On the Atomic Nature of Charge*

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We present an apparatus designed for the observation of charged oil droplets in an electric field for the purposes of determining the atomic nature of charge by measuring the force experienced by the particle in an electric field of known strength. While it is easy to produce an electric field of known strength, there is great difficulty in the observation of particles with little charge. By careful observation of charged oil droplets, we find that charge is quantized in nature, directly observing integer multiples of charge on our oil droplets

I. INTRODUCTION

1. *Experimental Measurement of Charge*

The motion of any charged particle in atmosphere, within an electromagnetic field are easily modelled as a combination free fall, buoyant, and coulomb interactions [**?**]. These forces take the form,

$$qE = mg + kv \tag{1}$$

By directly observing the motion of particles during free fall and in an electric field independently, we hope to directly determine the charge on the particle. Due to the interaction of buoyant forces on our particle, it may be extremely difficult to track their motion without sophisticated computer hardware, due to the nonlinear nature free fall velocity. For this reason, we opt to observe microscopic particles using with very low mass such that they can be assumed to always be at terminal velocity. A severe consequence of this decision is that the forces on such particles will be incredibly small–on the order of x Newtons. To accomplish this, we use non-volatile oil, introduced into the viewing chamber by an atomizer. With careful consideration of external conditions, it is possible to ascertain the charge on the oil droplets by their free fall velocity and coulomb interaction velocity alone. From (1) we can express

$$q = \frac{mg(v_f - v_i)}{Ev_f} \tag{2}$$

To eliminate m from equation (2), one uses the expression for the volume of a sphere:

$$m = \frac{4}{3}\pi a^3 \rho \tag{3}$$

Where a is the radius of the droplet and ρ is the density of oil. We assume that the oil droplets assume perfectly spherical shape due to extremely small terminal velocity. Then Stoke's law is used to relate the radius of the oil droplet to its velocity as it falls through a viscous medium.

$$a = \sqrt{\frac{9\eta v_f}{2g\rho}} \tag{4}$$

Stokes' Law, however, becomes incorrect when the velocity of fall of the droplets is less than 0.1 cm/s. (Droplets having this and smaller velocities have radii, on the order of 2 microns, comparable to the mean free path of air molecules, a condition which violates one of the assumptions made in deriving Stokes' Law.) Since the velocities of the droplets used in this experiment will be in the range of 0.01 to 0.001 cm/s, the viscosity must be multiplied by a correction factor. The resulting effective viscosity is

$$\eta_{\text{eff}} = \eta \left(\frac{1}{1 + \frac{b}{pa}} \right) \tag{5}$$

Where b is a constant, p is the atmospheric pressure, and a is the radius of the drop as calculated by the uncorrected form of Stokes' Law, equation (5). Then we arrive at a suitable radius for our oil droplets.

$$a = \sqrt{\left(\frac{b}{2p}\right)^2 + \frac{9\eta v_f}{2g\rho}} - \left(\frac{b}{2p}\right) \tag{6}$$

Which in turn yields the following equation for charge

$$q = \frac{6\pi}{E}\sqrt{\frac{9\eta^3}{2g\rho\left(1 + \frac{b}{pa}\right)^3}}(v_f + v_r)\sqrt{v_f} \tag{7}$$

Due to the use of a simple air-plate capacitor to generate an electric field, electric field is straightforwardly

$$E = \frac{V}{d} \tag{8}$$

Where V is the potential difference across the parallel plates separated by the distance d

2. *Considerations in Instrument Configuration*

There are a variety of ways to manipulate charged particles using external electromagnetic fields [**?**]. We

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employ a uniform electric field via a simple plate capacitor due to two key advantages over magnetic fields. The electromagnetic fields created must be uniform such that it is possible to reliably measure the forces acting on particles–for this it is possible to use several devices, however magnetic fields are conventionally produced using windings of wire, dramatically increasing the complexity of optical observation of the particles inside the field. Second, the motion of charged particles in a uniform magnetic field is known to be circular, increasing the complexity in the determination of force. For these reasons, we employ a simple plate capacitor to produce a uniform electric field, as it permits the construction of a straightforward viewing chamber, shown in figure **??** . A capacitor also has the advantage of producing uniform fields which drive particles in a perfectly vertical manner, simplifying the determination of their motion.

