_{\sigma_1}(p_1), \end{aligned} \quad (4)$$

$$\begin{aligned} \sum |M_g^{\text{viol}}|^2 = & \quad g_S^{2n-4}(Q^2) N^{n-2}(N^2 - 1) \\ & \times \left( \sum_{i < j} \right) \sum_{\text{perm}} \frac{1}{S_{12}} \frac{1}{S_{12}} \sum_{\tau} c_{\tau}^f. \end{aligned} \quad (5)$$

**Note:** Do not use `\label{#1}` on a line of a multiline equation if `\nonumber` is also used on that line. Incorrect cross-referencing will result. Notice the use `\text{#1}` for using a Roman font within a math environment.

To set a multiline equation without *any* equation numbers, use the `\begin{eqnarray*}`, `\end{eqnarray*}` format:

$$\sum |M_g^{\text{viol}}|^2 = g_S^{2n-4} (Q^2) N^{n-2} (N^2 - 1) \times \left( \sum_{i < j} \right) \left( \sum_{\text{perm}} \frac{1}{S_{12} S_{23} S_{n1}} \right) \frac{1}{S_{12}}.$$

To obtain numbers not normally produced by the automatic numbering, use the `\tag{#1}` command, where #1 is the desired equation number. For example, to get an equation number of (2.6'),

$$g^+ g^+ \rightarrow g^+ g^+ g^+ g^+ \dots, \quad q^+ q^+ \rightarrow q^+ g^+ g^+ \dots. \quad (2.6')$$

A few notes on `\tag{#1}`. `\tag{#1}` requires `amsmath`. The `\tag{#1}` must come before the `\label{#1}`, if any. The numbering set with `\tag{#1}` is *transparent* to the automatic numbering in REVTeX; therefore, the number must be known ahead of time, and it must be manually adjusted if other equations are added. `\tag{#1}` works with both single-line and multiline equations. `\tag{#1}` should only be used in exceptional case - do not use it to number all equations in a paper.

Enclosing single-line and multiline equations in `\begin{subequations}` and `\end{subequations}` will produce a set of equations that are “numbered” with letters, as shown in Eqs. (6a) and (6b) below:

$$\left\{ abc123456abcdef\alpha\beta\gamma\delta 1234556\alpha\beta \frac{1 \sum_a}{A^2} \right\}, \quad (6a)$$

$$\begin{aligned} \mathcal{M} = & \quad ig_Z^2 (4E_1 E_2)^{1/2} (l_i^2)^{-1} (g_{\sigma_2}^e)^2 \chi_{-\sigma_2}(p_2) \\ & \times [\varepsilon_i]_{\sigma_1} \chi_{\sigma_1}(p_1). \end{aligned} \quad (6b)$$

Putting a `\label{#1}` command right after the `\begin{subequations}`, allows one to reference all the equations in a subequations environment. For example, the equations in the preceding subequations environment were Eqs. (6).

### 1. Wide equations

The equation that follows is set in a wide format, i.e., it spans across the full page. The wide format is reserved for long equations that cannot be easily broken into four lines or less:

$$\mathcal{R}^{(d)} = g_{\sigma_2}^e \left( \frac{[\Gamma^Z(3, 21)]_{\sigma_1}}{Q_{12}^2 - M_W^2} + \frac{[\Gamma^Z(13, 2)]_{\sigma_1}}{Q_{13}^2 - M_W^2} \right) + x_W Q_e \left( \frac{[\Gamma^\gamma(3, 21)]_{\sigma_1}}{Q_{12}^2 - M_W^2} + \frac{[\Gamma^\gamma(13, 2)]_{\sigma_1}}{Q_{13}^2 - M_W^2} \right). \quad (7)$$

This is typed to show the output is in wide format. (Since there is no input line between `\equation` and this paragraph, there is no paragraph indent for this paragraph.)

## III. CROSS-REFERENCING

REVTeX will automatically number sections, equations, figure captions, and tables. In order to reference them in text, use the `\label{#1}` and `\ref{#1}` commands. To reference a particular page, use the `\pageref{#1}` command.

The `\label{#1}` should appear in a section heading, within an equation, or in a table or figure caption. The `\ref{#1}` command is used in the text where the citation is to be displayed. Some examples: Section I on page 1, Table I, and Fig. 1.

