The mandi package

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1 Introduction

This package provides a collection of commands useful in introductory physics and astronomy. The underlying philosophy is that the user, potentially an introductory student, should just type the name of a physical quantity, with a numerical value if needed, without having to think about the units. `mandi` will typeset everything correctly. For symbolic quantities, the user should type only what is necessary to get the desired result. What one types should correspond as closely as possible to what one thinks when writing. The package name derives from *Matter & Interactions*[1] by Ruth Chabay and Bruce Sherwood. The package certainly is rather tightly tied to that textbook but can be used for typesetting any document that requires consistent physics notation. With `mandi` many complicated expressions can be typeset with just a single command. Great thought has been given to command names and I hope users find the conventions logical and easy to remember.

There are other underlying philosophies and goals embedded within `mandi`, all of which are summarized here. These philosophies are

- to employ a *type what you think* model for remembering commands
- to relieve the user of having to explicitly worry about typesetting SI units
- to enforce certain concepts that are too frequently merged, such as the distinction between a vector quantity and its magnitude (e.g. we often use the same name for both)
- to enforce consistent terminology in the naming of quantities, with names that are both meaningful to introductory students and accurate (e.g. *duration* vs. *time*)
- to enforce consistent notation, especially for vector quantities

I hope that using `mandi` will cause users to form good habits that benefit physics students.

2 Building From Source

I am assuming the user will use pdfLaTeX, which creates PDF files as output, to build the documentation. I have not tested the build with with standard LaTeX, which creates DVI files.

3 Overleaf Users

Overleaf is an online LaTeX environment with widespread use. It uses a full TeX/LaTeX installation but doesn't always have the latest version of every package installed. Sometimes packages are updated more frequently than the large distributions are updated. If you want to always be sure you're using the latest version of `mandi` make sure the files `mandi.sty` and `mandi.pdf` are in your Overleaf project folder.

[1] See the *Matter & Interactions* home page at `https://www.matterandinteractions.org/` for more information about this innovative introductory calculus-based physics curriculum.

4 Loading the Package

To load `mandi` with its default options, simply put the line `\usepackage{mandi}` in your document's preamble. To use the package's available options, put the line `\usepackage[options]{mandi}` in your document's preamble. There are six available options, with one option being based on the absence of two of the others. The options are described below.

- **boldvectors** gives bold letters for the kernels of vector names. No arrows are used above the kernel.
- **romanvectors** gives Roman letters for the kernels of vectors names. An arrow appears over the kernel.
- If neither **boldvectors** nor **romanvectors** is specified (the default), vectors are displayed with italic letters for the kernels of vector names and an arrow appears over the kernel.
- **singlemagbars** gives single bars in symbols for vector magnitudes. Double bars may be more familiar to students from their calculus courses. Double bars is the default.
- **approxconsts** gives approximate values of constants to one or two significant figures, depending on how they appear in *Matter & Interactions*. Otherwise, the most precise currently available values are used. Precise constants is the default.
- **useradians** gives radians in the units of angular momentum, angular impulse, and torque. The default is to not use radians in the units of these quantities.
- **baseunits** causes all units to be displayed in *baseunits* form, with SI base units. No solidi (slashes) are used. Positive and negative exponents are used to denote powers of various base units.
- **drvdunits** causes all units to be displayed, when possible, in *drvdunits* form, with SI derived units. Students may already be familiar with many of these derived units.
- If neither **baseunits** nor **drvdunits** is specified (the default), units are displayed in what I call *tradunits* form, which is typically the way they would traditionally appear in textbooks. Units in this form frequently hide the underlying physical meaning and are probably not best pedagogically but are familiar to students and teachers. In this document, the default is to use traditional units. As you will see later, there are ways to override these options either temporarily or permanently.

`mandi` coexists with the `siunitx` package. While there is some functional overlap between the two packages, `mandi` is completely independent of `siunitx`. The two are designed for different purposes and probably also for different audiences, but can be used together if desired. `mandi` coexists with the `commath` package. There is no longer a conflict because `mandi`'s `\abs` command has been renamed to `\absof` →P. 81. `mandi` no longer checks for the presence of the `physymb` package. That package now incorporates `mandi` dependencies, and the two are completely compatible as far as I know.

`mandi` loads the `tensor` for likely future use. See that package's documentation for its commands and how to use them. There are no known conflicts between `mandi` and `tensor`.

`\mandiversion`

Gives the current package version number and build date.

`\mandiversion`	2.7.1 dated 2018/01/15

5 Student Quick Guide

Use `\vect`[→P. 53] to put an arrow over a symbol to make it the symbol for a vector. Typing `\vect{p}` gives $\vec{p}$.

Use `\vectsub`[→P. 59] if the symbol needs a subscript. Typing `\vectsub{p}{ball}` gives $\vec{p}_{\text{ball}}$.

Use `\magvect`[→P. 53] or `\magvectsub`[→P. 59] to get the symbol for a vector's magnitude. Typing `\magvect{p}` gives $\|\vec{p}\|$. Typing `\magvectsub{p}{ball}` gives $\|\vec{p}_{\text{ball}}\|$.

Use `\dirvect`[→P. 53] or `\dirvectsub`[→P. 60] to get the symbol for a vector's direction. Typing `\dirvect{p}` or `\dirvectsub{p}{ball}` gives $\widehat{p}$ or $\widehat{p}_{\text{ball}}$.

Use `\compvect`[→P. 55] to write the symbol for one of a vector's coordinate components. Typing `\compvect{v}{z}` gives v_z.

Use a physical quantity's name followed by a numerical value in curly braces to typeset that numerical value and an appropriate SI unit. Using `\velocity`[→P. 22] by typing `\velocity{2.5}` gives 2.5 m/s. Use `\newphysicsquantity`[→P. 15] to define any new quantity you need.

Many physical constants are defined in `mandi`. Read the section on physical constants to see which ones are defined and how to use them.

Use `\mivector`[→P. 54] to write the coordinate representation of a vector. Typing `\mivector{3,2,-4}` gives $\langle 3, 2, -4\rangle$. Typing `\mivector{a,b,c}` gives $\langle a, b, c\rangle$.

Use `\direction`[→P. 22] to write the coordinate representation of a unit vector, which some authors call a direction. Typing `\direction{1,0,0}` gives $\langle 1, 0, 0\rangle$. Directions have no units.

To specify a vector quantity in terms of its coordinate components, you have two options. One way is to type the vector quantity's name as above, but use `\mivector`[→P. 54] to specify a list of three components separated by commas in curly braces as in `\velocity{\mivector{3,2,-4}}` to get $\langle 3, 2, -4\rangle$ m/s. Another way is to prefix `\vector` to the quantity's name (with no leading backslash) and specify a list of three components separated by commas in curly braces as in `\vectorvelocity{3,2,-4}` to get $\langle 3, 2, -4\rangle$ m/s. The output is the same either way.

Use `\timestento`[→P. 82] or `\xtento`[→P. 82] to get scientific notation. Typing either `2.54\timestento{-4}` or `2.54\xtento{-4}` gives 2.54×10^{-4}.

Use `\inparens`[→P. 81] to surround quantities with nicely formatted parentheses. Typing `\inparens{x^2 + 4}` gives $\left(x^2 + 4\right)$.

Use `\define`[→P. 13] to create a variable that can be used in an intermediate step in a solution. This is discussed later in this section.

To typeset a matrix in parentheses, use the `\pmatrix` environment by putting the rows, between `\begin{pmatrix}` and `\end{pmatrix}`. Each row, except the last, must end with `\\`. Within each row, separate the columns with `&`. Note that `\pmatrix` typesets the matrix in parentheses. Use `\bmatrix` to typeset it in square brackets and `\vmatrix` to typeset it in single vertical bars to indicate a determinant. Use `\Vmatrix` to typeset it in double vertical bars.

```
A second rank tensor represented as a matrix.
  \[\begin{pmatrix}
      \hphantom{-}T_{00} & T_{01} & -T_{02} \\
      -T_{10} & T_{11} & -T_{12} \\
      \hphantom{-}T_{20} & T_{21} & \hphantom{-}T_{22}
    \end{pmatrix}\]
Alternate notation for a matrix.
  \[\begin{bmatrix}
      \hphantom{-}T_{00} & T_{01} & -T_{02} \\
      -T_{10} & T_{11} & -T_{12} \\
      \hphantom{-}T_{20} & T_{21} & \hphantom{-}T_{22}
    \end{bmatrix}\]
The determinant of a matrix.
  \[\begin{vmatrix}
      \hphantom{-}T_{00} & T_{01}  & -T_{02} \\
      -T_{10} & T_{11} & -T_{12} \\
      \hphantom{-}T_{20} & T_{21} & \hphantom{-}T_{22}
    \end{vmatrix}\]
```

A second rank tensor represented as a matrix.

$$\begin{pmatrix} \hphantom{-}T_{00} & T_{01} & -T_{02} \\ -T_{10} & T_{11} & -T_{12} \\ \hphantom{-}T_{20} & T_{21} & \hphantom{-}T_{22} \end{pmatrix}$$

Alternate notation for a matrix.

$$\begin{bmatrix} \hphantom{-}T_{00} & T_{01} & -T_{02} \\ -T_{10} & T_{11} & -T_{12} \\ \hphantom{-}T_{20} & T_{21} & \hphantom{-}T_{22} \end{bmatrix}$$

The determinant of a matrix.

$$\begin{vmatrix} \hphantom{-}T_{00} & T_{01} & -T_{02} \\ -T_{10} & T_{11} & -T_{12} \\ \hphantom{-}T_{20} & T_{21} & \hphantom{-}T_{22} \end{vmatrix}$$

Encapsulate an entire problem solution in a `problem` → P. 119 environment by putting it between `\begin{problem}` and `\end{problem}`.

Show the steps in a calculation in a `mysolution` → P. 117 environment by putting them between `\begin{mysolution}` and `\end{mysolution}`.

Use `\href` from the `hyperref` package to link to URLs. `\href{http://glowscript.org}{GlowScript}` gives GlowScript. You can link to a specific GlowScript program when necessary. Links are active.

Use `\image` → P. 120 to insert diagrams. The diagram should be a PDF file. You *must* remember to specify a meaningful caption for the diagram. You must also provide a unique label for the image so you can easily refer back to it elsewhere in your document.

There are two main design goals behind this package. The first is to typeset numerical values of scalar and vector physical quantities and their SI units. The idea is to simply type a command corresponding to the quantity's name, specifying as an argument a single scalar value or the numerical components of a traditional Cartesian 3-vector, and let `mandi` take care of the units. Every physical quantity you are likely to encounter in an introductory course is probably already defined, but there's a facility for defining new quantities if you need to.

The second main design goal provides a similar approach to typesetting the most frequently used symbolic expressions in introductory physics. If you want to save time in writing out the expression for the electric field of a particle, just use

```
\Efieldofparticle
```

$\frac{1}{4\pi\epsilon_0}\frac{Q}{\|\vec{r}\|^2}\widehat{r}$

which, as you can see, takes fewer keystrokes and it's easier to remember. Correct vector notation is automatically enforced, leading students to get used to seeing it and, hopefully, using it in their own calculations. Yes, this is a bit of an agenda on my part, but my experience has been that students don't recognize or appreciate the utility of vector notation and thus their physical reasoning may suffer as a result. So by using `mandi` they use simple commands that mirror what they're thinking, or what they're supposed to be thinking (yes, another agenda), and in the process see the correct typeset output.

There is another persistent problem with introductory physics textbooks, and that is that many authors do not use consistent notation. Many authors define the notation for a vector's magnitude to be either $\|\vec{a}\|$ or $|\vec{a}|$ in an early chapter, but then completely ignore that notation and simply use a later in the book. I have never understood the (lack of) logic behind this practice and find it more than annoying. Textbooks authors should know better, and should set a better example for introductory students. I propose that using `mandi` would eliminate all last vestiges of all excuses for not setting this one good example for introductory students.

If you are a student, using this package will very likely begin with using a pre-made document template supplied by your instructor. There will likely be a lot about the document that you won't understand at first. Look for a line that says `\begin{document}` and a corresponding line that says `\end{document}` You will add content between these two lines. Most of your content will be within the `problem` environment. Each use of the `problem` environment is intended to encapsulate one complete written solution to one physics problem. In this way, you can build a library of problem solutions for your own convenience.

Since students are this package's primary audience, nearly all of the commands have been defined with students in mind. Writing a problem solution in LaTeX can be tedious to the beginner and some of the commands have been designed to minimize the tedium. For example, if you want to calculate something using an equation, you typically must write the equation, substitute numerical quantities with units if necessary, do the actual calculation, and then state the final result. Sometimes it is necessary to show intermediate steps in a calculation. `mandi` can help with this.

Here is a set of commands that typeset standard equations with placeholders where numerical quantities must be eventually inserted. Note that all of these commands end with the word `places` as a reminder that they generate placeholders.

`\genericinteractionplaces{⟨const⟩}{⟨thing1⟩}{⟨thing2⟩}{⟨dist⟩}{⟨direction⟩}`

Command for generic expression for an inverse square interaction. The five required arguments are, from left to right, a constant of proportionality, a physical property of object 1, a physical property of object 2, the objects' mutual separation, and a vector direction. In practice, these should all be provided in numerical form. Note that negative signs must be placed manually.

```
\genericinteractionplaces{}{}{}{}{}
```

$$(\_)\,\frac{(\_)(\_)}{(\_)^2}\langle \_, \_, \_\rangle$$

`\genericfieldofparticleplaces{⟨const⟩}{⟨thing⟩}{⟨dist⟩}{⟨direction⟩}`

Command for generic expression for an inverse square field. The four required arguments are, from left to right, a constant of proportionality, a physical property, relative distance to field point, and a vector direction. In practice, these should all be provided in numerical form. Note that negative signs must be placed manually.

```
\genericfieldofparticleplaces{}{}{}{}
```

$$(\_)\,\frac{(\_)}{(\_)^2}\langle \_, \_, \_\rangle$$

\genericpotentialenergyplaces{⟨*const*⟩}{⟨*thing1*⟩}{⟨*thing2*⟩}{⟨*dist*⟩}

Command for generic expression for an inverse square energy. The four required arguments are, from left to right, a constant of proportionality, a physical property of object 1, a physical property of object 2, and the objects' mutual separation. In practice, these should all be provided in numerical form. Note that negative signs must be placed manually.

```
\genericpotentialenergyplaces{}{}{}{}
```

$(\_)\,\frac{(\_)(\_)}{(\_)}$

\gravitationalinteractionplaces{⟨*mass1*⟩}{⟨*mass2*⟩}{⟨*distance*⟩}{⟨*direction*⟩}

Command for gravitational interaction. The four required arguments are, from left to right, the first object's mass, the second object's mass, the objects' mutual separation, and a vector direction. In practice, these should all be provided in numerical form. Note that negative signs must be placed manually.

```
\gravitationalinteractionplaces{}{}{}{}
```

$(6.67408\times10^{-11}\,\mathrm{N\cdot m^2/kg^2})\,\frac{(\_)(\_)}{(\_)^2}\langle\_,\_,\_\rangle$

\gfieldofparticleplaces{⟨*mass*⟩}{⟨*distance*⟩}{⟨*direction*⟩}

Command for gravitational field of a particle. The three required arguments are, from left to right, the object's mass, the distance from the source to the field point, and a vector direction. In practice, these should all be provided in numerical form. Note that negative signs must be placed manually.

```
\gfieldofparticleplaces{}{}{}
```

$(6.67408\times10^{-11}\,\mathrm{N\cdot m^2/kg^2})\,\frac{(\_)}{(\_)^2}\langle\_,\_,\_\rangle$

\gravitationalpotentialenergyplaces{⟨*mass1*⟩}{⟨*mass2*⟩}{⟨*distance*⟩}

Command for gravitational potential energy. The three required arguments are, from left to right, the first object's mass, the second object's mass, and the object's mutual distance. In practice, these should all be provided in numerical form. Note the inclusion of the leading negative sign.

```
\gravitationalpotentialenergyplaces{}{}{}
```

$-(6.67408\times10^{-11}\,\mathrm{N\cdot m^2/kg^2})\,\frac{(\_)(\_)}{(\_)}$

\springinteractionplaces{⟨*stiffness*⟩}{⟨*stretch*⟩}{⟨*direction*⟩}

Command for a spring interaction. The three required arguments are, from left to right, the spring stiffness, the spring's stretch, and a vector direction. In practice, these should all be provided in numerical form. Note that negative signs must be placed manually or absorbed into the displacement vector.

```
\springinteractionplaces{}{}{}
```

$(\_)(\_)\langle\_,\_,\_\rangle$

\springpotentialenergyplaces{⟨*stiffness*⟩}{⟨*stretch*⟩}

Command for spring potential energy. The two required arguments are, from left to right, the spring stiffness and the spring stretch. In practice, these should be provided in numerical form.

```
\springpotentialenergyplaces{}{}
```

$\frac{1}{2}(\_)(\_)^2$

\genericelectricdipoleonaxisplaces{⟨*const*⟩}{⟨*charge*⟩}{⟨*separation*⟩}{⟨*dist*⟩}{⟨*direction*⟩}

Command for generic expression for dipole field on the dipole's axis. The five required arguments are, from left to right, a constant of proportionality, a charge, a dipole separation, the distance to the field point, and a vector direction. In practice, these should all be provided in numerical form.

```
\genericelectricdipoleonaxisplaces{}{}{}{}{}
```

$(\_)\frac{2(\_)(\_)}{(\_)^3}\langle\_,\_,\_\rangle$

\genericelectricdipoleplaces{⟨*const*⟩}{⟨*charge*⟩}{⟨*separation*⟩}{⟨*dist*⟩}{⟨*direction*⟩}

Command for generic expression for dipole field. The five required arguments are, from left to right, a constant of proportionality, a charge, a dipole separation, the distance to the field point, and a vector direction. In practice, these should all be provided in numerical form.

```
\genericelectricdipoleplaces{}{}{}{}{}
```

$(\_)\frac{(\_)(\_)}{(\_)^3}\langle\_,\_,\_\rangle$

\electricinteractionplaces{⟨*charge1*⟩}{⟨*charge2*⟩}{⟨*distance*⟩}{⟨*direction*⟩}

Command for electric interaction. The four required arguments are, from left to right, the first object's charge, the second object's charge, the objects' mutual separation, and a vector direction. In practice, these should all be provided in numerical form.

```
\electricinteractionplaces{}{}{}{}
```

$(8.9875517873681764\times10^9\ \mathrm{N\cdot m^2/C^2})\frac{(\_)(\_)}{(\_)^2}\langle\_,\_,\_\rangle$

\Efieldofparticleplaces{⟨*charge*⟩}{⟨*distance*⟩}{⟨*direction*⟩}

Command for electric field of a particle. The three required argument are, from left to right, the particle's charge, the distance form the source to the field point, and a vector direction. In practice, these should all be provided in numerical form.

```
\Efieldofparticleplaces{}{}{}
```

$(8.9875517873681764 \times 10^{9}\ \mathrm{N \cdot m^2/C^2})\ \frac{(\ \_\ )}{(\ \_\ )^2}\langle \_, \_, \_ \rangle$

`\Bfieldofparticleplaces{⟨charge⟩}{⟨magvel⟩}{⟨magr⟩}{⟨vhat⟩}{⟨rhat⟩}`

Command for magnetic field of a particle. The five required arguments are, from left to right, the particle's charge, the particle's velocity, the distance from the source to the field point, the velocity's direction, and a direction vector from the source to the field point. In practice, these should all be provided in numerical form.

```
\Bfieldofparticleplaces{}{}{}{}{}
```

$(10^{-7}\ \mathrm{T \cdot m/A})\ \frac{(\ \_\ )(\ \_\ )}{(\ \_\ )^2}\langle \_, \_, \_ \rangle \times \langle \_, \_, \_ \rangle$

`\electricpotentialenergyplaces{⟨charge1⟩}{⟨charge2⟩}{⟨distance⟩}`

Command for electric potential energy. The three required arguments are, from left to right, the first object's charge, the second object's charge, and the objects' mutual distance. In practice, these should all be provided in numerical form.

```
\electricpotentialenergyplaces{}{}{}
```

$(8.9875517873681764 \times 10^{9}\ \mathrm{N \cdot m^2/C^2})\ \frac{(\ \_\ )(\ \_\ )}{(\ \_\ )}$

`\electricdipoleonaxisplaces{⟨charge⟩}{⟨separation⟩}{⟨dist⟩}{⟨direction⟩}`

Command for dipole electric field on the dipole's axis. The four required arguments are, from left to right, a charge, a dipole separation, the distance to the field point, and a vector direction. In practice, these should all be provided in numerical form.

```
\electricdipoleonaxisplaces{}{}{}{}
```

$(8.9875517873681764 \times 10^{9}\ \mathrm{N \cdot m^2/C^2})\ \frac{2(|\ \_\ |)(\ \_\ )}{(\ \_\ )^3}\langle \_, \_, \_ \rangle$

`\electricdipoleonbisectorplaces{⟨charge⟩}{⟨separation⟩}{⟨dist⟩}{⟨direction⟩}`

Command for dipole electric field. The four required arguments are, from left to right, a charge, a dipole separation, the distance to the field point, and a vector direction. In practice, these should all be provided in numerical form.

```
\electricdipoleonbisectorplaces{}{}{}{}
```

$(8.9875517873681764 \times 10^{9}\ \mathrm{N \cdot m^2/C^2})\ \frac{(|\ \_\ |)(\ \_\ )}{(\ \_\ )^3}\langle \_, \_, \_ \rangle$

The underlying strategy is to *think about how you would say what you want to write and then write it the way you would say it.* With a few exceptions, this is how `mandi` works. You need not worry about units because `mandi` knows what SI units go with which physical quantities. You can define new quantities so that `mandi` knows about them and in doing so, you give the new quantities the same names they would normally have.