II. DETERMINATION OF CHARGE ON OIL DROPLETS

A. Observations

With the capacitor connected to the DC power supply with 500V, we manipulated the electric field in the viewing chamber by selectively switching between ground and charged modes. With the plates grounded, we introduce oil droplets between the plates through a port above. Then, we isolate droplets which we perceive to be of low charge and record their rise and fall velocity with plates charged and grounded, respectively. By carefully controlling the conditions within the viewing chamber, we then record the time using a stopwatch for the oil droplets to move between the 0.5 mm markings in the viewing chamber.

To eliminate uncertainty about the effects of the oil droplet on the motion in the electric field, we manipulate the charge on our oil droplets by means of ionization. An alpha source, Thorium-232, is placed near the drop and can be toggled using a lever on the side of the apparatus. Using this, we were able to modify the charge on an oil droplet to assess the effects of changes in charge on the oil droplets.

Droplet	Charge (Coulomb)	# Charges on Oil Drop
A	1.81276×10^{-19}	1.0
B	10.9941×10^{-19}	6.06482
C	12.8595×10^{-19}	7.09385

TABLE I. Measured charges on oil drops

The measured charges on the oil droplets exhibit distinct, quantized values, supporting the hypothesis that electric charge exists in discrete units rather than as a continuous variable. By analyzing the charge values obtained from multiple oil droplets, we observe that each charge closely corresponds to integer multiples of a fundamental unit of charge.

To determine this fundamental charge, we examine the measured charges in Table I. The smallest observed charge is approximately 1.81×10^{-19} C, which we identify as the unit charge. The charges of other droplets, such as Droplet B (10.99×10^{-19} C) and Droplet C (12.86×10^{-19} C), align well with integer multiples of this fundamental charge.

B. Uncertainty Analysis

Comparing our experimental result with the accepted value of the elementary charge, 1.602×10^{-19} C, we calculate the percentage error:

$$\text{Percentage error} = \left(\frac{|1.81 - 1.602|}{1.602} \right) \times 100 \approx 13.0\%$$

This deviation may result from quantities we lacked sufficient means to appropriately measure: namely atmospheric conditions locally. Furthermore, rudimentary means were used to time the motion of oil droplets, and we see a significant standard deviation in measurements.

todo: proper uncertainty calculations

III. DISCUSSION

The experimental observations point to the quantized nature of charge.

IV. REFERENCE:

1. Citations

Because REVTEX uses the `natbib` package of Patrick Daly, the entire repertoire of commands in that package are available for your document; see the `natbib` documentation for further details. Please note that REVTEX requires version 8.31a or later of `natbib`.

a. Syntax The argument of `\cite` may be a single *key*, or may consist of a comma-separated list of keys. The citation *key* may contain letters, numbers, the dash (-) character, or the period (.) character. New with natbib 8.3 is an extension to the syntax that allows for a star (*) form and two optional arguments on the citation key itself. The syntax of the `\cite` command is thus (informally stated)

`\cite {` *key* `}`, or
`\cite {` *optarg+key* `}`, or
`\cite {` *optarg+key* `,` *optarg+key...*`}`,
where *optarg+key* signifies

key, or
`*`*key*, or
`[`*pre*`]` *key*, or
`[`*pre*`]` `[`*post*`]` *key*, or even
`*[`*pre*`]` `[`*post*`]` *key*.
where *pre* and *post* is whatever text you wish to place at the beginning and end, respectively, of the bibliographic reference (see Ref. [**?**] and the two under Ref. [**?**]). (Keep in mind that no automatic space or punctuation is applied.) It is highly recommended that you put the entire *pre* or *post* portion within its own set of braces, for example: `\cite { [ {`*text*`}]` *key*`}`. The extra set of braces will keep LATEX out of trouble if your *text* contains the comma (,) character.

The star (*) modifier to the *key* signifies that the reference is to be merged with the previous reference into a single bibliographic entry, a common idiom in APS and AIP articles (see below, Ref. [**?**]). When references are merged in this way, they are separated by a semicolon instead of the period (full stop) that would otherwise appear.

b. Eliding repeated information When a reference is merged, some of its fields may be elided: for example, when the author matches that of the previous reference, it is omitted. If both author and journal match, both are omitted. If the journal matches, but the author does not, the journal is replaced by *ibid.*, as exemplified by Ref. [**?**]. These rules embody common editorial practice in APS and AIP journals and will only be in effect if the markup features of the APS and AIP BibTEX styles is employed.

c. The options of the cite command itself Please note that optional arguments to the *key* change the reference in the bibliography, not the citation in the body of the document. For the latter, use the optional arguments of the `\cite` command itself: `\cite *[`*pre-cite*`]` `[`*post-cite*`]{`*key-list*`}`.