## IV. FIGURES AND TABLES

Figures and tables are typically “floats”; L<sup>A</sup>T<sub>E</sub>X determines their final position via placement rules. L<sup>A</sup>T<sub>E</sub>X isn't always successful in automatically placing floats where you wish them.

Figures are marked up with the `figure` environment, the content of which imports the image (`\includegraphics`) followed by the figure caption (`\caption`). The argument of the latter command should itself contain a `\label` command if you wish to refer to your figure with `\ref`.

Import your image using either the `graphics` or `graphicx` packages. These packages both define the `\includegraphics{#1}` command, but they differ in the optional arguments for specifying the orientation, scaling, and translation of the figure. Fig. 1

TABLE I. This is a narrow table which fits into a text column when using `twocolumn` formatting. Note that REV $\TeX$  4 adjusts the intercolumn spacing so that the table fills the entire width of the column. Table captions are numbered automatically. This table illustrates left-aligned, centered, and right-aligned columns.

Left <sup>a</sup>	Centered <sup>b</sup>	Right
1	2	3
10	20	30
100	200	300

<sup>a</sup> Note a.

<sup>b</sup> Note b.



FIG. 1. A figure caption. The figure captions are automatically numbered.

is small enough to fit in a single column, while Fig. 2 is too wide for a single column, so instead the `figure*` environment has been used.

The analog of the `figure` environment is `table`, which uses the same `\caption` command. However, you should type your caption command first within the `table`, instead of last as you did for `figure`.

The heart of any table is the `tabular` environment, which represents the table content as a (vertical) sequence of table rows, each containing a (horizontal) sequence of table cells. Cells are separated by the `&` character; the row terminates with `\\`. The required argument for the `tabular` environment specifies how data are displayed in each of the columns. For instance, a column may be centered (`c`), left-justified (`l`), right-justified (`r`), or aligned on a decimal point (`d`). (Table II illustrates the use of decimal column alignment.)

Extra column-spacing may be specified as well, although REV $\TeX$  4 sets this spacing so that the columns fill the width of the table. Horizontal rules are typeset using the `\hrule` command. The doubled (or Scotch) rules that appear at the top and bottom of a table can be achieved by enclosing the `tabular` environment within a `ruledtabular` environment. Rows whose columns span multiple columns can be typeset using  $\LaTeX$ 's `\multicolumn{#1}{#2}{#3}` command (for example, see the first row of Table III).

The tables in this document illustrate various effects. Tables that fit in a narrow column are contained in a `table` environment. Table III is a wide table, therefore set with the `table*` environment. Lengthy tables may need to break across pages. A simple way to allow this is to specify the `[H]` float placement on the `table` or `table*` environment. Alternatively, using the standard  $\LaTeX$  2 $\epsilon$  package `longtable` gives more control over how tables break and allows headers and footers to be specified for each page of the table. An example of the use of `longtable` can be found in the file `summary.tex` that is included with the REV $\TeX$  4 distribution.

There are two methods for setting footnotes within a table (these footnotes will be displayed directly below the table rather

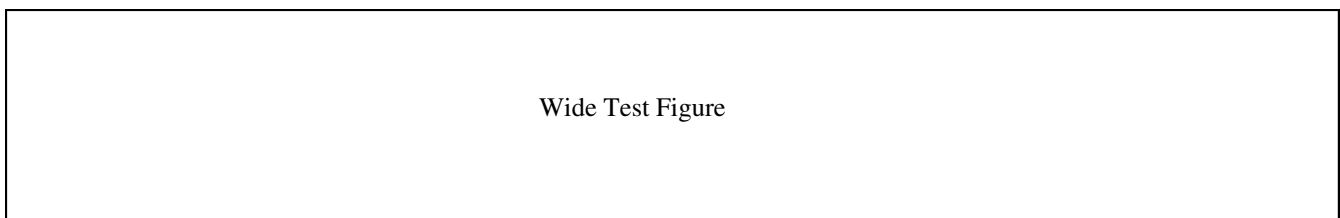


FIG. 2. Use the `figure*` environment to get a wide figure, spanning the page in `twocolumn` formatting.

TABLE II. Numbers in columns Three–Five have been aligned by using the “d” column specifier (requires the dcolumn package). Non-numeric entries (those entries without a “.”) in a “d” column are aligned on the decimal point. Use the “D” specifier for more complex layouts.