So now how to you go about getting numerical values (with units) into the placeholders? Use the `\define` command to define a variable containing a desired quantity, and then pass that variable to the above commands and that quantity will appear in the corresponding placeholder.

`\define{⟨variablename⟩}{⟨quantity⟩}`

Defines a variable, actually a new command, named `\variablename` and sets its value to `\quantity`. **Note that digits are not permitted in command names in LaTeX.**

```
\define{\massone}{\mass{25}}
```

Suppose you want to calculate the gravitational force on one object due to another. You need two masses, and their mutual distance, and a direction. You can say, for example, `\define{\massone}{\mass{5}` to create a variable `\massone` containing a mass of 5 kg. Note that you don't have to worry about units because the `\mass`→P. 17 command handles that for you. Similarly, you can go on and say `\define{\masstwo}{\mass{12}` and `\define{\myr}{\displacement{5}` and `\define{\mydir}{\mivector{0,-1,0}`. Now just call the `\gravitationalinteractionplaces`→P. 10 command with these arguments (in the correct order of course) and LaTeX will do the rest when you compile your document. The entire process would look like this:

```
\define{\massone}{\mass{5}}
\define{\masstwo}{\mass{12}}
\define{\myr}{\displacement{5}}
\define{\mydir}{\mivector{0,-1,0}}
\gravitationalinteractionplaces{\massone}{\masstwo}{\myr}{\mydir} =
\vectorforce{0,-1.60\xtento{-10},0}
```

$(6.67408 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2})\ \frac{(5\ \mathrm{kg})(12\ \mathrm{kg})}{(5\ \mathrm{m})^2} \langle 0, -1, 0 \rangle = \langle 0, -1.60 \times 10^{-10}, 0 \rangle\ \mathrm{N}$

Of course you must calculate the final numerical result yourself because `mandi` doesn't (yet) do calculations. One very important restriction on variable names is that LaTeX doesn't allow digits in command or variable names and thus that restriction applies here too.

This barely scratches the surface in describing `mandi` so continue reading this document to see everything it can do. You will learn new commands as you need them in your work. To start with, you should at least read the section on SI units and the section on physics quantities.

6 Features and Commands

6.1 SI Base Units and Dimensions

This is not a tutorial on SI units and the user is assumed to be familiar with SI rules and usage. Begin by defining shortcuts for the units for the seven SI base quantities: *spatial displacement* (what others call *length*), *mass*, *temporal displacement* (what others call *time*, but we will call it *duration* in most cases), *electric current*, *thermodynamic temperature*, *amount*, and *luminous intensity*. These shortcuts are used internally and need not explicitly be invoked by the user.

`\m`

Command for metre, the SI unit of spatial displacement (length).

`\kg`

Command for kilogram, the SI unit of mass.

`\s`

Command for second, the SI unit of temporal displacement (duration).

`\A`

Command for ampere, the SI unit of electric current.

`\K`

Command for kelvin, the SI unit of thermodynamic temperature.

`\mol`

Command for mole, the SI unit of amount.

`\cd`

Command for candela, the SI unit of luminous intensity.

If `mandi` was loaded with **baseunits**, then every physical quantity will have a unit that is some product of powers of these seven base SI units. Exceptions are angular quantities, which will include either degrees or radians depending upon the application. Again, this is what we mean by *baseunits* form.

Certain combinations of the SI base units have nicknames and each such combination and nickname constitutes a *derived unit*. Derived units are no more physically meaningful than the base units, they are merely nicknames for particular combinations of base units. An example of a derived unit is the newton, for which the symbol (it is not an abbreviation) is N. However, the symbol N is merely a nickname for a particular combination of base units. It is not the case that every unique combination of base units has a nickname, but those that do are usually named in honor of a scientist. Incidentally, in such cases, the symbol is capitalized but the *name* of the unit is *never* capitalized. Thus we would write the name of the derived unit of force as newton and not Newton. Again, using these select nicknames for certain combinations of base units is what we mean by *drvdunits* form.

6.2 SI Dimensions

For each SI unit, there is a corresponding dimension. Every physical quantity is some multiplicative product of each of the seven basic SI dimensions raised to a power.

`\dimddisplacement`
Command for the symbol for the dimension of displacement.

`displacement has dimension of \dimdisplacement`	displacement has dimension of L

`\dimmass`
Command for the symbol for the dimension of mass.

`mass has dimension of \dimmass`	mass has dimension of M

`\dimduration`
Command for the symbol for the dimension of duration.

`duration has dimension of \dimduration`	duration has dimension of T

`\dimcurrent`
Command for the symbol for the dimension of current.

`current has dimension of \dimcurrent`	current has dimension of I

`\dimtemperature`
Command for the symbol for the dimension of temperature.

`temperature has dimension of \dimtemperature`	temperature has dimension of Θ

`\dimamount`
Command for the symbol for the dimension of amount.

`amount has dimension of \dimamount`	amount has dimension of N

`\dimluminous`
Command for the symbol for the dimension of luminous intensity.

`luminous has dimension of \dimluminous`	luminous has dimension of J

6.3 Defining Physical Quantities

`\newphysicsquantity`{⟨*newname*⟩}{⟨baseunits⟩}[⟨drvdunits⟩][⟨tradunits⟩]
Defines a new physics quantity and its associated commands.

Using this command causes several things to happen.

- A command `\newname`{⟨*magnitude*⟩}, where newname is the first argument of `\newphysicsquantity`, is created that takes one mandatory argument, a numerical magnitude. Subsequent use of your defined scalar quantity can be invoked by typing `\newname` {⟨*magnitude*⟩} and the units will be typeset according to the options given when `mandi` was loaded. Note that if the *drvdunits* and *tradunits* forms are not specified, they will be populated with the *baseunits* form.

- A command `\newnamebaseunit{⟨magnitude⟩}` is created that expresses the quantity and its units in *baseunits* form.
- A command `\newnamedrvdunit{⟨magnitude⟩}` is created that expresses the quantity and its units in *drvdunits* form. This command is created whether or not the first optional argument is provided.
- A command `\newnametradunit{⟨magnitude⟩}` is created that expresses the quantity and its units in *tradunits* form. This command is created whether or not the first optional argument is provided.
- A command `\newnameonlybaseunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in *baseunits* form.
- A command `\newnameonlydrvdunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in *drvdunits* form.
- A command `\newnameonlytradunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in *tradunits* form.
- A command `\newnamevalue{⟨magnitude⟩}` is created that expresses **only** the quantity's numerical value.

As an example, consider momentum. The following commands are defined:

`\momentum{3}`	$3\,\mathrm{kg \cdot m/s}$	unit set by global options
`\momentumbaseunit{3}`	$3\,\mathrm{m \cdot kg \cdot s^{-1}}$	quantity with base unit
`\momentumdrvdunit{3}`	$3\,\mathrm{N \cdot s}$	quantity with derived unit
`\momentumtradunit{3}`	$3\,\mathrm{kg \cdot m/s}$	quantity with traditional unit
`\momentumvalue{3}`	3	selects only numerical value
`\momentumonlybaseunit`	$\mathrm{m \cdot kg \cdot s^{-1}}$	selects only base unit
`\momentumonlydrvdunit`	$\mathrm{N \cdot s}$	selects only derived unit
`\momentumonlytradunit`	$\mathrm{kg \cdot m/s}$	selects only traditional unit

Momentum is a vector quantity, so obviously this command really refers to the magnitude of a momentum vector. There is an interesting, and as far as I can tell unwritten, convention in physics that we use the same name for a vector and its magnitude with one exception, and that is for velocity, the magnitude of which we sometimes call speed. Conceptually, however, velocity and speed are different entities. Therefore, `mandi` has different commands for them. Actually, the `\speed`→P. 22 command is just an alias for `\velocity`→P. 22 and should only be used for scalars and never for vectors. This convention means that the same name is used for vector quantities and the corresponding magnitudes.

6.3.1 Defining Vector Quantities

All physical quantities are defined as in the momentum example above regardless of whether the quantity is a scalar or a vector. To typeset a vector quantity in terms of its components in some coordinate system (usually an orthonormal cartesian system, either specify an argument consisting of a vector with components as a comma separated list in a `\mivector`→P. 54 command or prepend the quantity name with `vector`. So specifying a momentum vector is as simple as

```
\momentum{\mivector{3,2,-1}} \\
\vectormomentum{3,2,-1}
```

$\langle 3, 2, -1\rangle$ kg · m/s
$\langle 3, 2, -1\rangle$ kg · m/s

where the notation corresponds to that used in *Matter & Interactions*.

6.3.2 First Semester Physics

The first semester of most traditional introductory calculus-based physics courses focuses on mechanics, dynamics, and statistical mechanics.

`\displacement`{⟨*magnitude or vector*⟩}
Command for displacement.

`\vectordisplacement`{⟨*commadelimitedlistofcomps*⟩}
Command for vector displacement.

```
\displacement{5}                 \\
\displacement{\mivector{3,2,-1}} \\
\vectordisplacement{1,2,3}
```

5 m
$\langle 3, 2, -1\rangle$ m
$\langle 1, 2, 3\rangle$ m

`\mass`{⟨*magnitude*⟩}
Command for mass.

```
\mass{5}
```

5 kg

`\duration`{⟨*magnitude*⟩}
Command for duration.

```
\duration{5}
```

5 s

`\current`{⟨*magnitude*⟩}
Command for current.

```
\current{5}
```

5 A

`\temperature`{⟨*magnitude*⟩}
Command for temperature.

```
\temperature{5}
```

5 K

`\amount`{⟨*magnitude*⟩}
Command for amount.

```
\amount{5}
```
5 mol

\luminous{⟨*magnitude*⟩}

Command for luminous intensity.

```
\luminous{5}
```
5 cd

While we're at it, let's also go ahead and define a few non-SI units from astronomy, astrophysics, and old school physics.

\infeet{⟨*magnitude*⟩}

Command for magnitude of displacement in feet. This is still sometimes used in engineering applications and is frequently seen in older physics textbooks.

\infeetpersecond{⟨*magnitude*⟩}

Command for magnitude of velocity in feet per second. This is still sometimes used in engineering applications and is frequently seen in older physics textbooks.

\infeetpersecondsquared{⟨*magnitude*⟩}

Command for magnitude of acceleration in feet per second. This is still sometimes used in engineering applications and is frequently seen in older physics textbooks.

```
\infeet{5}                   \\
\infeetpersecond{5}          \\
\infeetpersecondsquared{32}
```
5 ft
5 ft/s
32 $\mathrm{ft/s^2}$

\planeangle{⟨*magnitude*⟩}

Command for plane angle in radians.

```
\planeangle{5}
```
5 rad

\solidangle{⟨*magnitude*⟩}

Command for solidangle.

```
\solidangle{5}
```
5 sr

\indegrees{⟨*magnitude*⟩}

Command for plane angle in degrees.

```
\indegrees{5}
```
5°

\inarcminutes{⟨*magnitude*⟩}

Command for plane angle in minutes of arc.

```
\inarcminutes{5}
```
$5'$

\inarcseconds{⟨*magnitude*⟩}

Command for plane angle in seconds of arc.

`\inarcseconds{5}`	$5''$

\inFarenheit{⟨*magnitude*⟩}

Command for temperature in degrees Farenheit.

`\inFarenheit{68}`	68°F

\inCelsius{⟨*magnitude*⟩}

Command for temperature in degrees Celsius.

`\inCelsius{20}`	20°C

\ineV{⟨*magnitude*⟩}

Command for energy in electron volts.

`\ineV{10.2}`	10.2 eV

\ineVocs{⟨*magnitude*⟩}

Command for mass in eV/c^2.

`\ineVocs{1.1}`	$1.1\ \mathrm{eV}/c^2$

\ineVoc{⟨*magnitude*⟩}

Command for momentum in eV/c.

`\ineVoc{3.6}`	$3.6\ \mathrm{eV}/c$

\inMeV{⟨*magnitude*⟩}

Command for energy in millions of electron volts.

`\inMeV{2.2}`	2.2 MeV

\inMeVocs{⟨*magnitude*⟩}

Command for mass in MeV/c^2.

`\inMeVocs{0.511}`	$0.511\ \mathrm{MeV}/c^2$

\inMeVoc{⟨*magnitude*⟩}

Command for momentum in MeV/c.

`\inMeVoc{3.6}`	$3.6\ \mathrm{MeV}/c$

`\inGeV{⟨magnitude⟩}`
Command for energy in millions of electron volts.

```
\inGeV{2.2}
```
2.2 GeV

`\inGeVocs{⟨magnitude⟩}`
Command for mass in GeV/c^2.

```
\inGeVocs{0.511}
```
0.511 GeV/c^2

`\inGeVoc{⟨magnitude⟩}`
Command for momentum in GeV/c.

```
\inGeVoc{3.6}
```
3.6 GeV/c

`\inamu{⟨magnitude⟩}`
Command for mass in atomic mass units.

```
\inamu{4.002602}
```
4.002602 u

`\inAU{⟨magnitude⟩}`
Command for displacement in astronomical units.

```
\inAU{5.2}
```
5.2 AU

`\inly{⟨magnitude⟩}`
Command for displacement in light years.

```
\inly{4.3}
```
4.3 ly

`\incyr{⟨magnitude⟩}`
Command for displacement in light years written differently.

```
\incyr{4.3}
```
4.3 $c \cdot$ year

`\inpc{⟨magnitude⟩}`
Command for displacement in parsecs.

```
\inpc{4.3}
```
4.3 pc

`\insolarL{⟨magnitude⟩}`
Command for luminosity in solar multiples.

```
\insolarL{4.3}
```
4.3 $L_\odot$

\insolarT{⟨*magnitude*⟩}

Command for temperature in solar multiples.

```
\insolarT{2}
```

2 $T_\odot$

\insolarR{⟨*magnitude*⟩}

Command for radius in solar multiples.

```
\insolarR{4.3}
```

4.3 $R_\odot$

\insolarM{⟨*magnitude*⟩}

Command for mass in solar multiples.

```
\insolarM{4.3}
```

4.3 $M_\odot$

\insolarF{⟨*magnitude*⟩}

Command for flux in solar multiples.

```
\insolarF{4.3}
```

4.3 $F_\odot$

\insolarf{⟨*magnitude*⟩}

Command for apparent flux in solar multiples.

```
\insolarf{4.3}
```

4.3 $f_\odot$

\insolarMag{⟨*magnitude*⟩}

Command for absolute magnitude in solar multiples.

```
\insolarMag{2}
```

2 $M_\odot$

\insolarmag{⟨*magnitude*⟩}

Command for apparent magnitude in solar multiples.

```
\insolarmag{2}
```

2 $m_\odot$

\insolarD{⟨*magnitude*⟩}

Command for distance in solar multiples.

\insolard{⟨*magnitude*⟩}

Identical to \insolarD but uses d.

```
\insolarD{2} \\
\insolard{2}
```

2 $D_\odot$
2 $d_\odot$

Angles are confusing in introductory physics because sometimes we write the unit and sometimes we do not. Some concepts, such as flux, are simplified by introducing solid angle.

Now let us continue into first semester physics, defining quantities in the approximate order in which they appear in such a course. Use `\timestento` → P. 82 or `\xtento` → P. 82 to get scientific notation, with the mantissa immediately preceding the command and the power as the required argument. `\timestento` → P. 82 has an optional second argument that specifies a unit, but that is not needed or used in the following examples.

`\direction{`⟨*commadelimitedlistofcomps*⟩`}`

Command for coordinate representation of a vector direction. Direction has no unit.

`\vectordirection{`⟨*commadelimitedlistofcomps*⟩`}`

This is an alias for `\direction`.

```
\direction{a,b,c}                                                   \\
\direction{\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}} \\
\vectordirection{a,b,c}                                             \\
\vectordirection{\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}}
```

$\langle a, b, c\rangle$
$\left\langle \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}} \right\rangle$
$\langle a, b, c\rangle$
$\left\langle \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}} \right\rangle$

`\velocityc{`⟨*magnitude or vector*⟩`}`

Command for velocity as a fraction of c.

`\vectorvelocityc{`⟨*commadelimitedlistofcomps*⟩`}`

Command for vector velocity as a fraction of c.

```
\velocityc{0.9987}                     \\
\velocityc{\mivector{0,0.9987,0}}      \\
\mivector{\velocityc{\frac{1}{\sqrt{3}}} \\
\velocityc{\frac{1}{\sqrt{3}}}         \\
\velocityc{\frac{1}{\sqrt{3}}}}        \\
\vectorvelocityc{0,0.9987,0}
```

$0.9987c$
$\langle 0, 0.9987, 0\rangle\, c$
$\frac{1}{\sqrt{3}}c$
$\frac{1}{\sqrt{3}}c$
$\frac{1}{\sqrt{3}}c$
$\langle 0, 0.9987, 0\rangle\, c$

`\velocity{`⟨*magnitude or vector*⟩`}`

Command for velocity.

`\vectorvelocity{`⟨*commadelimitedlistofcomps*⟩`}`

Command for vector velocity.

```
\velocity{2.34}             \\
\velocity{\mivector{3,2,-1}} \\
\vectorvelocity{3,2,-1}
```

$2.34\ \mathrm{m/s}$
$\langle 3, 2, -1\rangle\ \mathrm{m/s}$
$\langle 3, 2, -1\rangle\ \mathrm{m/s}$

`\speed{`⟨*magnitude*⟩`}`

Command for speed. Technically, velocity is defined as the quotient of displacement and duration while speed is defined as the quotient of distance traveled and duration. They have the same dimension and unit, but are slightly conceptually different so separate commands are provided. I've never seen speed used as anything other than a scalar.

```
\velocity{8.25}
```

8.25 m/s

\lorentz{⟨*magnitude*⟩}

Command for relativistic Lorentz factor. Obviously this command doesn't do anything visually, but is included for thinking about calculations where this quantity is needed.

```
\lorentz{2.34}
```

2.34

\momentum{⟨*magnitude or vector*⟩}

Command for momentum.