2. Example citations

By default, citations are numerical[**?**]. Author-year citations are used when the journal is RMP. To give a textual citation, use `\onlinecite{#1}`: Refs. **? ?** . By default, the `natbib` package automatically sorts your citations into numerical order and "compresses" runs of three or more consecutive numerical citations. REVTEX provides the ability to automatically change the punctuation when switching between journal styles that provide citations in square brackets and those that use a superscript style instead. This is done through the `citeautoscript` option. For instance, the journal style `prb` automatically invokes this option because *Physical Review B* uses superscript-style citations. The effect is to move the punctuation, which normally comes after a citation in square brackets, to its proper position before the superscript. To illustrate, we cite several together [**? ? ? ? ? ?**], and once again in different order (Refs. [**? ? ? ? ? ?**]). Note that the citations were both compressed and sorted. Futhermore, running this sample file under the `prb` option will move the punctuation to the correct place.

When the `prb` class option is used, the `\cite{#1}` command displays the reference's number as a superscript rather than in square brackets. Note that the location of the `\cite{#1}` command should be adjusted for the reference style: the superscript references in `prb` style must appear after punctuation; otherwise the reference must appear before any punctuation. This sample was written for the regular (non-`prb`) citation style. The command `\onlinecite{#1}` in the `prb` style also displays the reference on the baseline.

3. References

A reference in the bibliography is specified by a `\bibitem{#1}` command with the same argument as the `\cite{#1}` command. `\bibitem{#1}` commands may be crafted by hand or, preferably, generated by BibTEX. REVTEX 4.2 includes BibTEX style files `apsrev4-2.bst`, `apsrmp4-2.bst` appropriate for *Physical Review* and *Reviews of Modern Physics*, respectively.

4. Example references

This sample file employs the `\bibliography` command, which formats the `default.bbl` file and specifies which bibliographic databases are to be used by BibTEX (one of these should be by arXiv convention `default.bib`). Running BibTEX (via `bibtex default`) after the first pass of LATEX produces the file `default.bbl` which contains the automatically formatted `\bibitem` commands (including extra markup information via `\bibinfo` and `\bibfield` commands). If not using BibTEX, you will have to create the `thebibiliography` environment and its `\bibitem` commands by hand.

Numerous examples of the use of the APS bibliographic entry types appear in the bibliography of this sample document. You can refer to the `default.bib` file, and compare its information to the formatted bibliography itself.

A. Footnotes

Footnotes, produced using the `\footnote{#1}` command, usually integrated into the bibliography alongside the other entries. Numerical citation styles do this[1]; author-year citation styles place the footnote at the bottom of the text column. 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*.

V. MATH AND EQUATIONS

Inline math may be typeset using the `$` delimiters. Bold math symbols may be achieved using the `bm` package and the `\bm{#1}` command it supplies. For instance, a bold α can be typeset as `$\bm{\alpha}$` giving $\boldsymbol{\alpha}$. 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 LaTeX 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; this is the most common type of equation in *Physical Review*:

$$\chi_+(p)\lesssim [2|\mathbf{p}|(|\mathbf{p}|+p_z)]^{-1/2}\left(\begin{array}{c} |\mathbf{p}|+p_z \\ px+ip_y \end{array}\right), \tag{9}$$

$$\left\{\mathbb{1}234567890abc123\alpha\beta\gamma\delta1234556\alpha\beta\frac{1\sum^{a}_{b}}{A^2}\right\}. \tag{10}$$

Note the open one in Eq. (10).

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:

$$\left\{ab12345678abc123456abcdef\alpha\beta\gamma\delta1234556\alpha\beta\frac{1\sum^{a}_{b}}{A^2}\right\}. \tag{11}$$

When the `\label{#1}` command is used [cf. input for Eq. (10)], the equation can be referred to in text without knowing the equation number that TEX 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:

$$g^+g^+\rightarrow g^+g^+g^+g^+\dots~,~~q^+q^+\rightarrow q^+g^+g^+\dots~.$$

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:

$$\begin{aligned}\mathcal{M}=&\ ig_Z^2(4E_1E_2)^{1/2}(l_i^2)^{-1}\delta_{\sigma_1,-\sigma_2}(g_{\sigma_2}^e)^2\chi_{-\sigma_2}(p_2)\\ &\times[\epsilon_jl_i\epsilon_i]_{\sigma_1}\chi_{\sigma_1}(p_1),\end{aligned} \tag{12}$$

$$\begin{aligned}\sum |M^{\text{viol}}_g|^2 &= g^{2n-4}_S(Q^2)~N^{n-2}(N^2-1)\\ &\times\left(\sum_{i<j}\right)\sum_{\text{perm}}\frac{1}{S_{12}}\frac{1}{S_{12}}\sum_\tau c^f_\tau~.\end{aligned} \tag{13}$$