One	Two	Three	Four	Five
one	two	three	four	five
He	2	2.77234	45672.	0.69
C <sup>a</sup>	C <sup>b</sup>	12537.64	37.66345	86.37

<sup>a</sup> Some tables require footnotes.

<sup>b</sup> Some tables need more than one footnote.

TABLE III. This is a wide table that spans the page width in twocolumn mode. It is formatted using the table\* environment. It also demonstrates the use of \multicolumn in rows with entries that span more than one column.

Ion	1st alternative	$D_{4h}^1$	2nd alternative	1st alternative	$D_{4h}^5$	2nd alternative
K	(2e) + (2f)		(4i)	(2c) + (2d)		(4f)
Mn	(2g) <sup>a</sup>		(a) + (b) + (c) + (d)	(4e)		(2a) + (2b)
Cl	(a) + (b) + (c) + (d)		(2g) <sup>b</sup>	(4e) <sup>a</sup>		
He	(8r) <sup>a</sup>		(4j) <sup>a</sup>	(4g) <sup>a</sup>		
Ag			(4k) <sup>a</sup>			(4h) <sup>a</sup>

<sup>a</sup> The  $z$  parameter of these positions is  $z \sim \frac{1}{4}$ .

<sup>b</sup> This is a footnote in a table that spans the full page width in twocolumn mode. It is supposed to set on the full width of the page, just as the caption does.

than at the bottom of the page or in the bibliography). The easiest and preferred method is just to use the `\footnote{#1}` command. This will automatically enumerate the footnotes with lowercase roman letters. However, it is sometimes necessary to have multiple entries in the table share the same footnote. In this case, create the footnotes using `\footnotemark[#1]` and `\footnotetext[#1]{#2}`. #1 is a numeric value. Each time the same value for #1 is used, the same mark is produced in the table. The `\footnotetext[#1]{#2}` commands are placed after the tabular environment. Examine the L<sup>A</sup>T<sub>E</sub>X source and output for Tables I and IV for an illustration.

All AIP journals require that the initial citation of figures or tables be in numerical order. L<sup>A</sup>T<sub>E</sub>X’s automatic numbering of floats is your friend here: just put each figure environment immediately following its first reference (`\ref`), as we have done in this example file.

TABLE IV. A table with more columns still fits properly in a column. Note that several entries share the same footnote. Inspect the L<sup>A</sup>T<sub>E</sub>X input for this table to see exactly how it is done.

	$r_c$ (Å)	$r_0$ (Å)	$\kappa r_0$		$r_c$ (Å)	$r_0$ (Å)	$\kappa r_0$
Cu	0.800	14.10	2.550	Sn <sup>a</sup>	0.680	1.870	3.700
Ag	0.990	15.90	2.710	Pb <sup>b</sup>	0.450	1.930	3.760
Au	1.150	15.90	2.710	Ca <sup>c</sup>	0.750	2.170	3.560
Mg	0.490	17.60	3.200	Sr <sup>d</sup>	0.900	2.370	3.720
Zn	0.300	15.20	2.970	Li <sup>b</sup>	0.380	1.730	2.830
Cd	0.530	17.10	3.160	Na <sup>e</sup>	0.760	2.110	3.120
Hg	0.550	17.80	3.220	K <sup>e</sup>	1.120	2.620	3.480
Al	0.230	15.80	3.240	Rb <sup>c</sup>	1.330	2.800	3.590
Ga	0.310	16.70	3.330	Cs <sup>d</sup>	1.420	3.030	3.740
In	0.460	18.40	3.500	Ba <sup>e</sup>	0.960	2.460	3.780
Tl	0.480	18.90	3.550				

<sup>a</sup> Here’s the first, from Ref. 1.

<sup>b</sup> Here’s the second.

<sup>c</sup> Here’s the third.

<sup>d</sup> Here’s the fourth.

<sup>e</sup> And etc.

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## DATA AVAILABILITY STATEMENT

AIP Publishing believes that all datasets underlying the conclusions of the paper should be available to readers. Authors are encouraged to deposit their datasets in publicly available repositories or present them in the main manuscript. All research articles must include a data availability statement stating where the data can be found. In this section, authors should add the respective statement from the chart below based on the availability of data in their paper.