\vectormomentum{⟨*commadelimitedlistofcomps*⟩}

Command for vector momentum.

```
\momentum{2.34}              \\
\momentum{\mivector{3,2,-1}} \\
\vectormomentum{3,2,-1}
```

$2.34\ \mathrm{kg \cdot m/s}$
$\langle 3, 2, -1 \rangle\ \mathrm{kg \cdot m/s}$
$\langle 3, 2, -1 \rangle\ \mathrm{kg \cdot m/s}$

\acceleration{⟨*magnitude or vector*⟩}

Command for acceleration.

\vectoracceleration{⟨*commadelimitedlistofcomps*⟩}

Command for vector acceleration.

```
\acceleration{2.34}              \\
\acceleration{\mivector{3,2,-1}} \\
\vectoracceleration{3,2,-1}
```

$2.34\ \mathrm{m/s^2}$
$\langle 3, 2, -1 \rangle\ \mathrm{m/s^2}$
$\langle 3, 2, -1 \rangle\ \mathrm{m/s^2}$

\gravitationalfield{⟨*commadelimitedlistofcomps*⟩}

Command for gravitational field.

\vectorgravitationalfield{⟨*magnitude or vector*⟩}

Command for vector gravitational field.

```
\gravitationalfield{2.34}              \\
\gravitationalfield{\mivector{3,2,-1}} \\
\vectorgravitationalfield{3,2,-1}
```

$2.34\ \mathrm{N/kg}$
$\langle 3, 2, -1 \rangle\ \mathrm{N/kg}$
$\langle 3, 2, -1 \rangle\ \mathrm{N/kg}$

\gravitationalpotential{⟨*magnitude*⟩}

Command for gravitational potential.

```
\gravitationalpotential{2.34}
```

$2.34\ \mathrm{J/kg}$

\impulse{⟨*magnitude or vector*⟩}

Command for impulse. Impulse and change in momentum are conceptually different and a case can be made for expressing the in different, but equivalent, units.

\vectorimpulse{⟨*commadelimitedlistofcomps*⟩}

Command for vector impulse.

```
\impulse{2.34}             \\
\impulse{\mivector{3,2,-1}} \\
\vectorimpulse{3,2,-1}
```

$2.34\ \mathrm{N\cdot s}$
$\langle 3,2,-1\rangle\ \mathrm{N\cdot s}$
$\langle 3,2,-1\rangle\ \mathrm{N\cdot s}$

`\force`{⟨*magnitude or vector*⟩}

Command for force.

`\vectorforce`{⟨*commadelimitedlistofcomps*⟩}

Command for vector force.

```
\force{2.34}             \\
\force{\mivector{3,2,-1}} \\
\vectorforce{3,2,-1}
```

$2.34\ \mathrm{N}$
$\langle 3,2,-1\rangle\ \mathrm{N}$
$\langle 3,2,-1\rangle\ \mathrm{N}$

`\springstiffness`{⟨*magnitude*⟩}

Command for spring stiffness.

```
\springstiffness{2.34}
```

$2.34\ \mathrm{N/m}$

`\springstretch`{⟨*magnitude*⟩}

Command for spring stretch.

```
\springstretch{2.34}
```

$2.34\ \mathrm{m}$

`\area`{⟨*magnitude*⟩}

Command for area.

```
\area{2.34}
```

$2.34\ \mathrm{m}^2$

`\volume`{⟨*magnitude*⟩}

Command for volume.

```
\volume{2.34}
```

$2.34\ \mathrm{m}^3$

`\linearmassdensity`{⟨*magnitude*⟩}

Command for linear mass density.

```
\linearmassdensity{2.34}
```

$2.34\ \mathrm{kg/m}$

`\areamassdensity`{⟨*magnitude*⟩}

Command for area mass density.

```
\areamassdensity{2.34}
```

$2.34\ \mathrm{kg/m}^2$

`\volumemassdensity`{⟨*magnitude*⟩}

Command for volume mass density.

`\volumemassdensity{2.34}`	2.34 kg/m^3

`\youngsmodulus{`⟨*magnitude*⟩`}`

Command for Young's modulus.

`\youngsmodulus{2.34\timestento{9}}`	2.34×10^9 Pa

`\work{`⟨*magnitude*⟩`}`

Command for work. Energy and work are conceptually different and a case can be made for expressing them in different, but equivalent, units.

`\work{2.34}`	2.34 J

`\energy{`⟨*magnitude*⟩`}`

Command for energy. Work and energy are conceptually different and a case can be made for expressing them in different, but equivalent, units.

`\energy{2.34}`	2.34 J

`\power{`⟨*magnitude*⟩`}`

Command for power.

`\power{2.34}`	2.34 W

`\specificheatcapacity{`⟨*magnitude*⟩`}`

Command for specific heat capacity.

`\specificheatcapacity{4.18\xtento{3}}`	4.18×10^3 J/K · kg

`\angularvelocity{`⟨*magnitude or vector*⟩`}`

Command for angular velocity.

`\vectorangularvelocity{`⟨*commadelimitedlistofcomps*⟩`}`

Command for vector angular velocity.

```
\angularvelocity{2.34}              \\
\angularvelocity{\mivector{3,2,-1}} \\
\vectorangularvelocity{3,2,-1}
```

2.34 rad/s
$\langle 3, 2, -1\rangle$ rad/s
$\langle 3, 2, -1\rangle$ rad/s

`\angularacceleration{`⟨*magnitude or vector*⟩`}`

Command for angular acceleration.

`\vectorangularacceleration{`⟨*commadelimitedlistofcomps*⟩`}`

Command for vector angular acceleration.

```
\angularacceleration{2.34}             \\
\angularacceleration{\mivector{3,2,-1}} \\
\vectorangularacceleration{3,2,-1}
```

$2.34\ \mathrm{rad/s^2}$
$\langle 3,2,-1\rangle\ \mathrm{rad/s^2}$
$\langle 3,2,-1\rangle\ \mathrm{rad/s^2}$

\angularmomentum{⟨*magnitude or vector*⟩}

Command for angular momentum. Whether or not the units contain radians is determined by whether the **useradians** option was used when `mandi` was loaded.

\vectorangularmomentum{⟨*commadelimitedlistofcomps*⟩}

Command for vector angular momentum.

```
\angularmomentum{2.34}             \\
\angularmomentum{\mivector{3,2,-1}} \\
\vectorangularmomentum{3,2,-1}
```

$2.34\ \mathrm{m^2\cdot kg\cdot s^{-1}}$
$\langle 3,2,-1\rangle\ \mathrm{m^2\cdot kg\cdot s^{-1}}$
$\langle 3,2,-1\rangle\ \mathrm{m^2\cdot kg\cdot s^{-1}}$

\angularimpulse{⟨*magnitude or vector*⟩}

Command for angular impulse. Whether or not the units contain radians is determined by whether the **useradians** option was used when `mandi` was loaded.

\vectorangularimpulse{⟨*commadelimitedlistofcomps*⟩}

Command for vector angular impulse.

```
\angularimpulse{2.34}             \\
\angularimpulse{\mivector{3,2,-1}} \\
\vectorangularimpulse{3,2,-1}
```

$2.34\ \mathrm{J\cdot s}$
$\langle 3,2,-1\rangle\ \mathrm{J\cdot s}$
$\langle 3,2,-1\rangle\ \mathrm{J\cdot s}$

\torque{⟨*magnitude or vector*⟩}

Command for torque. Whether or not the units contain radians is determined by whether the **useradians** option was used when `mandi` was loaded.

\vectortorque{⟨*commadelimitedlistofcomps*⟩}

Command for vector torque.

```
\torque{2.34}             \\
\torque{\mivector{3,2,-1}} \\
\vectortorque{3,2,-1}
```

$2.34\ \mathrm{J}$
$\langle 3,2,-1\rangle\ \mathrm{J}$
$\langle 3,2,-1\rangle\ \mathrm{J}$

\momentofinertia{⟨*magnitude*⟩}

Command for moment of inertia.

```
\momentofinertia{2.34}
```

$2.34\ \mathrm{J\cdot s^2}$

\entropy{⟨*magnitude*⟩}

Command for entropy.

```
\entropy{2.34}
```

$2.34\ \mathrm{J/K}$

\wavelength{⟨*magnitude*⟩}

Command for wavelength.

```
\wavelength{4.00\timestento{-7}}
```

4.00×10^{-7} m

\wavenumber{⟨*magnitude or vector*⟩}

Command for wavenumber.

\vectorwavenumber{⟨*commadelimitedlistofcomps*⟩}

Command for vector wavenumber.

```
\wavenumber{2.50\timestento{6}} \\
\wavenumber{\mivector{3,2,-1}}  \\
\vectorwavenumber{3,2,-1}
```

2.50×10^{6} /m
$\langle 3, 2, -1 \rangle$ /m
$\langle 3, 2, -1 \rangle$ /m

\frequency{⟨*magnitude*⟩}

Command for frequency.

```
\frequency{7.50\timestento{14}}
```

7.50×10^{14} Hz

\angularfrequency{⟨*magnitude*⟩}

Command for angularfrequency.

```
\angularfrequency{4.70\timestento{15}}
```

4.70×10^{15} rad/s

6.3.3 Second Semester Physics

The second semester of introductory physics focuses on electromagnetic theory, and there are many primary and secondary quantities.

\charge{⟨*magnitude*⟩}

Command for electric charge.

```
\charge{2\timestento{-9}}
```

2×10^{-9} C

\permittivity{⟨*magnitude*⟩}

Command for permittivity.

```
\permittivity{9\timestento{-12}}
```

9×10^{-12} $C^2/N \cdot m^2$

\electricfield{⟨*magnitude or vector*⟩}

Command for electric field.

\vectorelectricfield{⟨*commadelimitedlistofcomps*⟩}

Command for vector electric field.

```
\electricfield{2\timestento{5}}   \\
\electricfield{\mivector{3,2,-1}} \\
\vectorelectricfield{3,2,-1}
```

2×10^5 N/C
$\langle 3, 2, -1\rangle$ N/C
$\langle 3, 2, -1\rangle$ N/C

`\electricdipolemoment`{⟨*magnitude or vector*⟩}

Command for electric dipole moment.

`\vectorelectricdipolemoment`{⟨*commadelimitedlistofcomps*⟩}

Command for vector electric dipole moment.

```
\electricdipolemoment{2\timestento{5}}   \\
\electricdipolemoment{\mivector{3,2,-1}} \\
\vectorelectricdipolemoment{3,2,-1}
```

2×10^5 C · m
$\langle 3, 2, -1\rangle$ C · m
$\langle 3, 2, -1\rangle$ C · m

`\permeability`{⟨*magnitude*⟩}

Command for permeability.

```
\permeability{4\pi\timestento{-7}}
```

$4\pi \times 10^{-7}$ T · m/A

`\magneticfield`{⟨*magnitude or vector*⟩}

Command for magnetic field (also called magnetic induction).

`\vectormagneticfield`{⟨*commadelimitedlistofcomps*⟩}

Command for vector magnetic field (also called magnetic induction).

```
\magneticfield{1.25}              \\
\magneticfield{\mivector{3,2,-1}} \\
\vectormagneticfield{3,2,-1}
```

1.25 N/C · (m/s)
$\langle 3, 2, -1\rangle$ N/C · (m/s)
$\langle 3, 2, -1\rangle$ N/C · (m/s)

`\cmagneticfield`{⟨*magnitude or vector*⟩}

Command for product of c and magnetic field. This quantity is convenient for symmetry.

`\vectorcmagneticfield`{⟨*commadelimitedlistofcomps*⟩}

Command for product of c and magnetic field as a vector.

```
\cmagneticfield{1.25}              \\
\cmagneticfield{\mivector{3,2,-1}} \\
\vectorcmagneticfield{3,2,-1}
```

1.25 N/C
$\langle 3, 2, -1\rangle$ N/C
$\langle 3, 2, -1\rangle$ N/C

`\linearchargedensity`{⟨*magnitude*⟩}

Command for linear charge density.

```
\linearchargedensity{4.5\timestento{-3}}
```

4.5×10^{-3} C/m

`\areachargedensity`{⟨*magnitude*⟩}

Command for area charge density.

```
\areachargedensity{1.25}
```

1.25 C/m^2

`\volumechargedensity{⟨magnitude⟩}`

Command for volume charge density.

```
\volumechargedensity{1.25}
```

$1.25\ \mathrm{C/m^3}$

`\mobility{⟨magnitude⟩}`

Command for electron mobility.

```
\areachargedensity{4.5\timestento{-3}}
```

$4.5 \times 10^{-3}\ \mathrm{C/m^2}$

`\numberdensity{⟨magnitude⟩}`

Command for electron number density.

```
\numberdensity{2\timestento{18}}
```

$2 \times 10^{18}\ /\mathrm{m^3}$

`\polarizability{⟨magnitude⟩}`

Command for polarizability.

```
\polarizability{1.96\timestento{-40}}
```

$1.96 \times 10^{-40}\ \mathrm{C \cdot m/(N/C)}$

`\electricpotential{⟨magnitude⟩}`

Command for electric potential.

```
\electricpotential{1.5}
```

1.5 V

`\emf{⟨magnitude⟩}`

Command for emf.

```
\emf{1.5}
```

1.5 V

`\dielectricconstant{⟨magnitude⟩}`

Command for dielectric constant.

```
\dielectricconstant{1.5}
```

1.5

`\indexofrefraction{⟨magnitude⟩}`

Command for index of refraction.

```
\indexofrefraction{1.5}
```

1.5

`\relativepermittivity{⟨magnitude⟩}`

Command for relative permittivity.

```
\relativepermittivity{0.9}
```

0.9

`\relativepermeability{⟨magnitude⟩}`

Command for relative permeability.

`\relativepermeability{0.9}`	0.9

`\poyntingvector{⟨commadelimitedlistofcomps⟩}`

Command for Poynting vector. This is an alias for `\vectorenergyflux`.

`\poyntingvector{3,2,-1}`	$\langle 3, 2, -1\rangle$ W/m^2

`\energydensity{⟨magnitude⟩}`

Command for energy density.

`\energydensity{1.25}`	1.25 J/m^3

`\energyflux{⟨magnitude or vector⟩}`

Command for energy flux.

`\vectorenergyflux{⟨commadelimitedlistofcomps⟩}`

Command for vector energy flux.

```
\energyflux{4\timestento{26}}  \\
\energyflux{\mivector{3,2,-1}} \\
\vectorenergyflux{3,2,-1}
```

4×10^{26} W/m^2
$\langle 3, 2, -1\rangle$ W/m^2
$\langle 3, 2, -1\rangle$ W/m^2

`\momentumflux{⟨magnitude or vector⟩}`

Command for momentum flux.

`\vectormomentumflux{⟨commadelimitedlistofcomps⟩}`

Command for vector momentum flux.

```
\momentumflux{4\timestento{26}}  \\
\momentumflux{\mivector{3,2,-1}} \\
\vectormomentumflux{3,2,-1}
```

4×10^{26} N/m^2
$\langle 3, 2, -1\rangle$ N/m^2
$\langle 3, 2, -1\rangle$ N/m^2

`\electroncurrent{⟨magnitude⟩}`

Command for electron current.

`\electroncurrent{2\timestento{18}}`	2×10^{18} e/s

`\conventionalcurrent{⟨magnitude⟩}`

Command for conventional current.

`\conventionalcurrent{0.003}`	0.003 A

`\magneticdipolemoment{⟨magnitude or vector⟩}`

Command for magnetic dipole moment.

\vectormagneticdipolemoment{⟨*commadelimitedlistofcomps*⟩}

Command for vector magnetic dipole moment.

```
\magneticdipolemoment{1.25}               \\
\magneticdipolemoment{\mivector{3,2,-1}} \\
\vectormagneticdipolemoment{3,2,-1}
```

$1.25\ \mathrm{A \cdot m^2}$
$\langle 3, 2, -1 \rangle\ \mathrm{A \cdot m^2}$
$\langle 3, 2, -1 \rangle\ \mathrm{A \cdot m^2}$

\currentdensity{⟨*magnitude or vector*⟩}

Command for current density.

\vectorcurrentdensity{⟨*commadelimitedlistofcomps*⟩}

Command for vector current density.

```
\currentdensity{1.25}              \\
\currentdensity{\mivector{3,2,-1}} \\
\vectorcurrentdensity{3,2,-1}
```

$1.25\ \mathrm{A/m^2}$
$\langle 3, 2, -1 \rangle\ \mathrm{A/m^2}$
$\langle 3, 2, -1 \rangle\ \mathrm{A/m^2}$

\electricflux{⟨*magnitude*⟩}

Command for electric flux.

```
\electricflux{1.25}
```

$1.25\ \mathrm{N \cdot m^2/C}$

\magneticflux{⟨*magnitude*⟩}

Command for magnetic flux.

```
\magneticflux{1.25}
```

$1.25\ \mathrm{T \cdot m^2}$

\capacitance{⟨*magnitude*⟩}

Command for capacitance.

```
\capacitance{1.00}
```

$1.00\ \mathrm{C/V}$

\inductance{⟨*magnitude*⟩}

Command for inductance.

```
\inductance{1.00}
```

$1.00\ \mathrm{V \cdot s/A}$

\conductivity{⟨*magnitude*⟩}

Command for conductivity.

```
\conductivity{1.25}
```

$1.25\ \mathrm{(A/m^2)/(V/m)}$

\resistivity{⟨*magnitude*⟩}

Command for resistivity.

```
\resistivity{1.25}
```

$1.25\ \mathrm{(V/m)/(A/m^2)}$

\resistance{⟨*magnitude*⟩}

Command for resistance.

```
\resistance{1\timestento{6}}
```

$1 \times 10^6\ \Omega$

\conductance{⟨*magnitude*⟩}

Command for conductance.

```
\conductance{1\timestento{6}}
```

1×10^6 S

\magneticcharge{⟨*magnitude*⟩}

Command for magnetic charge, in case it actually exists.

```
\magneticcharge{1.25}
```

$1.25\ \mathrm{m} \cdot \mathrm{A}$

6.3.4 Further Words on Units

The form of a quantity's unit can be changed on the fly regardless of the global format determined by **baseunits** and **drvdunits**. One way, as illustrated in the table above, is to append `baseunit`, `drvdunit`, `tradunit` to the quantity's name, and this will override the global options for that instance.

A second way is to use the commands that change a quantity's unit on the fly.

\hereusebaseunit{⟨*magnitude*⟩}

Command for using base units in place.

```
\hereusebaseunit{\momentum{3}}
```

$3\ \mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$

\hereusedrvdunit{⟨*magnitude*⟩}

Command for using derived units in place.

```
\hereusedrvdunit{\momentum{3}}
```

$3\ \mathrm{N} \cdot \mathrm{s}$

\hereusetradunit{⟨*magnitude*⟩}

Command for using traditional units in place.

```
\hereusetradunit{\momentum{3}}
```

$3\ \mathrm{kg} \cdot \mathrm{m/s}$

A third way is to use the environments that change a quantity's unit for the duration of the environment.

\begin{usebaseunit}
⟨*environment content*⟩
\end{usebaseunit}

Environment for using base units.

```
\begin{usebaseunit}
  \momentum{3}
\end{usebaseunit}
```

$3\ \mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$

`\begin{usedrvdunit}`
⟨*environment content*⟩
`\end{usedrvdunit}`

Environment for using derived units.

```
\begin{usedrvdunit}
  \momentum{3}
\end{usedrvdunit}
```

$3\ \mathrm{N} \cdot \mathrm{s}$

`\begin{usetradunit}`
⟨*environment content*⟩
`\end{usetradunit}`

Environment for using traditional units.

```
\begin{usetradunit}
  \momentum{3}
\end{usetradunit}
```

$3\ \mathrm{kg} \cdot \mathrm{m/s}$

A fourth way is to use the three global switches that perpetually change the default unit. **It's important to remember that these switches override the global options for the rest of the document or until overridden by one of the other two switches.**

`\perpusebaseunit`

Command for perpetually using base units.