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:

$$\begin{aligned}\sum |M^{\text{viol}}_g|^2 &= g^{2n-4}_S(Q^2)~N^{n-2}(N^2-1)\\ &\times\left(\sum_{i<j}\right)\left(\sum_{\text{perm}}\frac{1}{S_{12}S_{23}S_{n1}}\right)\frac{1}{S_{12}}~.\end{aligned}$$

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′),

$$g^+g^+\rightarrow g^+g^+g^+g^+\dots~,~~q^+q^+\rightarrow q^+g^+g^+\dots~. \tag{2.6$'$}$$

a. A few notes on `tags` `\tag{#1}` requires the `amsmath` package. Place the `\tag{#1}` command before the `\label{#1}`, if any. The numbering produced by `\tag{#1}` *does not affect* 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 cases—do not use it to number many equations in your paper. Please note that this feature of the `amsmath` package is *not* compatible with the `hyperref` (6.77u) package.

Enclosing display math within `\begin{subequations}` and `\end{subequations}` will produce a set of equations that are labeled with letters, as shown in Eqs. (14b) and (14a) below. You may include any number of single-line and multiline equations, although it is probably not a good idea to follow one display math directly after another.

$$\begin{aligned}\mathcal{M} = \quad & ig_Z^2(4E_1E_2)^{1/2}(l_i^2)^{-1}(g_{\sigma_2}^e)^2\chi_{-\sigma_2}(p_2) \\ & \times[\epsilon_i]_{\sigma_1}\chi_{\sigma_1}(p_1). \end{aligned} \tag{14a}$$

$$\left\{abc123456abcdef\alpha\beta\gamma\delta1234556\alpha\beta\frac{1\sum_b^a}{A^2}\right\}, \tag{14b}$$

Giving a `\label{#1}` command directly after the `\begin{subequations}`, allows you to reference all the equations in the `subequations` environment. For example, the equations in the preceding subequations environment were Eqs. (14).

1. Wide equations

The equation that follows is set in a wide format, i.e., it spans the full page. The wide format is reserved for long equations that cannot easily be set in a single column:

$$\mathcal{R}^{(\mathrm{d})} = g_{\sigma_2}^e\left(\frac{[\Gamma^Z(3,21)]_{\sigma_1}}{Q_{12}^2-M_W^2}+\frac{[\Gamma^Z(13,2)]_{\sigma_1}}{Q_{13}^2-M_W^2}\right)+x_WQ_e\left(\frac{[\Gamma^\gamma(3,21)]_{\sigma_1}}{Q_{12}^2-M_W^2}+\frac{[\Gamma^\gamma(13,2)]_{\sigma_1}}{Q_{13}^2-M_W^2}\right). \tag{15}$$

This is typed to show how the output appears in wide format. (Incidentally, since there is no blank line between the `equation` environment above and the start of this paragraph, this paragraph is not indented.)

VI. CROSS-REFERENCING

REVTEX will automatically number such things as sections, footnotes, equations, figure captions, and table captions. 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 within the section heading, within the footnote text, within the equation, or within the table or figure caption. The `\ref{#1}` command is used in text at the point where the reference is to be displayed. Some examples: Section III on page 2, Table II, and Fig. 1.

TABLE II. A table that fits into a single column of a two-column layout. Note that REVTEX 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-, center-, decimal- and right-aligned columns, along with the use of the `ruledtabular` environment which sets the Scotch (double) rules above and below the alignment, per APS style.

Left[a]	Centered[b]	Decimal	Right
1	2	3.001	4
10	20	30	40
100	200	300.0	400

[a] Note a.
[b] Note b.

VII. FLOATS: FIGURES, TABLES, VIDEOS, ETC.

Figures and tables are usually allowed to "float", which means that their placement is determined by LATEX, while the document is being typeset.

Use the `figure` environment for a figure, the `table` environment for a table. In each case, use the `\caption` command within to give the text of the figure or table caption along with the `\label` command to provide a key for referring to this figure or table. The typical content of a figure is an image of some kind; that of a table is an alignment.

Insert an image using either the `graphics` or `graphix` packages, which define the `\includegraphics{#1}` command. (The two packages differ in respect of the optional arguments used to specify the orientation, scaling, and translation of the image.) To create an alignment, use the `tabular` environment.