AVAILABILITY OF DATA	STATEMENT OF DATA AVAILABILITY
Data available on request from the authors	The data that support the findings of this study are available from the corresponding author upon reasonable request.
Data available in article or supplementary material	The data that support the findings of this study are available within the article [and its supplementary material].
Data openly available in a public repository that issues datasets with DOIs	The data that support the findings of this study are openly available in [repository name] at <a href="http://doi.org/[doi]">http://doi.org/[doi]</a> , reference number [reference number].
Data openly available in a public repository that does not issue DOIs	The data that support the findings of this study are openly available in [repository name], reference number [reference number].
Data sharing not applicable – no new data generated	Data sharing is not applicable to this article as no new data were created or analyzed in this study.
Data generated at a central, large scale facility	Raw data were generated at the [facility name] large scale facility. Derived data supporting the findings of this study are available from the corresponding author upon reasonable request.
Embargo on data due to commercial restrictions	The data that support the findings will be available in [repository name] at [DOI link] following an embargo from the date of publication to allow for commercialization of research findings.
Data available on request due to privacy/ethical restrictions	The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due [state restrictions such as privacy or ethical restrictions].
Data subject to third party restrictions	The data that support the findings of this study are available from [third party]. Restrictions apply to the availability of these data, which were used under license for this study. Data are available from the authors upon reasonable request and with the permission of [third party].

## Appendix A: Appendixes

To start the appendixes, use the `\appendix` command. This signals that all following section commands refer to appendixes instead of regular sections. Therefore, the `\appendix` command should be used only once—to set up the section commands to act as appendixes. Thereafter normal section commands are used. The heading for a section can be left empty. For example,

```
\appendix
\section{}
```

will produce an appendix heading that says “APPENDIX A” and

```
\appendix
\section{Background}
```

will produce an appendix heading that says “APPENDIX A: BACKGROUND” (note that the colon is set automatically).

If there is only one appendix, then the letter “A” should not appear. This is suppressed by using the star version of the appendix command (`\appendix*` in the place of `\appendix`).

**Appendix B: A little more on appendixes**

Observe that this appendix was started by using

```
\section{A little more on appendixes}
```

Note the equation number in an appendix:

$$E = mc^2. \tag{B1}$$

**1. A subsection in an appendix**

You can use a subsection or subsubsection in an appendix. Note the numbering: we are now in Appendix B 1.

**a. A subsubsection in an appendix**

Note the equation numbers in this appendix, produced with the subequations environment:

$$E = mc, \tag{B2a}$$

$$E = mc^2, \tag{B2b}$$

$$E \gtrsim mc^3. \tag{B2c}$$

They turn out to be Eqs. (B2a), (B2b), and (B2c).

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<sup>4</sup>N. D. Birell and P. C. W. Davies, *Quantum Fields in Curved Space* (Cambridge University Press, 1982).  
<sup>5</sup>G. P. Berman, Jr. and F. M. Izrailev, Jr., “Stability of nonlinear modes,” Physica D **88**, 445 (1983).  
<sup>6</sup>Automatically placing footnotes into the bibliography requires using BibTeX to compile the bibliography.  
<sup>7</sup>E. B. Davies and L. Parns, “Trapped modes in acoustic waveguides,” Q. J. Mech. Appl. Math. **51**, 477–492 (1988).  
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<sup>17</sup>Y. Burstyn, “Proceedings of the 5th International Molecular Beam Epitaxy Conference, Santa Fe, NM,” (2004), (unpublished).  
<sup>18</sup>B. Quinn, ed., *Proceedings of the 2003 Particle Accelerator Conference, Portland, OR, 12-16 May 2005* (Wiley, New York, 2001) albeit the conference was held in 2005, it was the 2003 conference, and the proceedings were published in 2001; go figure.  
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<sup>20</sup>R. Smith, “Hummingbirds are our friends,” J. Appl. Phys. (these proceedings) Abstract No. DA-01.  
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<sup>22</sup>T. Terrific, “An  $O(n \log n / \log \log n)$  sorting algorithm,” Wishful Research Result 7 (Fanstord University, Computer Science Department, Fanstord, California, 1988) a full TECHREPORT entry.  
<sup>23</sup>J. Nelson, TWI Report 666/1999 (Jan. 1999) required institution missing.  
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