`\perpusedrvdunit`

Command for perpetually using derived units.

`\perpusetradunit`

Command for perpetually using traditional units.

6.3.5 All Predefined Quantities

`\chkquantity{`⟨*quantityname*⟩`}`

Diagnostic command for all of the units for a defined physical quantity. See table below.

Here are all the predefined quantities and their units.

name	baseunit	drvdunit	tradunit
`\displacement`	m	m	m

name	baseunit	drvdunit	tradunit
`\mass`	kg	kg	kg

name	baseunit	drvdunit	tradunit
`\duration`	s	s	s
name	baseunit	drvdunit	tradunit
`\current`	A	A	A
name	baseunit	drvdunit	tradunit
`\temperature`	K	K	K
name	baseunit	drvdunit	tradunit
`\amount`	mol	mol	mol
name	baseunit	drvdunit	tradunit
`\luminous`	cd	cd	cd
name	baseunit	drvdunit	tradunit
`\infeetpersecond`			
name	baseunit	drvdunit	tradunit
`\infeet`			
name	baseunit	drvdunit	tradunit
`\planeangle`	$\mathrm{m} \cdot \mathrm{m}^{-1}$	rad	rad
name	baseunit	drvdunit	tradunit
`\solidangle`	$\mathrm{m}^{2} \cdot \mathrm{m}^{-2}$	sr	sr
name	baseunit	drvdunit	tradunit
`\velocity`	$\mathrm{m} \cdot \mathrm{s}^{-1}$	$\mathrm{m} \cdot \mathrm{s}^{-1}$	m/s
name	baseunit	drvdunit	tradunit
`\acceleration`	$\mathrm{m} \cdot \mathrm{s}^{-2}$	N/kg	$\mathrm{m/s}^{2}$
name	baseunit	drvdunit	tradunit
`\gravitationalfield`	$\mathrm{m} \cdot \mathrm{s}^{-2}$	N/kg	N/kg
name	baseunit	drvdunit	tradunit
`\gravitationalpotential`	$\mathrm{m}^{2} \cdot \mathrm{s}^{-2}$	J/kg	J/kg
name	baseunit	drvdunit	tradunit
`\momentum`	$\mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$	$\mathrm{N} \cdot \mathrm{s}$	$\mathrm{kg} \cdot \mathrm{m/s}$
name	baseunit	drvdunit	tradunit
`\impulse`	$\mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$	$\mathrm{N} \cdot \mathrm{s}$	$\mathrm{N} \cdot \mathrm{s}$
name	baseunit	drvdunit	tradunit
`\force`	$\mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-2}$	N	N
name	baseunit	drvdunit	tradunit
`\springstiffness`	$\mathrm{kg} \cdot \mathrm{s}^{-2}$	N/m	N/m
name	baseunit	drvdunit	tradunit
`\springstretch`	m	m	m

name	baseunit	drvdunit	tradunit
`\area`	m^2	m^2	m^2
name	baseunit	drvdunit	tradunit
`\volume`	m^3	m^3	m^3
name	baseunit	drvdunit	tradunit
`\linearmassdensity`	$\mathrm{m}^{-1} \cdot \mathrm{kg}$	$\mathrm{kg/m}$	$\mathrm{kg/m}$
name	baseunit	drvdunit	tradunit
`\areamassdensity`	$\mathrm{m}^{-2} \cdot \mathrm{kg}$	$\mathrm{kg/m}^2$	$\mathrm{kg/m}^2$
name	baseunit	drvdunit	tradunit
`\volumemassdensity`	$\mathrm{m}^{-3} \cdot \mathrm{kg}$	$\mathrm{kg/m}^3$	$\mathrm{kg/m}^3$
name	baseunit	drvdunit	tradunit
`\youngsmodulus`	$\mathrm{m}^{-1} \cdot \mathrm{kg} \cdot \mathrm{s}^{-2}$	$\mathrm{N/m}^2$	Pa
name	baseunit	drvdunit	tradunit
`\stress`	$\mathrm{m}^{-1} \cdot \mathrm{kg} \cdot \mathrm{s}^{-2}$	$\mathrm{N/m}^2$	Pa
name	baseunit	drvdunit	tradunit
`\pressure`	$\mathrm{m}^{-1} \cdot \mathrm{kg} \cdot \mathrm{s}^{-2}$	$\mathrm{N/m}^2$	Pa
name	baseunit	drvdunit	tradunit
`\strain`			
name	baseunit	drvdunit	tradunit
`\work`	$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-2}$	$\mathrm{N} \cdot \mathrm{m}$	J
name	baseunit	drvdunit	tradunit
`\energy`	$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-2}$	$\mathrm{N} \cdot \mathrm{m}$	J
name	baseunit	drvdunit	tradunit
`\power`	$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-3}$	$\mathrm{J/s}$	W
name	baseunit	drvdunit	tradunit
`\specificheatcapacity`	$\mathrm{J/K} \cdot \mathrm{kg}$	$\mathrm{J/K} \cdot \mathrm{kg}$	$\mathrm{J/K} \cdot \mathrm{kg}$
name	baseunit	drvdunit	tradunit
`\angularvelocity`	$\mathrm{rad} \cdot \mathrm{s}^{-1}$	$\mathrm{rad/s}$	$\mathrm{rad/s}$
name	baseunit	drvdunit	tradunit
`\angularacceleration`	$\mathrm{rad} \cdot \mathrm{s}^{-2}$	$\mathrm{rad/s}^2$	$\mathrm{rad/s}^2$
name	baseunit	drvdunit	tradunit
`\momentofinertia`	$\mathrm{m}^2 \cdot \mathrm{kg}$	$\mathrm{m} \cdot \mathrm{kg}^2$	$\mathrm{J} \cdot \mathrm{s}^2$
name	baseunit	drvdunit	tradunit
`\angularmomentum`	$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$	$\mathrm{N} \cdot \mathrm{m} \cdot \mathrm{s}$	$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$
name	baseunit	drvdunit	tradunit
`\angularimpulse`	$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$	$\mathrm{N} \cdot \mathrm{m} \cdot \mathrm{s}$	$\mathrm{J} \cdot \mathrm{s}$

name	baseunit	drvdunit	tradunit
`\torque`	$\mathrm{m^2 \cdot kg \cdot s^{-2}}$	$\mathrm{N \cdot m}$	J
name	baseunit	drvdunit	tradunit
`\entropy`	$\mathrm{m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}}$	$\mathrm{J/K}$	$\mathrm{J/K}$
name	baseunit	drvdunit	tradunit
`\wavelength`	m	m	m
name	baseunit	drvdunit	tradunit
`\wavenumber`	$\mathrm{m^{-1}}$	$\mathrm{/m}$	$\mathrm{/m}$
name	baseunit	drvdunit	tradunit
`\frequency`	$\mathrm{s^{-1}}$	Hz	Hz
name	baseunit	drvdunit	tradunit
`\angularfrequency`	$\mathrm{rad \cdot s^{-1}}$	$\mathrm{rad/s}$	$\mathrm{rad/s}$
name	baseunit	drvdunit	tradunit
`\charge`	$\mathrm{A \cdot s}$	C	C
name	baseunit	drvdunit	tradunit
`\permittivity`	$\mathrm{m^{-3} \cdot kg^{-1} \cdot s^{-4} \cdot A^2}$	$\mathrm{F/m}$	$\mathrm{C^2/N \cdot m^2}$
name	baseunit	drvdunit	tradunit
`\permeability`	$\mathrm{m \cdot kg \cdot s^{-2} \cdot A^{-2}}$	$\mathrm{H/m}$	$\mathrm{T \cdot m/A}$
name	baseunit	drvdunit	tradunit
`\linearchargedensity`	$\mathrm{m^{-1} \cdot s \cdot A}$	$\mathrm{C/m}$	$\mathrm{C/m}$
name	baseunit	drvdunit	tradunit
`\areachargedensity`	$\mathrm{m^{-2} \cdot s \cdot A}$	$\mathrm{C/m^2}$	$\mathrm{C/m^2}$
name	baseunit	drvdunit	tradunit
`\volumechargedensity`	$\mathrm{m^{-3} \cdot s \cdot A}$	$\mathrm{C/m^3}$	$\mathrm{C/m^3}$
name	baseunit	drvdunit	tradunit
`\electricfield`	$\mathrm{m \cdot kg \cdot s^{-3} \cdot A^{-1}}$	$\mathrm{V/m}$	$\mathrm{N/C}$
name	baseunit	drvdunit	tradunit
`\electricdipolemoment`	$\mathrm{m \cdot s \cdot A}$	$\mathrm{C \cdot m}$	$\mathrm{C \cdot m}$
name	baseunit	drvdunit	tradunit
`\electricflux`	$\mathrm{m^3 \cdot kg \cdot s^{-3} \cdot A^{-1}}$	$\mathrm{V \cdot m}$	$\mathrm{N \cdot m^2/C}$
name	baseunit	drvdunit	tradunit
`\magneticfield`	$\mathrm{kg \cdot s^{-2} \cdot A^{-1}}$	T	$\mathrm{N/C \cdot (m/s)}$
name	baseunit	drvdunit	tradunit
`\magneticflux`	$\mathrm{m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}}$	$\mathrm{V \cdot s}$	$\mathrm{T \cdot m^2}$
name	baseunit	drvdunit	tradunit
`\cmagneticfield`	$\mathrm{m \cdot kg \cdot s^{-3} \cdot A^{-1}}$	$\mathrm{V/m}$	$\mathrm{N/C}$

name	baseunit	drvdunit	tradunit
`\mobility`	$\mathrm{m^2 \cdot kg \cdot s^{-4} \cdot A^{-1}}$	$\mathrm{m^2/V \cdot s}$	$\mathrm{(m/s)/(N/C)}$
name	baseunit	drvdunit	tradunit
`\numberdensity`	$\mathrm{m^{-3}}$	$\mathrm{/m^3}$	$\mathrm{/m^3}$
name	baseunit	drvdunit	tradunit
`\polarizability`	$\mathrm{kg^{-1} \cdot s^4 \cdot A^2}$	$\mathrm{C \cdot m^2/V}$	$\mathrm{C \cdot m/(N/C)}$
name	baseunit	drvdunit	tradunit
`\electricpotential`	$\mathrm{m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}}$	$\mathrm{J/C}$	V
name	baseunit	drvdunit	tradunit
`\emf`	$\mathrm{m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}}$	$\mathrm{J/C}$	V
name	baseunit	drvdunit	tradunit
`\dielectricconstant`			
name	baseunit	drvdunit	tradunit
`\indexofrefraction`			
name	baseunit	drvdunit	tradunit
`\relativepermittivity`			
name	baseunit	drvdunit	tradunit
`\relativepermeability`			
name	baseunit	drvdunit	tradunit
`\energydensity`	$\mathrm{m^{-1} \cdot kg \cdot s^{-2}}$	$\mathrm{J/m^3}$	$\mathrm{J/m^3}$
name	baseunit	drvdunit	tradunit
`\momentumflux`	$\mathrm{m^{-1} \cdot kg \cdot s^{-2}}$	$\mathrm{N/m^2}$	$\mathrm{N/m^2}$
name	baseunit	drvdunit	tradunit
`\energyflux`	$\mathrm{kg \cdot s^{-3}}$	$\mathrm{W/m^2}$	$\mathrm{W/m^2}$
name	baseunit	drvdunit	tradunit
`\electroncurrent`	$\mathrm{s^{-1}}$	$\mathrm{e/s}$	$\mathrm{e/s}$
name	baseunit	drvdunit	tradunit
`\conventionalcurrent`	A	$\mathrm{C/s}$	A
name	baseunit	drvdunit	tradunit
`\magneticdipolemoment`	$\mathrm{m^2 \cdot A}$	$\mathrm{J/T}$	$\mathrm{A \cdot m^2}$
name	baseunit	drvdunit	tradunit
`\currentdensity`	$\mathrm{m^{-2} \cdot A}$	$\mathrm{C \cdot s/m^2}$	$\mathrm{A/m^2}$
name	baseunit	drvdunit	tradunit
`\capacitance`	$\mathrm{m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2}$	F	$\mathrm{C/V}$
name	baseunit	drvdunit	tradunit
`\inductance`	$\mathrm{m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}}$	H	$\mathrm{V \cdot s/A}$

name	baseunit	drvdunit	tradunit
`\conductivity`	$m^{-3} \cdot kg^{-1} \cdot s^3 \cdot A^2$	S/m	$(A/m^2)/(V/m)$
name	baseunit	drvdunit	tradunit
`\resistivity`	$m^3 \cdot kg \cdot s^{-3} \cdot A^{-2}$	$\Omega \cdot m$	$(V/m)/(A/m^2)$
name	baseunit	drvdunit	tradunit
`\resistance`	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$	V/A	Ω
name	baseunit	drvdunit	tradunit
`\conductance`	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$	A/V	S
name	baseunit	drvdunit	tradunit
`\magneticcharge`	$m \cdot A$	$m \cdot A$	$m \cdot A$

6.4 When to Write Radians

A word of clarification is in order for plane angles, solid angles, and other angular quantities. There is the perpetually confusing issue of when to explicitly write radians as a unit and when to omit it. The answer is that if the numerical value of a quantity explicitly depends on the angular unit, then the unit should be written. An example would be angular displacement; the numerical value obviously depends on the unit used. If the numerical value of a quantity does not explicitly depend on the angular unit, then the unit is omitted. An example would be the linear, or translational, velocity or a particle in circular motion. This quantity doesn't explicitly depends on the angular unit, so the angular unit is not written.

Torque, angular impulse, and angular momentum present special a special problem in that it is sometimes pedagogically helpful to explicitly include angular units in their operational definitions. While this may not be in strict accordance with SI standards, loading `mandi` with the **useradians** option includes angular units in these quantities. See Loading the Package for details.

6.5 Physical Constants

6.5.1 Defining Physical Constants

mandi has many predefined physical constants. This section explains how to use them.

\newphysicsconstant{⟨*name*⟩}{⟨*symbol*⟩}{\mi@p{⟨*approx*⟩}{⟨*precise*⟩}}{⟨baseunits⟩}
[⟨drvdunits⟩][⟨tradunits⟩]

Defines a new physical constant with a name, a symbol, approximate and precise numerical values, required base units, optional derived units, and optional traditional units. The \mi@p command is defined internally and is not meant to be otherwise used.

```
Here is how \planck (Planck's constant) is defined internally, showing
each part of the definition on a separate line.
\newphysicsconstant{planck}
  {\ensuremath{h}}
  {\mi@p{6.6}{6.626070040}\timestento{-34}}
  {\m\squared\usk\kg\usk\reciprocal\s}
  [\J\usk\s]
  [\J\usk\s]
```

Using this command causes several things to happen.

- A command \name is created and contains the constant and units typeset according to the options given when mandi was loaded.
- A command \namemathsymbol is created that expresses **only** the constant's mathematical symbol.
- A command \namevalue is created that expresses **only** the constant's approximate or precise numerical value. Note that both values must be present when the constant is defined. By default, precise values are always used but this can be changed when mandi is loaded. Note how the values are specified in the definition of the constant.
- A command \namebaseunit is created that expresses the constant and its units in *baseunits* form.
- A command \namedrvdunit is created that expresses the constant and its units in *drvdunits* form.
- A command \nametradunit is created that expresses the constant and its units in *tradunits* form.
- A command \nameonlybaseunit is created that expresses **only** the constant's units in *baseunits* form.
- A command \nameonlydrvdunit is created that expresses **only** the constant's units in *drvdunits* form.
- A command \nameonlytradunit is created that expresses **only** the constant's units in *tradunits* form.

None of these commands takes any arguments.

6.5.2 Predefined Physical Constants

In this section, precise values of constants are used. Approximate values are available as an option when the package is loaded. Precise values are sourced as accurately as possible, beginning with Wikipedia and following sources therein. I tried to use the most recent NIST or similarly authoritative values. In no case did I make up any values.

`\oofpez`

Coulomb constant.

```
\(\oofpezmathsymbol \approx \oofpez\)
```

$\frac{1}{4\pi\epsilon_0} \approx 8.9875517873681764 \times 10^{9}\ \mathrm{N \cdot m^2/C^2}$

`\oofpezcs`

Alternate form of Coulomb constant.

```
\(\oofpezcsmathsymbol \approx \oofpezcs\)
```

$\frac{1}{4\pi\epsilon_0 c^2} \approx 10^{-7}\ \mathrm{N \cdot s^2/C^2}$

`\vacuumpermittivity`

Vacuum permittivity.

```
\(\vacuumpermittivitymathsymbol \approx \vacuumpermittivity\)
```

$\epsilon_0 \approx 8.854187817 \times 10^{-12}\ \mathrm{C^2/N \cdot m^2}$

`\mzofp`

Biot-Savart constant.

```
\(\mzofpmathsymbol \approx \mzofp\)
```

$\frac{\mu_0}{4\pi} \approx 10^{-7}\ \mathrm{T \cdot m/A}$

`\vacuumpermeability`

Vacuum permeability.

```
\(\vacuumpermeabilitymathsymbol \approx \vacuumpermeability\)
```

$\mu_0 \approx 4\pi \times 10^{-7}\ \mathrm{T \cdot m/A}$

`\boltzmann`

Boltzmann constant.

```
\(\boltzmannmathsymbol \approx \boltzmann\)
```

$k_B \approx 1.38064852 \times 10^{-23}$ J/K

\boltzmannineV

Alternate form of Boltlzmann constant.

```
\(\boltzmannineVmathsymbol \approx \boltzmannineV\)
```

$k_B \approx 8.6173303 \times 10^{-5}$ eV/K

\stefan

Stefan-Boltzmann constant.

```
\(\stefanboltzmannmathsymbol \approx \stefanboltzmann\)
```

$\sigma \approx 5.670367 \times 10^{-8}$ W/m$^2 \cdot$ K^4

\planck

Planck constant.

```
\(\planckmathsymbol \approx \planck\)
```

$h \approx 6.626070040 \times 10^{-34}$ J $\cdot$ s

\planckineV

Alternate form of Planck constant.

```
\(\planckmathsymbol \approx \planckineV\)
```

$h \approx 4.135667662 \times 10^{-15}$ eV $\cdot$ s

\planckbar

Reduced Planck constant (Dirac constant).

```
\(\planckbarmathsymbol \approx \planckbar\)
```

$\hbar \approx 1.054571800 \times 10^{-34}$ J $\cdot$ s

\planckbarineV

Alternate form of reduced Planck constant (Dirac constant).

```
\(\planckbarmathsymbol \approx \planckbarineV\)
```

$\hbar \approx 6.582119514 \times 10^{-16}$ eV $\cdot$ s

`\planckc`

Planck constant times light speed.

```
\(\planckcmathsymbol \approx \planckc\)
```

$hc \approx 1.98644568 \times 10^{-25}\ \mathrm{J \cdot m}$

`\planckcineV`

Alternate form of Planck constant times light speed.

```
\(\planckcineVmathsymbol \approx \planckcineV\)
```

$hc \approx 1.23984193 \times 10^{3}\ \mathrm{eV \cdot nm}$

`\rydberg`

Rydberg constant.

```
\(\rydbergmathsymbol \approx \rydberg\)
```

$R_\infty \approx 1.0973731568508 \times 10^{7}\ \mathrm{m}^{-1}$

`\bohrradius`

Bohr radius.

```
\(\bohrradiusmathsymbol \approx \bohrradius\)
```

$a_0 \approx 5.2917721067 \times 10^{-11}\ \mathrm{m}$

`\finestructure`

Fine structure constant.

```
\(\finestructuremathsymbol \approx \finestructure\)
```

$\alpha \approx 7.2973525664 \times 10^{-3}$

`\avogadro`

Avogadro constant.

```
\(\avogadromathsymbol \approx \avogadro\)
```

$N_A \approx 6.022140857 \times 10^{23}\ \mathrm{mol}^{-1}$

`\universalgrav`

Universal gravitational constant.

```
\(\universalgravmathsymbol \approx \universalgrav\)
```

$G \approx 6.67408 \times 10^{-11}\ \mathrm{N \cdot m^2/kg^2}$

`\surfacegravfield`

Earth's surface gravitational field strength.

```
\(\surfacegravfieldmathsymbol \approx \surfacegravfield\)
```

$g \approx 9.807\ \mathrm{N/kg}$

`\clight`

Magnitude of light's velocity (photon constant).

```
\(\clightmathsymbol \approx \clight\)
```

$c \approx 2.99792458 \times 10^8\ \mathrm{m/s}$

`\clightinfeet`

Alternate of magnitude of light's velocity (photon constant).

```
\(\clightinfeetmathsymbol \approx \clightinfeet\)
```

$c \approx 0.983571\ \mathrm{ft/ns}$

`\Ratom`

Approximate atomic radius.

```
\(\Ratommathsymbol \approx \Ratom\)
```

$r_{\mathrm{atom}} \approx 10^{-10}\ \mathrm{m}$

`\Mproton`

Proton mass.

```
\(\Mprotonmathsymbol \approx \Mproton\)
```

$m_p \approx 1.672621898 \times 10^{-27}\ \mathrm{kg}$

`\Mneutron`

Neutron mass.

```
\(\Mneutronmathsymbol \approx \Mneutron\)
```

$m_n \approx 1.674927471 \times 10^{-27}\ \mathrm{kg}$

`\Mhydrogen`

Hydrogen atom mass.

```
\(\Mhydrogenmathsymbol \approx \Mhydrogen\)
```

$m_H \approx 1.6737236 \times 10^{-27}$ kg

`\Melectron`

Electron mass.

```
\(\Melectronmathsymbol \approx \Melectron\)
```

$m_e \approx 9.10938356 \times 10^{-31}$ kg

`\echarge`

Elementary charge quantum.

```
\(\echargemathsymbol \approx \echarge\)
```

$e \approx 1.6021766208 \times 10^{-19}$ C

`\Qelectron`

Electron charge.