The best place to locate the `figure` or `table` environment is immediately following its first reference in text; this sample document illustrates this practice for Fig. 1, which shows a figure that is small enough to fit in a single column.

In exceptional cases, you will need to move the float earlier in the document, as was done with Table III: LATEX's float placement algorithms need to know about a full-page-width float earlier.

Fig. 2 has content that is too wide for a single column, so the `figure*` environment has been used.

The content of a table is typically a `tabular` environment, giving rows of type in aligned columns. Column entries separated by `&`'s, and each row ends with `\\`. The required argument for the `tabular` environment specifies how data are aligned in the columns. For

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

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

TABLE III. This is a wide table that spans the full page width in a two-column layout. It is formatted using the `table*` environment. It also demonstates the use of `\multicolumn` in rows with entries that span more than one column.

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

[a] The z parameter of these positions is $z \sim \frac{1}{4}$.

instance, entries may be centered, left-justified, right-justified, aligned on a decimal point. Extra column-spacing may be be specified as well, although REVTEX 4 sets this spacing so that the columns fill the width of the table. Horizontal rules are typeset using the `\hline` command. The doubled (or Scotch) rules that appear at the top and bottom of a table can be achieved enclosing the `tabular` environment within a `ruledtabular` environment. Rows whose columns span multiple columns can be typeset using the `\multicolumn{#1}{#2}{#3}` command (for example, see the first row of Table III).

Tables II, III, IV, and V show various effects. A table that fits in a single column employs the `table` environment. Table III is a wide table, set with the `table*` environment. Long tables may need to break across pages. The most straightforward way to accomplish this is to specify the `[H]` float placement on the `table` or `table*` environment. However, the LATEX 2ε package `longtable` allows headers and footers to be specified for each page of the table. A simple example of the use of `longtable` can be found in the file `summary.tex` that is included with the REVTEX 4 distribution.

There are two methods for setting footnotes within a table (these footnotes will be displayed directly below the table rather 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, there is no choice but to manually 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 LATEX source and output for Tables II and V for examples.

Video 1 illustrates several features new with REVTEX4.2, starting with the `video` environment, which is in the same category with `figure` and `table`. The `\setfloatlink` command causes the title of the video to be a hyperlink to the indicated URL; it may be used

TABLE IV. Numbers in columns Three–Five are aligned with 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[a]	C[b]	12537.64	37.66345	86.37

[a] Some tables require footnotes.
[b] Some tables need more than one footnote.

Video 1. Students explain their initial idea about Newton's third law to a teaching assistant. Clip (a): same force. Clip (b): move backwards.

TABLE V. A table with numerous columns that still fits into a single column. Here, several entries share the same footnote. Inspect the LATEX input for this table to see exactly how it is done.

	r_c (Å)	r_0 (Å)	κr_0		r_c (Å)	r_0 (Å)	κr_0
Cu	0.800	14.10	2.550	Sn[a]	0.680	1.870	3.700
Ag	0.990	15.90	2.710	Pb[b]	0.450	1.930	3.760
Au	1.150	15.90	2.710	Ca[c]	0.750	2.170	3.560
Mg	0.490	17.60	3.200	Sr[d]	0.900	2.370	3.720
Zn	0.300	15.20	2.970	Li[b]	0.380	1.730	2.830
Cd	0.530	17.10	3.160	Na[e]	0.760	2.110	3.120
Hg	0.550	17.80	3.220	K[e]	1.120	2.620	3.480
Al	0.230	15.80	3.240	Rb[c]	1.330	2.800	3.590
Ga	0.310	16.70	3.330	Cs[d]	1.420	3.030	3.740
In	0.460	18.40	3.500	Ba[e]	0.960	2.460	3.780
Tl	0.480	18.90	3.550				

[a] Here's the first, from Ref. **?** .
[b] Here's the second.
[c] Here's the third.
[d] Here's the fourth.
[e] And etc.

with any environment that takes the `\caption` command. The `\href` command has the same significance as it does in the context of the `hyperref` package: the second argument is a piece of text to be typeset in your document; the first is its hyperlink, a URL.

Physical Review style requires that the initial citation of figures or tables be in numerical order in text, so don't cite Fig. 2 until Fig. 1 has been cited.

ACKNOWLEDGMENTS

We wish to acknowledge the support of the author community in using REVTEX, offering suggestions and encouragement, testing new versions, ...

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 setup 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.

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).

[1] Automatically placing footnotes into the bibliography requires using BibTeX to compile the bibliography.