`\qelectron`

Alias for `\Qelectron`.

```
\(\Qelectronmathsymbol \approx \Qelectron\)
```

$Q_e \approx -1.6021766208 \times 10^{-19}$ C

`\Qproton`

Proton charge.

`\qproton`

Alias for `\Qproton`.

```
\(\Qprotonmathsymbol \approx \Qproton\)
```

$Q_p \approx +1.6021766208 \times 10^{-19}$ C

`\MEarth`

Earth's mass.

```
\(\MEarthmathsymbol \approx \MEarth\)
```

$M_{\text{Earth}} \approx 5.97237 \times 10^{24}$ kg

`\MMoon`

Moon's mass.

```
\(\MMoonmathsymbol \approx \MMoon\)
```

$M_{\text{Moon}} \approx 7.342 \times 10^{22}$ kg

`\MSun`

Sun's mass.

```
\(\MSunmathsymbol \approx \MSun\)
```

$M_{\text{Sun}} \approx 1.98855 \times 10^{30}$ kg

`\REarth`

Earth's radius.

```
\(\REarthmathsymbol \approx \REarth\)
```

$R_{\text{Earth}} \approx 6.371 \times 10^{6}$ m

`\RMoon`

Moon's radius.

```
\(\RMoonmathsymbol \approx \RMoon\)
```

$R_{\text{Moon}} \approx 1.7371 \times 10^{6}$ m

`\RSun`

Sun's radius.

```
\(\RSunmathsymbol \approx \RSun\)
```

$R_{\text{Sun}} \approx 6.957 \times 10^{8}$ m

`\ESdist`

Earth-Sun distance.

`\SEdist`

Alias for `\ESdist`.

```
\(\ESdistmathsymbol \approx \SEdist\)
```

$\|\vec{r}_{\text{ES}}\| \approx 1.496 \times 10^{11}$ m

`\EMdist`

Earth-Moon distance.

`\MEdist`

Alias for `\EMdist`.

```
\(\EMdistmathsymbol \approx \EMdist\)
```

$\|\vec{r}_{\text{EM}}\| \approx 3.81550 \times 10^{8}$ m

6.5.3 All Predefined Constants

`\chkconstant{`⟨*constantname*⟩`}`

Diagnostic command for the symbol, value (either approximate or precise depending on how the package was loaded), and units for a defined physical constant. See table below.

Here are all the predefined constants and their units.

name	symbol	value
`\oofpez`	$\frac{1}{4\pi\epsilon_0}$	$8.9875517873681764 \times 10^{9}$
baseunit	drvdunit	tradunit
$\mathrm{m}^3 \cdot \mathrm{kg} \cdot \mathrm{s}^{-4} \cdot \mathrm{A}^{-2}$	m/F	$\mathrm{N} \cdot \mathrm{m}^2/\mathrm{C}^2$
name	symbol	value
`\oofpezcs`	$\frac{1}{4\pi\epsilon_0 c^2}$	10^{-7}
baseunit	drvdunit	tradunit
$\mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-2} \cdot \mathrm{A}^{-2}$	$\mathrm{T} \cdot \mathrm{m}^2$	$\mathrm{N} \cdot \mathrm{s}^2/\mathrm{C}^2$
name	symbol	value
`\vacuumpermittivity`	ϵ_0	$8.854187817 \times 10^{-12}$
baseunit	drvdunit	tradunit
$\mathrm{m}^{-3} \cdot \mathrm{kg}^{-1} \cdot \mathrm{s}^4 \cdot \mathrm{A}^2$	F/m	$\mathrm{C}^2/\mathrm{N} \cdot \mathrm{m}^2$
name	symbol	value
`\mzofp`	$\frac{\mu_0}{4\pi}$	10^{-7}
baseunit	drvdunit	tradunit
$\mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-2} \cdot \mathrm{A}^{-2}$	H/m	$\mathrm{T} \cdot \mathrm{m}/\mathrm{A}$
name	symbol	value
`\vacuumpermeability`	μ_0	$4\pi \times 10^{-7}$
baseunit	drvdunit	tradunit
$\mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-2} \cdot \mathrm{A}^{-2}$	H/m	$\mathrm{T} \cdot \mathrm{m}/\mathrm{A}$
name	symbol	value
`\boltzmann`	k_B	$1.38064852 \times 10^{-23}$
baseunit	drvdunit	tradunit
$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-2} \cdot \mathrm{K}^{-1}$	J/K	J/K

name	symbol	value
`\boltzmannineV`	k_B	8.6173303×10^{-5}
baseunit	drvdunit	tradunit
$\mathrm{eV} \cdot \mathrm{K}^{-1}$	eV/K	eV/K

name	symbol	value
`\stefanboltzmann`	σ	5.670367×10^{-8}
baseunit	drvdunit	tradunit
$\mathrm{kg} \cdot \mathrm{s}^{-3} \cdot \mathrm{K}^{-4}$	$\mathrm{W}/\mathrm{m}^2 \cdot \mathrm{K}^4$	$\mathrm{W}/\mathrm{m}^2 \cdot \mathrm{K}^4$

name	symbol	value
`\planck`	h	$6.626070040 \times 10^{-34}$
baseunit	drvdunit	tradunit
$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$	$\mathrm{J} \cdot \mathrm{s}$	$\mathrm{J} \cdot \mathrm{s}$

name	symbol	value
`\planckineV`	h	$4.135667662 \times 10^{-15}$
baseunit	drvdunit	tradunit
$\mathrm{eV} \cdot \mathrm{s}$	$\mathrm{eV} \cdot \mathrm{s}$	$\mathrm{eV} \cdot \mathrm{s}$

name	symbol	value
`\planckbar`	$\hbar$	$1.054571800 \times 10^{-34}$
baseunit	drvdunit	tradunit
$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$	$\mathrm{J} \cdot \mathrm{s}$	$\mathrm{J} \cdot \mathrm{s}$

name	symbol	value
`\planckbarineV`	$\hbar$	$6.582119514 \times 10^{-16}$
baseunit	drvdunit	tradunit
$\mathrm{eV} \cdot \mathrm{s}$	$\mathrm{eV} \cdot \mathrm{s}$	$\mathrm{eV} \cdot \mathrm{s}$

name	symbol	value
`\planckc`	hc	$1.98644568 \times 10^{-25}$
baseunit	drvdunit	tradunit
$\mathrm{m}^3 \cdot \mathrm{kg} \cdot \mathrm{s}^{-2}$	$\mathrm{J} \cdot \mathrm{m}$	$\mathrm{J} \cdot \mathrm{m}$

name	symbol	value
`\planckcineV`	hc	1.23984193×10^{3}
baseunit	drvdunit	tradunit
$\mathrm{eV} \cdot \mathrm{nm}$	$\mathrm{eV} \cdot \mathrm{nm}$	$\mathrm{eV} \cdot \mathrm{nm}$

name	symbol	value
`\rydberg`	R_∞	$1.0973731568508 \times 10^{7}$
baseunit	drvdunit	tradunit
m^{-1}	m^{-1}	m^{-1}

name	symbol	value
`\bohrradius`	a_0	$5.2917721067 \times 10^{-11}$
baseunit	drvdunit	tradunit
m	m	m

name	symbol	value
`\finestructure`	α	$7.2973525664 \times 10^{-3}$
baseunit	drvdunit	tradunit

name	symbol	value
`\avogadro`	N_A	$6.022140857 \times 10^{23}$
baseunit	drvdunit	tradunit
mol^{-1}	mol^{-1}	mol^{-1}

name	symbol	value
`\universalgrav`	G	6.67408×10^{-11}
baseunit	drvdunit	tradunit
$\mathrm{m}^3 \cdot \mathrm{kg}^{-1} \cdot \mathrm{s}^{-2}$	$\mathrm{J} \cdot \mathrm{m/kg}^2$	$\mathrm{N} \cdot \mathrm{m}^2/\mathrm{kg}^2$

name	symbol	value
`\surfacegravfield`	g	9.807
baseunit	drvdunit	tradunit
$\mathrm{m} \cdot \mathrm{s}^{-2}$	N/kg	N/kg

name	symbol	value
`\clight`	c	2.99792458×10^{8}
baseunit	drvdunit	tradunit
$\mathrm{m} \cdot \mathrm{s}^{-1}$	m/s	m/s

name	symbol	value
`\clightinfeet`	c	0.983571
baseunit	drvdunit	tradunit
$\mathrm{ft} \cdot \mathrm{ns}^{-1}$	ft/ns	ft/ns

name	symbol	value
`\Ratom`	r_{atom}	10^{-10}
baseunit	drvdunit	tradunit
m	m	m

name	symbol	value
`\Mproton`	m_p	$1.672621898 \times 10^{-27}$
baseunit	drvdunit	tradunit
kg	kg	kg

name	symbol	value
`\Mneutron`	m_n	$1.674927471 \times 10^{-27}$
baseunit	drvdunit	tradunit
kg	kg	kg

name	symbol	value
`\Mhydrogen`	m_H	$1.6737236 \times 10^{-27}$
baseunit	drvdunit	tradunit
kg	kg	kg

name	symbol	value
`\Melectron`	m_e	$9.10938356 \times 10^{-31}$
baseunit	drvdunit	tradunit
kg	kg	kg

name	symbol	value
`\echarge`	e	$1.6021766208 \times 10^{-19}$
baseunit	drvdunit	tradunit
$\mathrm{A \cdot s}$	C	C

name	symbol	value
`\Qelectron`	Q_e	$-1.6021766208 \times 10^{-19}$
baseunit	drvdunit	tradunit
$\mathrm{A \cdot s}$	C	C

name	symbol	value
`\qelectron`	q_e	$-1.6021766208 \times 10^{-19}$
baseunit	drvdunit	tradunit
$\mathrm{A \cdot s}$	C	C

name	symbol	value
`\Qproton`	Q_p	$+1.6021766208 \times 10^{-19}$
baseunit	drvdunit	tradunit
$\mathrm{A \cdot s}$	C	C

name	symbol	value
`\qproton`	q_p	$+1.6021766208 \times 10^{-19}$
baseunit	drvdunit	tradunit
$\mathrm{A \cdot s}$	C	C

name	symbol	value
`\MEarth`	M_{Earth}	5.97237×10^{24}
baseunit	drvdunit	tradunit
kg	kg	kg

name	symbol	value
`\MMoon`	M_{Moon}	7.342×10^{22}
baseunit	drvdunit	tradunit
kg	kg	kg

name	symbol	value
`\MSun`	M_{Sun}	1.98855×10^{30}
baseunit	drvdunit	tradunit
kg	kg	kg

name	symbol	value
`\REarth`	R_{Earth}	6.371×10^{6}
baseunit	drvdunit	tradunit
m	m	m

name	symbol	value
\RMoon	R_{Moon}	1.7371×10^{6}
baseunit	drvdunit	tradunit
m	m	m

name	symbol	value
\RSun	R_{Sun}	6.957×10^{8}
baseunit	drvdunit	tradunit
m	m	m

name	symbol	value
\ESdist	$\lVert \vec{r}_{\mathrm{ES}} \rVert$	1.496×10^{11}
baseunit	drvdunit	tradunit
m	m	m

name	symbol	value
\EMdist	$\lVert \vec{r}_{\mathrm{EM}} \rVert$	3.81550×10^{8}
baseunit	drvdunit	tradunit
m	m	m

name	symbol	value
\LSun	L_{Sun}	3.8460×10^{26}
baseunit	drvdunit	tradunit
$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-3}$	W	J/s

name	symbol	value
\TSun	T_{Sun}	5778
baseunit	drvdunit	tradunit
K	K	K

name	symbol	value
\MagSun	M_{Sun}	+4.83
baseunit	drvdunit	tradunit

name	symbol	value
\magSun	m_{Sun}	−26.74
baseunit	drvdunit	tradunit

6.6 Astronomical Constants and Quantities

\LSun

Sun's luminosity.

```
\(\LSunmathsymbol \approx \LSun\)
```

$L_{\mathrm{Sun}} \approx 3.8460 \times 10^{26}$ J/s

\TSun

Sun's effective temperature.

`\(\TSunmathsymbol \approx \TSun\)`	$T_{\mathrm{Sun}} \approx 5778$ K

`\MagSun`

Sun's absolute magnitude.

`\(\MagSunmathsymbol \approx \MagSun\)`	$M_{\mathrm{Sun}} \approx +4.83$

`\magSun`

Sun's apparent magnitude.

`\(\magSunmathsymbol \approx \magSun\)`	$m_{\mathrm{Sun}} \approx -26.74$

`\Lstar[`⟨*object*⟩`]`

Symbol for stellar luminosity.

`\Lstar or \Lstar[Sirius]`	$L_\star$ or L_{Sirius}

`\Lsolar`

Symbol for solar luminosity as a unit. Really just an alias for `\Lstar[\(\odot\)]`.

`\Lsolar`	$L_\odot$

`\Tstar[`⟨*object*⟩`]`

Symbol for stellar temperature.

`\Tstar or \Tstar[Sirius]`	$T_\star$ or T_{Sirius}

`\Tsolar`

Symbol for solar temperature as a unit. Really just an alias for `\Tstar[\(\odot\)]`.

`\Tsolar`	$T_\odot$

`\Rstar[`⟨*object*⟩`]`

Symbol for stellar radius.

`\Rstar or \Rstar[Sirius]`	$R_\star$ or R_{Sirius}

`\Rsolar`

Symbol for solar radius as a unit. Really just an alias for `\Rstar[\(\odot\)]`.

`\Rsolar`	$R_\odot$

`\Mstar[`⟨*object*⟩`]`

Symbol for stellar mass.

`\Mstar or \Mstar[Sirius]`	$M_\star$ or M_{Sirius}

`\Msolar`

Symbol for solar mass as a unit. Really just an alias for `\Mstar[\(\odot\)]`.

`\Msolar`	$M_\odot$

`\Fstar[⟨object⟩]`

Symbol for stellar flux.

`\fstar`

Alias for `\Fstar`.

`\Fstar or \Fstar[Sirius]`	$F_\star$ or F_{Sirius}

`\Fsolar`

Symbol for solar flux as a unit. Really just an alias for `\Fstar[\(\odot\)]`.

`\fsolar`

Alias for `\fsolar`.

`\Fsolar`	$F_\odot$

`\Magstar[⟨object⟩]`

Symbol for stellar absolute magnitude.

`\Magstar or \Magstar[Sirius]`	$M_\star$ or M_{Sirius}

`\Magsolar`

Symbol for solar absolute magnitude as a unit. Really just an alias for `\Magstar[\(\odot\)]`.

`\Magsolar`	$M_\odot$

`\magstar[⟨object⟩]`

Symbol for stellar apparent magnitude.

`\magstar or \magstar[Sirius]`	$m_\star$ or m_{Sirius}

`\magsolar`

Symbol for solar apparent magnitude as a unit. Really just an alias for `\magstar[\(\odot\)]`.

`\magsolar`	$m_\odot$

`\Dstar[⟨object⟩]`

Symbol for stellar distance.

\dstar

Alias for \Dstar that uses a lower case d.

`\Dstar or \Dstar[Sirius]`	$D_\star$ or D_{Sirius}

\Dsolar

Symbol for solar distance as a unit. Really just an alias for `\Dstar[\(\odot\)]`.

\dsolar

Alias for \Dsolar that uses a lower case d.

`\Dsolar`	$D_\odot$

6.7 Symbolic Expressions with Vectors

6.7.1 Basic Vectors

\vect{⟨*kernel*⟩}

Symbol for a vector quantity.

`\vect{p}`	$\vec{p}$

\magvect{⟨*kernel*⟩}

Symbol for magnitude of a vector quantity.

`\magvect{p}`	$\lVert\vec{p}\rVert$

\magsquaredvect{⟨*kernel*⟩}

Symbol for squared magnitude of a vector quantity.

`\magsquaredvect{p}`	$\lVert\vec{p}\rVert^2$

\magnvect{⟨*kernel*⟩}{⟨*exponent*⟩}

Symbol for magnitude of a vector quantity to arbitrary power.

`\magnvect{r}{5}`	$\lVert\vec{r}\rVert^5$

\dirvect{⟨*kernel*⟩}

Symbol for direction of a vector quantity.

`\dirvect{p}`	$\widehat{p}$

\factorvect{⟨*kernel*⟩}

Symbol for a vector factored into its magnitude and direction.

`\factorvect{E}`	$\left\lVert\vec{E}\right\rVert\widehat{E}$

`\componentalong{⟨alongvector⟩}{⟨ofvector⟩}`
Symbol for the component along a vector of another vector.

`\componentalong{\vect{v}}{\vect{u}}`	$\mathrm{comp}_{\vec{v}}\,\vec{u}$

`\expcomponentalong{⟨alongvector⟩}{⟨ofvector⟩}`
Symbolic expression for the component along a vector of another vector.

`\expcomponentalong{\vect{v}}{\vect{u}}`	$\frac{\vec{u}\cdot\vec{v}}{\lVert\vec{v}\rVert}$

`\ucomponentalong{⟨alongvector⟩}{⟨ofvector⟩}`
Symbolic expression with unit vectors for the component along a vector of another vector.

`\ucomponentalong{\dirvect{v}}{\vect{u}}`	$\vec{u}\cdot\widehat{v}$

`\projectiononto{⟨ontovector⟩}{⟨ofvector⟩}`
Symbol for the projection onto a vector of another vector.

`\projectiononto{\vect{v}}{\vect{u}}`	$\mathrm{proj}_{\vec{v}}\,\vec{u}$

`\expprojectiononto{⟨alongvector⟩}{⟨ofvector⟩}`
Symbolic expression for the projection onto a vector of another vector.

`\expprojectiononto{\vect{v}}{\vect{u}}`	$\left(\frac{\vec{u}\cdot\vec{v}}{\lVert\vec{v}\rVert}\right)\frac{\vec{v}}{\lVert\vec{v}\rVert}$

`\uprojectiononto{⟨alongvector⟩}{⟨ofvector⟩}`
Symbolic expression with unit vectors for the projection onto a vector of another vector.

`\uprojectiononto{\dirvect{v}}{\vect{u}}`	$(\vec{u}\cdot\widehat{v})\,\widehat{v}$

`\mivector[⟨printeddelimiter⟩]{⟨commadelimitedlistofcomps⟩}[⟨unit⟩]`
Generic workhorse command for vectors formatted as in *Matter & Interactions*. Unless the first optional argument is specified, a comma is used in the output. Commas are always required in the mandatory argument.

```
\begin{mysolution*}
  \msub{u}{\mu} &= \mivector{\ezero,\eone,\etwo,\ethree}        \\
  \msub{u}{\mu} &= \mivector[\quad]{\ezero,\eone,\etwo,\ethree} \\
  \vect{v} &= \mivector{1,3,5}[\velocityonlytradunit]           \\
  \vect{E} &= \mivector{\oofpezmathsymbol \frac{Q}{x^2},0,0}    \\
  \vect{E} &= \mivector[\quad]{\oofpezmathsymbol \frac{Q}{x^2},0,0}
\end{mysolution*}
```

$$\begin{aligned} u_\mu &= \langle \boldsymbol{e}_0, \boldsymbol{e}_1, \boldsymbol{e}_2, \boldsymbol{e}_3 \rangle \\ u_\mu &= \langle \boldsymbol{e}_0 \quad \boldsymbol{e}_1 \quad \boldsymbol{e}_2 \quad \boldsymbol{e}_3 \rangle \\ \vec{v} &= \langle 1, 3, 5 \rangle \ \mathrm{m/s} \\ \vec{E} &= \left\langle \frac{1}{4\pi\epsilon_0} \frac{Q}{x^2}, 0, 0 \right\rangle \\ \vec{E} &= \left\langle \frac{1}{4\pi\epsilon_0} \frac{Q}{x^2} \quad 0 \quad 0 \right\rangle \end{aligned}$$

\magvectncomps{⟨*listofcomps*⟩}[⟨*unit*⟩]

Expression for a vector's magnitude with numerical components and an optional unit. The first example is the preferred and recommended way to handle units when they are needed. The second example requires explicitly picking out the desired unit form. The third example demonstrates components of a unit vector.

```
\magvectncomps{\velocity{3.12},\velocity{4.04},\velocity{6.73}} \\
\magvectncomps{3.12,4.04,6.73}[\velocityonlytradunit]           \\
\magvectncomps{\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}}
```

$\sqrt{(3.12\ \mathrm{m/s})^2 + (4.04\ \mathrm{m/s})^2 + (6.73\ \mathrm{m/s})^2}$
$\sqrt{(3.12\ \mathrm{m/s})^2 + (4.04\ \mathrm{m/s})^2 + (6.73\ \mathrm{m/s})^2}$
$\sqrt{\left(\frac{1}{\sqrt{3}}\right)^2 + \left(\frac{1}{\sqrt{3}}\right)^2 + \left(\frac{1}{\sqrt{3}}\right)^2}$

\scompsvect{⟨*kernel*⟩}

Expression for a vector's symbolic components.

```
\scompsvect{E}
```

$\langle E_x, E_y, E_z \rangle$

\compvect{⟨*kernel*⟩}{⟨*component*⟩}

Isolates one of a vector's symbolic components.

```
\compvect{E}{y}
```

E_y

\scompsdirvect{⟨*kernel*⟩}

Expression for a direction's symbolic components. The hats are necessary to denote a direction.

```
\scompsdirvect{r}
```

$\langle \widehat{r}_x, \widehat{r}_y, \widehat{r}_z \rangle$

\compdirvect{⟨*kernel*⟩}{⟨*component*⟩}

Isolates one of a direction's symbolic components. The hat is necessary to denote a direction.

```
\compdirvect{r}{z}
```

$\widehat{r}_z$

\magvectscomps{⟨*kernel*⟩}

Expression for a vector's magnitude in terms of its symbolic components.

```
\magvectscomps{B}
```

$\sqrt{B_x^2 + B_y^2 + B_z^2}$

6.7.2 Differentials and Derivatives of Vectors

\dvect{⟨*kernel*⟩}

Symbol for the differential of a vector.

\Dvect{⟨*kernel*⟩}

Identical to \dvect but uses Δ.

```
a change \dvect{E} in electric field \\
a change \Dvect{E} in electric field
```

a change $\mathrm{d}\vec{E}$ in electric field
a change $\Delta\vec{E}$ in electric field

\dirdvect{⟨*kernel*⟩}

Symbol for the direction of a vector's differential.

\dirDvect{⟨*kernel*⟩}

Identical to \dirdvect but uses Δ.

```
the direction \dirdvect{E} of the change \\
the direction \dirDvect{E} of the change
```

the direction $\widehat{\mathrm{d}\vec{E}}$ of the change
the direction $\widehat{\Delta\vec{E}}$ of the change

\ddirvect{⟨*kernel*⟩}

Symbol for the differential of a vector's direction.

\Ddirvect{⟨*kernel*⟩}

Identical to \ddirvect but uses Δ.

\ddirection{⟨*kernel*⟩}

Alias for \ddirvect.

\Ddirection{⟨*kernel*⟩}

Alias for \Ddirvect.

```
the change \ddirvect{E} or \ddirection{E} in the direction of \vect{E} \\
the change \Ddirvect{E} or \Ddirection{E} in the direction of \vect{E}
```

the change $\mathrm{d}\widehat{E}$ or $\mathrm{d}\widehat{E}$ in the direction of $\vec{E}$
the change $\Delta\widehat{E}$ or $\Delta\widehat{E}$ in the direction of $\vec{E}$

`\magdvect{⟨kernel⟩}`

Symbol for the magnitude of a vector's differential.

`\magDvect{⟨kernel⟩}`

Identical to `\magdvect` but uses Δ.

```
the magnitude \magdvect{E} of the change \\
the magnitude \magDvect{E} of the change
```

the magnitude $\left\lVert \mathrm{d}\vec{E} \right\rVert$ of the change
the magnitude $\left\lVert \Delta\vec{E} \right\rVert$ of the change

`\dmagvect{⟨kernel⟩}`

Symbol for the differential of a vector's magnitude.

`\Dmagvect{⟨kernel⟩}`

Identical to `\dmagvect` but uses Δ.

```
the change \dmagvect{E} in the magnitude \\
the change \Dmagvect{E} in the magnitude
```

the change $\mathrm{d}\left\lVert \vec{E} \right\rVert$ in the magnitude
the change $\Delta\left\lVert \vec{E} \right\rVert$ in the magnitude

`\scompsdvect{⟨kernel⟩}`

Symbolic components of a vector.

`\scompsDvect{⟨kernel⟩}`

Identical to `\scompsdvect` but uses Δ.

```
the vector \scompsdvect{E} \\
the vector \scompsDvect{E}
```

the vector $\langle \mathrm{d}E_x, \mathrm{d}E_y, \mathrm{d}E_z \rangle$
the vector $\langle \Delta E_x, \Delta E_y, \Delta E_z \rangle$

`\compdvect{⟨kernel⟩}{⟨component⟩}`

Isolates one symbolic component of a vector's differential.

`\compDvect{⟨kernel⟩}{⟨component⟩}`

Identical to `\compdvect` but uses Δ.

```
the \compdvect{E}{y} component of the change \\
the \compDvect{E}{y} component of the change
```

the $\mathrm{d}E_y$ component of the change
the ΔE_y component of the change

`\dervect{⟨kernel⟩}{⟨indvar⟩}`

Symbol for a vector's derivative with respect to an independent variable.

`\Dervect{⟨kernel⟩}{⟨indvar⟩}`

Identical to `\dervect` but uses Δ.

```
the derivative \dervect{E}{t} \\
the derivative \Dervect{E}{t}
```

the derivative $\frac{\mathrm{d}\vec{E}}{\mathrm{d}t}$
the derivative $\frac{\Delta\vec{E}}{\Delta t}$

`\dermagvect{⟨kernel⟩}{⟨indvar⟩}`

Symbol for the derivative of a vector's magnitude with respect to an independent variable.

\Dermagvect{⟨*kernel*⟩}{⟨*indvar*⟩}

Identical to \dermagvect but uses Δ.

```
the derivative \dermagvect{E}{t} \\
the derivative \Dermagvect{E}{t}
```

the derivative $\frac{\mathrm{d}\lVert\vec{E}\rVert}{\mathrm{d}t}$
the derivative $\frac{\Delta\lVert\vec{E}\rVert}{\Delta t}$

\derdirvect{⟨*kernel*⟩}{⟨*indvar*⟩}

Symbol for the derivative of a vector's direction with respect to an independent variable.

\derdirection{⟨*kernel*⟩}{⟨*indvar*⟩}

Alias for \derdirvect.

\Derdirvect{⟨*kernel*⟩}{⟨*indvar*⟩}

Identical to \derdirvect but uses Δ.

\Derdirection{⟨*kernel*⟩}{⟨*indvar*⟩}

Alias for \Derdirvect.

```
the derivative \derdirvect{E}{t} or \derdirection{E}{t} \\
the derivative \Derdirvect{E}{t} or \Derdirection{E}{t}
```

the derivative $\frac{\mathrm{d}\widehat{E}}{\mathrm{d}t}$ or $\frac{\mathrm{d}\widehat{E}}{\mathrm{d}t}$
the derivative $\frac{\Delta\widehat{E}}{\Delta t}$ or $\frac{\Delta\widehat{E}}{\Delta t}$

\scompsdervect{⟨*kernel*⟩}{⟨*indvar*⟩}

Symbolic components of a vector's derivative with respect to an independent variable.

\scompsDervect{⟨*kernel*⟩}{⟨*indvar*⟩}

Identical to \scompsdervect but uses Δ.

```
the derivative \scompsdervect{E}{t} \\
the derivative \scompsdervect{E}{t}
```

the derivative $\left\langle \frac{\mathrm{d}E_x}{\mathrm{d}t}, \frac{\mathrm{d}E_y}{\mathrm{d}t}, \frac{\mathrm{d}E_z}{\mathrm{d}t} \right\rangle$
the derivative $\left\langle \frac{\mathrm{d}E_x}{\mathrm{d}t}, \frac{\mathrm{d}E_y}{\mathrm{d}t}, \frac{\mathrm{d}E_z}{\mathrm{d}t} \right\rangle$

\compdervect{⟨*kernel*⟩}{⟨*component*⟩}{⟨*indvar*⟩}

Isolates one component of a vector's derivative with respect to an independent variable.

\compDervect{⟨*kernel*⟩}{⟨*component*⟩}{⟨*indvar*⟩}

Identical to \compdervect but uses Δ.

```
the derivative \compdervect{E}{y}{t} \\
the derivative \compDervect{E}{y}{t}
```

the derivative $\frac{\mathrm{d}E_y}{\mathrm{d}t}$
the derivative $\frac{\Delta E_y}{\Delta t}$

\magdervect{⟨*kernel*⟩}{⟨*indvar*⟩}

Symbol for the magnitude of a vector's derivative with respect to an independent variable.

\magDervect{⟨*kernel*⟩}{⟨*indvar*⟩}

Identical to \magdervect but uses Δ.

```
the derivative \magdervect{E}{t} \\
the derivative \magDervect{E}{t}
```

the derivative $\left\|\frac{\mathrm{d}\vec{E}}{\mathrm{d}t}\right\|$
the derivative $\left\|\frac{\Delta\vec{E}}{\Delta t}\right\|$

6.7.3 Naming Conventions You Have Seen

By now you probably understand that commands are named as closely as possible to the way you would say or write what you want. Every time you see `comp` you should think of a single component. Every time you see `scomps` you should think of a set of symbolic components. Every time you see `der` you should think derivative. Every time you see `dir` you should think direction. I have tried to make the names simple both logically and lexically.

6.7.4 Subscripted or Indexed Vectors

Now we have commands for vectors that carry subscripts or indices, usually to identify an object or something similar. Basically, `\vect`→ P. 53 becomes `\vectsub`. Ideally, a subscript should not contain mathematical symbols. However, if you wish to do so, just wrap the symbol with `\(...\)` as you normally would. All of the commands for non-subscripted vectors are available for subscripted vectors.

As a matter of convention, when the initial and final values of a quantity are referenced, they should be labeled with subscripts `i` and `f` respectively using the commands in this section and similarly named commands in other sections. If the quantity also refers to a particular entity (e.g. a ball), specify the `i` or `f` with a comma after the label (e.g. `\vectsub{r}{ball,f}`).

`\vectsub{⟨kernel⟩}{⟨sub⟩}`
Symbol for a subscripted vector.

```
the vector \vectsub{p}{ball}
```

the vector $\vec{p}_{\text{ball}}$

`\magvectsub{⟨kernel⟩}{⟨sub⟩}`
Symbol for a subscripted vector's magnitude.

```
\magvectsub{p}{ball}
```

$\|\vec{p}_{\text{ball}}\|$

`\magsquaredvectsub{⟨kernel⟩}{⟨sub⟩}`
Symbol for a subscripted vector's squared magnitude.

```
\magsquaredvectsub{p}{ball}
```

$\|\vec{p}_{\text{ball}}\|^2$

`\magnvectsub{⟨kernel⟩}{⟨sub⟩}{⟨exponent⟩}`
Symbol for a subscripted vector's magnitude to an arbitrary power.

```
\magnvectsub{r}{dipole}{5}
```

$\|\vec{r}_{\text{dipole}}\|^5$

\dirvectsub{⟨*kernel*⟩}{⟨*sub*⟩}

Symbol for a subscripted vector's direction.

```
\dirvectsub{p}{ball}
```

$\widehat{p}_{\mathrm{ball}}$

\scompsvectsub{⟨*kernel*⟩}{⟨*sub*⟩}

Symbolic components of a subscripted vector.

```
\scompsvectsub{p}{ball}
```

$\left\langle p_{\mathrm{ball},x}, p_{\mathrm{ball},y}, p_{\mathrm{ball},z}\right\rangle$

\compvectsub{⟨*kernel*⟩}{⟨*sub*⟩}{⟨*component*⟩}

Isolates one component of a subscripted vector.

```
\compvectsub{p}{ball}{z}
```

$p_{\mathrm{ball},z}$

\magvectsubscomps{⟨*kernel*⟩}{⟨*sub*⟩}

Expression for a subscripted vector's magnitude in terms of symbolic components.

```
\magvectsubscomps{p}{ball}
```

$\sqrt{p^2_{\mathrm{ball},x} + p^2_{\mathrm{ball},y} + p^2_{\mathrm{ball},z}}$

\dvectsub{⟨*kernel*⟩}{⟨*sub*⟩}

Differential of a subscripted vector.

\Dvectsub{⟨*kernel*⟩}{⟨*sub*⟩}

Identical to \dvectsub but uses Δ.

```
\dvectsub{p}{ball} \\
\Dvectsub{p}{ball}
```

$\mathrm{d}\vec{p}_{\mathrm{ball}}$
$\Delta\vec{p}_{\mathrm{ball}}$

\scompsdvectsub{⟨*kernel*⟩}{⟨*sub*⟩}

Symbolic components of a subscripted vector's differential.

\scompsDvectsub{⟨*kernel*⟩}{⟨*sub*⟩}

Identical to \scompsdvectsub but uses Δ.

```
\scompsdvectsub{p}{ball} \\
\scompsDvectsub{p}{ball}
```

$\left\langle \mathrm{d}p_{\mathrm{ball},x}, \mathrm{d}p_{\mathrm{ball},y}, \mathrm{d}p_{\mathrm{ball},z}\right\rangle$
$\left\langle \Delta p_{\mathrm{ball},x}, \Delta p_{\mathrm{ball},y}, \Delta p_{\mathrm{ball},z}\right\rangle$

\compdvectsub{⟨*kernel*⟩}{⟨*sub*⟩}{⟨*component*⟩}

Isolates one component of a subscripted vector's differential.

\compDvectsub{⟨*kernel*⟩}{⟨*sub*⟩}{⟨*component*⟩}

Identical to \compdvectsub but uses Δ.

```
\compdvectsub{p}{ball}{y} \\
\compDvectsub{p}{ball}{y}
```

$\mathrm{d}p_{\mathrm{ball},y}$
$\Delta p_{\mathrm{ball},y}$

`\dervectsub{⟨kernel⟩}{⟨sub⟩}{⟨indvar⟩}`

Symbol for derivative of a subscripted vector with respect to an independent variable.

`\Dervectsub{⟨kernel⟩}{⟨sub⟩}{⟨indvar⟩}`

Identical to `\dervectsub` but uses Δ.

```
\dervectsub{p}{ball}{t} \\
\Dervectsub{p}{ball}{t}
```

$\frac{\mathrm{d}\,\vec{p}_{\text{ball}}}{\mathrm{d}t}$
$\frac{\Delta\,\vec{p}_{\text{ball}}}{\Delta t}$

`\dermagvectsub{⟨kernel⟩}{⟨sub⟩}{⟨indvar⟩}`

Symbol for the derivative of a subscripted vector's magnitude with respect to an independent variable.

`\Dermagvectsub{⟨kernel⟩}{⟨sub⟩}{⟨indvar⟩}`

Identical to `\dermagvectsub` but uses Δ.

```
\dermagvectsub{E}{ball}{t} \\
\Dermagvectsub{E}{ball}{t}
```

$\frac{\mathrm{d}\|\vec{E}_{\text{ball}}\|}{\mathrm{d}t}$
$\frac{\Delta\|\vec{E}_{\text{ball}}\|}{\Delta t}$

`\scompsdervectsub{⟨kernel⟩}{⟨sub⟩}{⟨indvar⟩}`

Symbolic components of a subscripted vector's derivative with respect to an independent variable.

`\scompsDervectsub{⟨kernel⟩}{⟨sub⟩}{⟨indvar⟩}`

Identical to `\scompsdervectsub` but uses Δ.

```
\scompsdervectsub{p}{ball}{t} \\
\scompsDervectsub{p}{ball}{t}
```

$\left\langle \frac{\mathrm{d}p_{\text{ball},x}}{\mathrm{d}t}, \frac{\mathrm{d}p_{\text{ball},y}}{\mathrm{d}t}, \frac{\mathrm{d}p_{\text{ball},z}}{\mathrm{d}t} \right\rangle$
$\left\langle \frac{\Delta p_{\text{ball},x}}{\Delta t}, \frac{\Delta p_{\text{ball},y}}{\Delta t}, \frac{\Delta p_{\text{ball},z}}{\Delta t} \right\rangle$

`\compdervectsub{⟨kernel⟩}{⟨sub⟩}{⟨component⟩} {⟨indvar⟩}`

Isolates one component of a subscripted vector's derivative with respect to an independent variable.

`\compDervectsub{⟨kernel⟩}{⟨sub⟩}{⟨component⟩} {⟨indvar⟩}`

Identical to `\compdervectsub` but uses Δ.

```
\compdervectsub{p}{ball}{y}{t} \\
\compDervectsub{p}{ball}{y}{t}
```

$\frac{\mathrm{d}p_{\text{ball},y}}{\mathrm{d}t}$
$\frac{\Delta p_{\text{ball},y}}{\Delta t}$

`\magdervectsub{⟨kernel⟩}{⟨sub⟩}{⟨indvar⟩}`

Symbol for magnitude of a subscripted vector's derivative with respect to an independent variable.

`\magDervectsub{⟨kernel⟩}{⟨sub⟩}{⟨indvar⟩}`

Identical to `\magdervectsub` but uses Δ.

```
\magdervectsub{p}{ball}{t} \\
\magDervectsub{p}{ball}{t}
```

$\left\| \frac{\mathrm{d}\,\vec{p}_{\text{ball}}}{\mathrm{d}t} \right\|$
$\left\| \frac{\Delta\,\vec{p}_{\text{ball}}}{\Delta t} \right\|$

6.7.5 Expressions Containing Dots

Now we get to commands that will save you many, many keystrokes. All of the naming conventions documented in earlier commands still apply. There are some new ones though. Every time you see `dot` you should think *dot product*. When you see `dots` you should think *dot product in terms of symbolic components*. When you see `dote` you should think *dot product expanded as a sum*. These, along with the previous naming conventions, handle many dot product expressions.

`\vectdotvect{⟨kernel1⟩}{⟨kernel2⟩}`
Symbol for dot of two vectors as a single symbol.

`\vectDotvect{⟨kernel1⟩}{⟨kernel2⟩}`
Same as `\vectdotvect` but uses `\bullet`.

```
\vectdotvect{\vect{F}}{\vect{v}} \\
\vectDotvect{\vect{F}}{\vect{v}}
```

$\vec{F} \cdot \vec{v}$
$\vec{F} \bullet \vec{v}$

`\vectdotsvect{⟨kernel1⟩}{⟨kernel2⟩}`
Symbol for dot of two vectors with symbolic components.

`\vectDotsvect{⟨kernel1⟩}{⟨kernel2⟩}`
Same as `\vectdotsvect` but uses `\bullet`.

```
\vectdotsvect{F}{v} \\
\vectDotsvect{F}{v}
```

$\langle F_x, F_y, F_z \rangle \cdot \langle v_x, v_y, v_z \rangle$
$\langle F_x, F_y, F_z \rangle \bullet \langle v_x, v_y, v_z \rangle$

`\vectdotevect{⟨kernel1⟩}{⟨kernel2⟩}`
Symbol for dot of two vectors as an expanded sum.

```
\vectdotevect{F}{v}
```

$F_x v_x + F_y v_y + F_z v_z$

`\vectdotsdvect{⟨kernel1⟩}{⟨kernel2⟩}`
Dot of a vector a vector's differential with symbolic components.

`\vectdotsDvect{⟨kernel1⟩}{⟨kernel2⟩}`
Identical to `\vectdotsdvect` but uses Δ.

```
\vectdotsdvect{F}{r} \\
\vectdotsDvect{F}{r}
```

$\langle F_x, F_y, F_z \rangle \cdot \langle \mathrm{d}r_x, \mathrm{d}r_y, \mathrm{d}r_z \rangle$
$\langle F_x, F_y, F_z \rangle \cdot \langle \Delta r_x, \Delta r_y, \Delta r_z \rangle$

`\vectdotedvect{⟨kernel1⟩}{⟨kernel2⟩}`
Dot of a vector a vector's differential as an expanded sum.

`\vectdoteDvect{⟨kernel1⟩}{⟨kernel2⟩}`
Identical to `\vectdotedvect` but uses Δ.

```
\vectdotedvect{F}{r} \\
\vectdoteDvect{F}{r}
```

$F_x \mathrm{d}r_x + F_y \mathrm{d}r_y + F_z \mathrm{d}r_z$
$F_x \Delta r_x + F_y \Delta r_y + F_z \Delta r_z$

`\vectsubdotsvectsub{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}{`$\langle$*sub2*$\rangle$`}`

Dot of two subscripted vectors with symbolic components.

```
\vectsubdotsvectsub{F}{grav}{r}{ball}
```

$\langle F_{\text{grav},x}, F_{\text{grav},y}, F_{\text{grav},z}\rangle \cdot \langle r_{\text{ball},x}, r_{\text{ball},y}, r_{\text{ball},z}\rangle$

`\vectsubdotevectsub{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}{`$\langle$*sub2*$\rangle$`}`

Dot of two subscripted vectors as an expanded sum.

```
\vectsubdotevectsub{F}{grav}{r}{ball}
```

$F_{\text{grav},x} r_{\text{ball},x} + F_{\text{grav},y} r_{\text{ball},y} + F_{\text{grav},z} r_{\text{ball},z}$

`\vectsubdotsdvectsub{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}{`$\langle$*sub2*$\rangle$`}`

Dot of a subscripted vector and a subscripted vector's differential with symbolic components.

`\vectsubdotsDvectsub{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}{`$\langle$*sub2*$\rangle$`}`

Identical to `\vectsubdotsdvectsub` but uses Δ.

```
\vectsubdotsdvectsub{A}{ball}{B}{car} \\
\vectsubdotsDvectsub{A}{ball}{B}{car}
```

$\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z}\rangle \cdot \langle \mathrm{d}B_{\text{car},x}, \mathrm{d}B_{\text{car},y}, \mathrm{d}B_{\text{car},z}\rangle$
$\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z}\rangle \cdot \langle \Delta B_{\text{car},x}, \Delta B_{\text{car},y}, \Delta B_{\text{car},z}\rangle$

`\vectsubdotedvectsub{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}{`$\langle$*sub2*$\rangle$`}`

Dot of a subscripted vector and a subscripted vector's differential as an expanded sum.

`\vectsubdoteDvectsub{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}{`$\langle$*sub2*$\rangle$`}`

Identical to `\vectsubdotedvectsub` but uses Δ.

```
\vectsubdotedvectsub{A}{ball}{B}{car} \\
\vectsubdoteDvectsub{A}{ball}{B}{car}
```

$A_{\text{ball},x}\mathrm{d}B_{\text{car},x} + A_{\text{ball},y}\mathrm{d}B_{\text{car},y} + A_{\text{ball},z}\mathrm{d}B_{\text{car},z}$
$A_{\text{ball},x}\Delta B_{\text{car},x} + A_{\text{ball},y}\Delta B_{\text{car},y} + A_{\text{ball},z}\Delta B_{\text{car},z}$

`\vectsubdotsdvect{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}`

Dot of a subscripted vector and a vector's differential with symbolic components.

`\vectsubdotsDvect{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}`

Identical to `\vectsubdotsdvect` but uses Δ.

```
\vectsubdotsdvect{A}{ball}{B} \\
\vectsubdotsDvect{A}{ball}{B}
```

$\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z}\rangle \cdot \langle \mathrm{d}B_x, \mathrm{d}B_y, \mathrm{d}B_z\rangle$
$\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z}\rangle \cdot \langle \Delta B_x, \Delta B_y, \Delta B_z\rangle$

`\vectsubdotedvect{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}`

Dot of a subscripted vector and a vector's differential as an expanded sum.

`\vectsubdoteDvect{`$\langle$*kernel1*$\rangle$`}{`$\langle$*sub1*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}`

Identical to `\vectsubdotedvect` but uses Δ.

```
\vectsubdotedvect{A}{ball}{B} \\
\vectsubdoteDvect{A}{ball}{B}
```

$A_{\text{ball},x}\mathrm{d}B_x + A_{\text{ball},y}\mathrm{d}B_y + A_{\text{ball},z}\mathrm{d}B_z$
$A_{\text{ball},x}\Delta B_x + A_{\text{ball},y}\Delta B_y + A_{\text{ball},z}\Delta B_z$

`\dervectdotsvect{`$\langle$*kernel1*$\rangle$`}{`$\langle$*indvar*$\rangle$`}{`$\langle$*kernel2*$\rangle$`}`

Dot of a vector's derivative and a vector with symbolic components.

\Dervectdotsvect{⟨kernel1⟩}{⟨indvar⟩}{⟨kernel2⟩}

Identical to \dervectdotsvect but uses Δ.

```
\dervectdotsvect{A}{t}{B} \\
\Dervectdotsvect{A}{t}{B}
```

$$\left\langle \frac{\mathrm{d}A_x}{\mathrm{d}t}, \frac{\mathrm{d}A_y}{\mathrm{d}t}, \frac{\mathrm{d}A_z}{\mathrm{d}t} \right\rangle \cdot \langle B_x, B_y, B_z \rangle$$
$$\left\langle \frac{\Delta A_x}{\Delta t}, \frac{\Delta A_y}{\Delta t}, \frac{\Delta A_z}{\Delta t} \right\rangle \cdot \langle B_x, B_y, B_z \rangle$$

\dervectdotevect{⟨kernel1⟩}{⟨indvar⟩}{⟨kernel2⟩}

Dot of a vector's derivative and a vector as an expanded sum.

\Dervectdotevect{⟨kernel1⟩}{⟨indvar⟩}{⟨kernel2⟩}

Identical to \dervectdotevect but uses Δ.

```
\dervectdotevect{A}{t}{B} \\
\Dervectdotevect{A}{t}{B}
```

$$\frac{\mathrm{d}A_x}{\mathrm{d}t} B_x + \frac{\mathrm{d}A_y}{\mathrm{d}t} B_y + \frac{\mathrm{d}A_z}{\mathrm{d}t} B_z$$
$$\frac{\Delta A_x}{\Delta t} B_x + \frac{\Delta A_y}{\Delta t} B_y + \frac{\Delta A_z}{\Delta t} B_z$$

\vectdotsdervect{⟨kernel1⟩}{⟨kernel2⟩}{⟨indvar⟩}

Dot of a vector and a vector's derivative with symbolic components.

\vectdotsDervect{⟨kernel1⟩}{⟨kernel2⟩}{⟨indvar⟩}

Identical to \vectdotsdervect but uses Δ.

```
\vectdotsdervect{A}{B}{t} \\
\vectdotsDervect{A}{B}{t}
```

$$\langle A_x, A_y, A_z \rangle \cdot \left\langle \frac{\mathrm{d}B_x}{\mathrm{d}t}, \frac{\mathrm{d}B_y}{\mathrm{d}t}, \frac{\mathrm{d}B_z}{\mathrm{d}t} \right\rangle$$
$$\langle A_x, A_y, A_z \rangle \cdot \left\langle \frac{\Delta B_x}{\Delta t}, \frac{\Delta B_y}{\Delta t}, \frac{\Delta B_z}{\Delta t} \right\rangle$$

\vectdotedervect{⟨kernel1⟩}{⟨kernel2⟩}{⟨indvar⟩}

Dot of a vector and a vector's derivative as an expanded sum.

\vectdoteDervect{⟨kernel1⟩}{⟨kernel2⟩}{⟨indvar⟩}

Identical to \vectdotedervect but uses Δ.

```
\vectdotedervect{A}{B}{t} \\
\vectdoteDervect{A}{B}{t}
```

$$A_x \frac{\mathrm{d}B_x}{\mathrm{d}t} + A_y \frac{\mathrm{d}B_y}{\mathrm{d}t} + A_z \frac{\mathrm{d}B_z}{\mathrm{d}t}$$
$$A_x \frac{\Delta B_x}{\Delta t} + A_y \frac{\Delta B_y}{\Delta t} + A_z \frac{\Delta B_z}{\Delta t}$$

\dervectdotsdvect{⟨kernel1⟩}{⟨indvar⟩}{⟨kernel2⟩}

Dot of a vector's derivative and a vector's differential with symbolic components.

\DervectdotsDvect{⟨kernel1⟩}{⟨indvar⟩}{⟨kernel2⟩}

Identical to \dervectdotsdvect but uses Δ.

```
\dervectdotsdvect{A}{t}{B} \\
\DervectdotsDvect{A}{t}{B}
```

$$\left\langle \frac{\mathrm{d}A_x}{\mathrm{d}t}, \frac{\mathrm{d}A_y}{\mathrm{d}t}, \frac{\mathrm{d}A_z}{\mathrm{d}t} \right\rangle \cdot \langle \mathrm{d}B_x, \mathrm{d}B_y, \mathrm{d}B_z \rangle$$
$$\left\langle \frac{\Delta A_x}{\Delta t}, \frac{\Delta A_y}{\Delta t}, \frac{\Delta A_z}{\Delta t} \right\rangle \cdot \langle \Delta B_x, \Delta B_y, \Delta B_z \rangle$$

\dervectdotedvect{⟨kernel1⟩}{⟨indvar⟩}{⟨kernel2⟩}

Dot of a vector's derivative and a vector's differential as an expanded sum.

\DervectdoteDvect{⟨*kernel1*⟩}{⟨*indvar*⟩}{⟨*kernel2*⟩}

Identical to \dervectdotedvect but uses Δ.

```
\dervectdotedvect{A}{t}{B} \\
\DervectdoteDvect{A}{t}{B}
```

$\frac{dA_x}{dt}dB_x + \frac{dA_y}{dt}dB_y + \frac{dA_z}{dt}dB_z$
$\frac{\Delta A_x}{\Delta t}\Delta B_x + \frac{\Delta A_y}{\Delta t}\Delta B_y + \frac{\Delta A_z}{\Delta t}\Delta B_z$

6.7.6 Expressions Containing Crosses

All of the naming conventions documented in earlier commands still apply.

\vectcrossvect{⟨*kernel1*⟩}{⟨*kernel2*⟩}

Cross of two vectors.

```
\vectcrossvect{\vect{r}}{\vect{p}}
```

$\vec{r} \times \vec{p}$

\ltriplecross{⟨*kernel1*⟩}{⟨*kernel2*⟩}{⟨*kernel3*⟩}

Symbol for left associated triple cross product.

```
\ltriplecross{\vect{A}}{\vect{B}}{\vect{C}}
```

$\left(\vec{A} \times \vec{B}\right) \times \vec{C}$

\rtriplecross{⟨*kernel1*⟩}{⟨*kernel2*⟩}{⟨*kernel3*⟩}

Symbol for right associated triple cross product.

```
\rtriplecross{\vect{A}}{\vect{B}}{\vect{C}}
```

$\vec{A} \times \left(\vec{B} \times \vec{C}\right)$

\ltriplescalar{⟨*kernel1*⟩}{⟨*kernel2*⟩}{⟨*kernel3*⟩}

Symbol for left associated triple scalar product.

```
\ltriplescalar{\vect{A}}{\vect{B}}{\vect{C}}
```

$\vec{A} \times \vec{B} \cdot \vec{C}$

\rtriplescalar{⟨*kernel1*⟩}{⟨*kernel2*⟩}{⟨*kernel3*⟩}

Symbol for right associated triple scalar product.

```
\rtriplescalar{\vect{A}}{\vect{B}}{\vect{C}}
```

$\vec{A} \cdot \vec{B} \times \vec{C}$

6.7.7 Basis Vectors and Bivectors

If you use geometric algebra or tensors, eventually you will need symbols for basis vectors and basis bivectors.

\ezero

Symbols for basis vectors with lower indices up to 4.

\eone

\etwo

\ethree

\efour

```
\ezero, \eone, \etwo, \ethree, \efour
```

$\boldsymbol{e}_0$, $\boldsymbol{e}_1$, $\boldsymbol{e}_2$, $\boldsymbol{e}_3$, $\boldsymbol{e}_4$

\uezero

Symbols for normalized basis vectors with lower indices up to 4.

\ueone

\uetwo

\uethree

\uefour

```
\uezero, \ueone, \uetwo, \uethree, \uefour
```

$\widehat{\boldsymbol{e}}_0$, $\widehat{\boldsymbol{e}}_1$, $\widehat{\boldsymbol{e}}_2$, $\widehat{\boldsymbol{e}}_3$, $\widehat{\boldsymbol{e}}_4$

\ezerozero

Symbols for basis bivectors with lower indices up to 4.

\ezeroone

\ezerotwo

\ezerothree

\ezerofour

\eoneone

\eonetwo

\eonethree

\eonefour

\etwoeone

\etwotwo

\etwothree

\etwofour

\ethreeeone

\ethreetwo

\ethreethree

\ethreefour

\efoureone

\efourtwo

\efourthree

\efourfour

```
\ezerozero, \ezeroone, \ezerotwo, \ezerothree, \ezerofour,    \\
\eoneone, \eonetwo, \eonethree, \eonefour, \etwoone,          \\
\etwotwo, \etwothree, \etwofour, \ethreeone, \ethreetwo,      \\
\ethreethree, \ethreefour, \efourone, \efourtwo, \efourthree, \\
\efourfour
```

$\boldsymbol{e}_{00}$, $\boldsymbol{e}_{01}$, $\boldsymbol{e}_{02}$, $\boldsymbol{e}_{03}$, $\boldsymbol{e}_{04}$,
$\boldsymbol{e}_{11}$, $\boldsymbol{e}_{12}$, $\boldsymbol{e}_{13}$, $\boldsymbol{e}_{14}$, $\boldsymbol{e}_{21}$,
$\boldsymbol{e}_{22}$, $\boldsymbol{e}_{23}$, $\boldsymbol{e}_{24}$, $\boldsymbol{e}_{31}$, $\boldsymbol{e}_{32}$,
$\boldsymbol{e}_{33}$, $\boldsymbol{e}_{34}$, $\boldsymbol{e}_{41}$, $\boldsymbol{e}_{42}$, $\boldsymbol{e}_{43}$,
$\boldsymbol{e}_{44}$

\euzero

Symbols for basis vectors with upper indices up to 4.

\euone

\eutwo

\euthree

\eufour

```
\euzero, \euone, \eutwo, \euthree, \eufour
```

$\boldsymbol{e}^0$, $\boldsymbol{e}^1$, $\boldsymbol{e}^2$, $\boldsymbol{e}^3$, $\boldsymbol{e}^4$

\ueuzero

Symbols for normalized basis vectors with upper indices up to 4.

\ueuone

\ueutwo

\ueuthree

\ueufour

```
\ueuzero, \ueuone, \ueutwo, \ueuthree, \ueufour
```

$\widehat{\boldsymbol{e}}^0$, $\widehat{\boldsymbol{e}}^1$, $\widehat{\boldsymbol{e}}^2$, $\widehat{\boldsymbol{e}}^3$, $\widehat{\boldsymbol{e}}^4$

\euzerozero

Symbols for basis bivectors with upper indices up to 4.

\euzeroone

\euzerotwo

\euzerothree

\euzerofour

\euoneone

\euonetwo

\euonethree

\euonefour

\eutwoeone

\eutwotwo

\eutwothree

\eutwofour

\euthreeeone

\euthreetwo

\euthreethree

\euthreefour

\eufoureone

\eufourtwo

\eufourthree

\eufourfour

```
\euzerozero, \euzeroone, \euzerotwo, \euzerothree, \euzerofour,    \\
\euoneone, \euonetwo, \euonethree, \euonefour, \eutwoone,          \\
\eutwotwo, \eutwothree, \eutwofour, \euthreeone, \euthreetwo,      \\
\euthreethree, \euthreefour, \eufourone, \eufourtwo, \eufourthree, \\
\eufourfour
```

$\boldsymbol{e}^{00}$, $\boldsymbol{e}^{01}$, $\boldsymbol{e}^{02}$, $\boldsymbol{e}^{03}$, $\boldsymbol{e}^{04}$,
$\boldsymbol{e}^{11}$, $\boldsymbol{e}^{12}$, $\boldsymbol{e}^{13}$, $\boldsymbol{e}^{14}$, $\boldsymbol{e}^{21}$,
$\boldsymbol{e}^{22}$, $\boldsymbol{e}^{23}$, $\boldsymbol{e}^{24}$, $\boldsymbol{e}^{31}$, $\boldsymbol{e}^{32}$,
$\boldsymbol{e}^{33}$, $\boldsymbol{e}^{34}$, $\boldsymbol{e}^{41}$, $\boldsymbol{e}^{42}$, $\boldsymbol{e}^{43}$,
$\boldsymbol{e}^{44}$

\gzero

Symbols for basis vectors, with γ as the kernel, with lower indices up to 4.

```
\gzero, \gone, \gtwo, \gthree, \gfour
```

$\boldsymbol{\gamma}_0$, $\boldsymbol{\gamma}_1$, $\boldsymbol{\gamma}_2$, $\boldsymbol{\gamma}_3$, $\boldsymbol{\gamma}_4$

\guzero

Symbols for basis vectors, with γ as the kernel, with upper indices up to 4.

```
\guzero, \guone, \gutwo, \guthree, \gufour
```

$\boldsymbol{\gamma}^0$, $\boldsymbol{\gamma}^1$, $\boldsymbol{\gamma}^2$, $\boldsymbol{\gamma}^3$, $\boldsymbol{\gamma}^4$

\gzerozero

Symbols for basis bivectors, with γ as the kernel, with lower indices up to 4.

\gzeroone

\gzerotwo

\gzerothree

\gzerofour

\goneone

\gonetwo

\gonethree

\gonefour

\gtwoeone

\gtwotwo

\gtwothree

\gtwofour

\gthreeeone

\gthreetwo

\gthreethree

\gthreefour

\gfoureone

\gfourtwo

\gfourthree

\gfourfour

```
\gzerozero, \gzeroone, \gzerotwo, \gzerothree, \gzerofour,    \\
\goneone, \gonetwo, \gonethree, \gonefour, \gtwoone,          \\
\gtwotwo, \gtwothree, \gtwofour, \gthreeone, \gthreetwo,      \\
\gthreethree, \gthreefour, \gfourone, \gfourtwo, \gfourthree, \\
\gfourfour
```

γ_{00}, γ_{01}, γ_{02}, γ_{03}, γ_{04},
γ_{11}, γ_{12}, γ_{13}, γ_{14}, γ_{21},
γ_{22}, γ_{23}, γ_{24}, γ_{31}, γ_{32},
γ_{33}, γ_{34}, γ_{41}, γ_{42}, γ_{43},
γ_{44}

\guzerozero

Symbols for basis bivectors, with γ as the kernel, with upper indices up to 4.

\guzeroone

\guzerotwo

\guzerothree

\guzerofour

\guoneone

\guonetwo

\guonethree

\guonefour

\gutwoeone

\gutwotwo

\gutwothree

\gutwofour

\guthreeeone

\guthreetwo

\guthreethree

\guthreefour

\gufoureone

\gufourtwo

\gufourthree

\gufourfour

```
\guzerozero, \guzeroone, \guzerotwo, \guzerothree, \guzerofour,    \\
\guoneone, \guonetwo, \guonethree, \guonefour, \gutwoone,          \\
\gutwotwo, \gutwothree, \gutwofour, \guthreeone, \guthreetwo,      \\
\guthreethree, \guthreefour, \gufourone, \gufourtwo, \gufourthree, \\
\gufourfour
```

γ^{00}, γ^{01}, γ^{02}, γ^{03}, γ^{04},
γ^{11}, γ^{12}, γ^{13}, γ^{14}, γ^{21},
γ^{22}, γ^{23}, γ^{24}, γ^{31}, γ^{32},
γ^{33}, γ^{34}, γ^{41}, γ^{42}, γ^{43},
γ^{44}

6.7.8 Other Vector Related

\colvector{⟨*commadelimitedlistofcomps*⟩}

Typesets column vectors.

```
\colvector{x^0,x^1,x^2,x^3} \\
\colvector{x_0,x_1,x_2,x_3}
```

$$\begin{pmatrix} x^0 \\ x^1 \\ x^2 \\ x^3 \end{pmatrix}$$
$$\begin{pmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{pmatrix}$$

\rowvector{⟨*commadelimitedlistofcomps*⟩}

Typesets row vectors.

```
\rowvector{x^0,x^1,x^2,x^3} \\
\rowvector{x_0,x_1,x_2,x_3}
```

$\begin{pmatrix} x^0 & x^1 & x^2 & x^3 \end{pmatrix}$
$\begin{pmatrix} x_0 & x_1 & x_2 & x_3 \end{pmatrix}$

\scompscvect[⟨*anynonzero*⟩]{⟨*kernel*⟩}

Typesets subscripted symbolic components of column 3- or 4-vectors (use any nonzero value for the optional argument to typeset a 4-vector).

```
\begin{mysolution*}
  \vect{p} &= \scompscvect{p}   \\
  \vect{p} &= \scompscvect[4]{p}
\end{mysolution*}
```

$$\vec{p} = \begin{pmatrix} p_1 \\ p_2 \\ p_3 \end{pmatrix}$$
$$\vec{p} = \begin{pmatrix} p_0 \\ p_1 \\ p_2 \\ p_3 \end{pmatrix}$$

\scompsCvect[⟨*anynonzero*⟩]{⟨*kernel*⟩}

Typesets superscripted symbolic components of column 3- or 4-vectors (use any nonzero value for the optional argument to typeset a 4-vector).

```
\begin{mysolution*}
  \vect{p} &= \scompsCvect{p}   \\
  \vect{p} &= \scompsCvect[4]{p}
\end{mysolution*}
```

$$\vec{p} = \begin{pmatrix} p^1 \\ p^2 \\ p^3 \end{pmatrix}$$
$$\vec{p} = \begin{pmatrix} p^0 \\ p^1 \\ p^2 \\ p^3 \end{pmatrix}$$

\scompsrvect[⟨*anynonzero*⟩]{⟨*kernel*⟩}

Typesets subscripted symbolic components of row 3- or 4-vectors (use any nonzero value for the optional argument to typeset a 4-vector).

```
\begin{mysolution*}
  \vect{p} &= \scompsrvect{p}   \\
  \vect{p} &= \scompsrvect[4]{p}
\end{mysolution*}
```

$$\vec{p} = (p_1 \; p_2 \; p_3)$$
$$\vec{p} = (p_0 \; p_1 \; p_2 \; p_3)$$

\scompsRvect[⟨*anynonzero*⟩]{⟨*kernel*⟩}

Typesets superscripted symbolic components of row 3- or 4-vectors (use any nonzero value for the optional argument to typeset a 4-vector).

```
\begin{mysolution*}
  \vect{p} &= \scompsRvect{p}   \\
  \vect{p} &= \scompsRvect[4]{p}
\end{mysolution*}
```

$$\vec{p} = (p^1 \; p^2 \; p^3)$$
$$\vec{p} = (p^0 \; p^1 \; p^2 \; p^3)$$

\bra{⟨*bra*⟩}

Typesets a Dirac bra.

```
\bra{\Psi^*} or \bra{\frac{1}{a}\Psi^*}
```

$\langle\Psi^*|$ or $\left\langle\frac{1}{a}\Psi^*\right|$

\ket{⟨*ket*⟩}

Typesets a Dirac ket.

```
\ket{\Psi} or \ket{\frac{1}{b}\Psi^*}
```

$|\Psi\rangle$ or $\left|\frac{1}{b}\Psi^*\right\rangle$

`\bracket{⟨bra⟩}{⟨ket⟩}`

Typesets a Dirac bracket.

```
\bracket{\Psi^*}{\Psi}
```

$\langle\Psi^*|\Psi\rangle$

6.8 Frequently Used Fractions

`\onehalf`

Small fractions with numerator 1 and denominators up to 10.

`\onethird`

`\onefourth`

`\onefifth`

`\onesixth`

`\oneseventh`

`\oneeighth`

`\onenineth`

`\onetenth`

```
\(\onehalf, \onethird, \onefourth, \onefifth, \onesixth, \\
\oneseventh, \oneeighth, \oneninth, \onetenth\)
```

$\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{1}{5}, \frac{1}{6},$
$\frac{1}{7}, \frac{1}{8}, \frac{1}{9}, \frac{1}{10}$

`\twooneths`

Small fractions with numerator 2 and denominators up to 10.

`\twohalves`

`\twothirds`

`\twofourths`

`\twofifths`

`\twosixths`

`\twosevenths`

`\twoeighths`

`\twonineths`

`\twotenths`

```
\(\twooneths, \twohalves, \twothirds, \twofourths, \twofifths, \\
\twosixths, \twosevenths, \twoeighths, \twoninths, \twotenths\)
```

$\frac{2}{1}, \frac{2}{2}, \frac{2}{3}, \frac{2}{4}, \frac{2}{5},$
$\frac{2}{6}, \frac{2}{7}, \frac{2}{8}, \frac{2}{9}, \frac{2}{10}$

`\threeoneths`

Small fractions with numerator 3 and denominators up to 10.

`\threehalves`

`\threethirds`

`\threefourths`

`\threefifths`

`\threesixths`

`\threesevenths`

`\threeeighths`

`\threenineths`

`\threetenths`

```
\(\threeoneths, \threehalves, \threethirds, \threefourths, \threefifths, \\
\threesixths, \threesevenths, \threeeighths, \threeninths, \threetenths\)
```

$\frac{3}{1}, \frac{3}{2}, \frac{3}{3}, \frac{3}{4}, \frac{3}{5},$
$\frac{3}{6}, \frac{3}{7}, \frac{3}{8}, \frac{3}{9}, \frac{3}{10}$

`\fouroneths`{⟨*magnitude*⟩}

Small fractions with numerator 4 and denominators up to 10.

`\fourhalves`

`\fourthirds`

`\fourfourths`

`\fourfifths`

`\foursixths`

`\foursevenths`

`\foureighths`

`\fournineths`

`\fourtenths`

```
\(\fouroneths, \fourhalves, \fourthirds, \fourfourths, \fourfifths, \\
\foursixths, \foursevenths, \foureighths, \fourninths, \fourtenths\)
```

$\frac{4}{1}, \frac{4}{2}, \frac{4}{3}, \frac{4}{4}, \frac{4}{5},$
$\frac{4}{6}, \frac{4}{7}, \frac{4}{8}, \frac{4}{9}, \frac{4}{10}$

6.9 Calculus

\sumoverall{⟨*variable*⟩}

Properly typesets summation over all of some user specified entities.

```
\( \sumoverall{particles} \)
```

$\sum_{\text{all particles}}$

\dx{⟨*variable*⟩}

Properly typesets variables of integration (the d should not be in italics and should be properly spaced relative to the integrand).

```
\( \dx{y} \)
```

$\mathrm{d}y$

\dslashx{⟨*variable*⟩}

Symbol indicating an inexact differential. Frequently used in physics.

```
\( \dslashx{Q} \)
```

$đQ$

\evaluatedfromto{⟨*lower*⟩}[⟨*upper*⟩]

Properly typesets the evaluation of definite integrals. Note that the upper limit is optional.

```
\( {\onethird y^3}\evaluatedfromto{0}[3] \) \\
\( {\onethird y^3}\evaluatedfromto{0} \)
```

$\frac{1}{3}y^3\Big|_0^3$

$\frac{1}{3}y^3\Big|_0$

\evaluatedat{⟨*evaluationpoint*⟩}

Properly indicates evaluation at a particular point or value without specifying the quantity. This is really just an alias for `\evaluatedfromto` with no optional upper limit.

```
\( \text{LMST}\evaluatedat{\longitude{0}} \)
```

$\text{LMST}\Big|_{0^\circ}$

\integral[⟨*lower*⟩][⟨*upper*⟩]{⟨*integrand*⟩}{⟨*var*⟩}

Typesets indefinite and definite integrals.

```
\[ \integral{y^2}{y} \]
\[ \integral[0][3]{y^2}{y} \]
```

$$\int y^2\,\mathrm{d}y$$

$$\int_{y=0}^{y=3} y^2\,\mathrm{d}y$$

\opensurfaceintegral{⟨*surfacename*⟩}{⟨*vectorname*⟩}

Integral over an open surface of the normal component of a vector field.

```
\[ \opensurfaceintegral{S}{\vect{E}} \]
```

$$\iint_S \vec{E} \cdot \hat{n} \, \mathrm{d}A$$

\closedsurfaceintegral{⟨*surfacename*⟩}{⟨*vectorname*⟩}

Integral over a closed surface of the normal component of a vector field.

```
\[ \closedsurfaceintegral{S}{\vect{E}} \]
```

$$\oiint_S \vec{E} \cdot \hat{n} \, \mathrm{d}A$$

\openlineintegral{⟨*pathname*⟩}{⟨*vectorname*⟩}

Integral over an open path of the tangential component of a vector field.

```
\[ \openlineintegral{C}{\vect{E}} \]
```

$$\int_C \vec{E} \cdot \hat{t} \, \mathrm{d}\ell$$

\closedlineintegral{⟨*pathname*⟩}{⟨*vectorname*⟩}

Integral over a closed path of the tangential component of a vector field.

```
\[ \closedlineintegral{C}{\vect{E}} \]
```

$$\oint_C \vec{E} \cdot \hat{t} \, \mathrm{d}\ell$$

For line integrals, I have not employed the common $\mathrm{d}\vec{\ell}$ symbol. Instead, I use $\hat{t}\,\mathrm{d}\ell$ for two main reason. The first is that line integrals require the component of a vector that is tangent to a curve, and I use $\hat{t}$ to denote a unit tangent. The second is that the new notation looks more like that for surface integrals.

\volumeintegral{⟨*volumename*⟩}{⟨*integrand*⟩}

Integral over a volume.

```
\[ \volumeintegral{V}{\rho} \]
```

$$\iiint_V \rho \, \mathrm{d}V$$

\dbydt[⟨*operand*⟩]

First time derivative operator.

\DbyDt[⟨*operand*⟩]

Identical to \dbydt but uses Δ.

```
\( \dbydt \) or \( \dbydt x \) or \dbydt[x] \\
\( \DbyDt \) or \( \DbyDt x \) or \DbyDt[x]
```

$\frac{\mathrm{d}}{\mathrm{d}t}$ or $\frac{\mathrm{d}}{\mathrm{d}t}x$ or $\frac{\mathrm{d}x}{\mathrm{d}t}$
$\frac{\Delta}{\Delta t}$ or $\frac{\Delta}{\Delta t}x$ or $\frac{\Delta x}{\Delta t}$

\ddbydt[⟨*operand*⟩]

Second time derivative operator.

\DDbyDt[⟨*operand*⟩]

Identical to \ddbydt but uses Δ.

```
\( \ddbydt \) or \( \ddbydt x \) or \ddbydt[x] \\
\( \DDbyDt \) or \( \DDbyDt x \) or \DDbyDt[x]
```

$\frac{\mathrm{d}^2}{\mathrm{d}t^2}$ or $\frac{\mathrm{d}^2}{\mathrm{d}t^2}x$ or $\frac{\mathrm{d}^2x}{\mathrm{d}t^2}$
$\frac{\Delta^2}{\Delta t^2}$ or $\frac{\Delta^2}{\Delta t^2}x$ or $\frac{\Delta^2x}{\Delta t^2}$

\pbypt[⟨*operand*⟩]

First partial time derivative operator.

```
\( \pbypt \) or \( \pbypt x \) or \pbypt[x]
```

$\frac{\partial}{\partial t}$ or $\frac{\partial}{\partial t}x$ or $\frac{\partial x}{\partial t}$

\ppbypt[⟨*operand*⟩]

Second partial time derivative operator.

```
\( \ppbypt \) or \( \ppbypt x \) or \ppbypt[x]
```

$\frac{\partial^2}{\partial t^2}$ or $\frac{\partial^2}{\partial t^2}x$ or $\frac{\partial^2x}{\partial t^2}$

\dbyd{⟨*dependentvariable*⟩}{⟨*indvar*⟩}

Generic first derivative operator.

\DbyD{⟨*dependentvariable*⟩}{⟨*indvar*⟩}

Identical to \dbyd but uses Δ.

```
\( \dbyd{f}{y} \) \\
\( \DbyD{f}{y} \)
```

$\frac{\mathrm{d}f}{\mathrm{d}y}$
$\frac{\Delta f}{\Delta y}$

\ddbyd{⟨*dependentvariable*⟩}{⟨*indvar*⟩}

Generic second derivative operator.

\DDbyD{⟨*dependentvariable*⟩}{⟨*indvar*⟩}

Identical to \ddbyd but uses Δ.

```
\( \ddbyd{f}{y} \) \\
\( \DDbyD{f}{y} \)
```

$\frac{\mathrm{d}^2f}{\mathrm{d}y^2}$
$\frac{\Delta^2f}{\Delta y^2}$

\pbyp{⟨*dependentvariable*⟩}{⟨*indvar*⟩}

Generic first partial derivative operator.

```
\( \pbyp{f}{y} \)
```

$\frac{\partial f}{\partial y}$

\ppbyp{⟨*dependentvariable*⟩}{⟨*indvar*⟩}

Generic second partial derivative operator.

```
\( \ppbyp{f}{y} \)
```

$\frac{\partial^2f}{\partial y^2}$

\gradient

Gibbs' gradient operator. It's just an alias for `\nabla`.

`\gradient`	$\boldsymbol{\nabla}$

`\divergence`

Gibbs' divergence operator.

`\divergence`	$\boldsymbol{\nabla}\bullet$

`\curl`

Gibbs' curl operator.

`\curl`	$\boldsymbol{\nabla}\times$

`\taigrad`

Tai's gradient operator. It's just an alias for `\nabla`.

`\taigrad`	∇

`\taisvec`

Tai's symbol for symbolic vector.

`\taisvec`	∇

`\taidivg`

Tai's symbol for divergence operator.

`\taidivg`	∇

`\taicurl`

Tai's symbol for curl operator.

`\taicurl`	∇

`\laplacian`

Laplacian operator.

`\laplacian`	$\boldsymbol{\nabla}^2$

`\dalembertian`

D'Alembertian operator.

`\dalembertian`	$\square$

`\seriesfofx`

Series expansion of $f(x)$ around $x = a$.

```
\seriesfofx
```

$f(x) \approx f(a) + \frac{f'(a)}{1!}(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \frac{f'''(a)}{3!}(x-a)^3 + \ldots$

\seriesexpx

Series expansion of e^x.

```
\seriesexpx
```

$e^x \approx 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots$

\seriessinx

Series expansion of $\sin x$.

```
\seriessinx
```

$\sin x \approx x - \frac{x^3}{3!} + \frac{x^5}{5!} - \ldots$

\seriescosx

Series expansion of $\cos x$.

```
\seriescosx
```

$\cos x \approx 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \ldots$

\seriestanx

Series expansion of $\tan x$.

```
\seriestanx
```

$\tan x \approx x + \frac{x^3}{3} + \frac{2x^5}{15} + \ldots$

\seriesatox

Series expansion of a^x.

```
\seriesatox
```

$a^x \approx 1 + x\ln a + \frac{(x\ln a)^2}{2!} + \frac{(x\ln a)^3}{3!} + \ldots$

\serieslnoneplusx

Series expansion of $\ln(1+x)$.

```
\serieslnoneplusx
```

$\ln(1 \pm x) \approx \pm\, x - \frac{x^2}{2} \pm \frac{x^3}{3} - \frac{x^4}{4} \pm \dots$

`\binomialseries`

Series expansion of $(1+x)^n$.

```
\binomialseries
```

$(1+x)^n \approx 1 + nx + \frac{n(n-1)}{2!} x^2 + \dots$

`\diracdelta{⟨arg⟩}`

Dirac delta function.

`\diracdelta{x}`	$\delta(\mathrm{x})$

`\orderof{⟨arg⟩}`

Order of indicator.

`\orderof{x^2}`	$\mathcal{O}(x^2)$

`\eulerlagrange[⟨operand⟩]`

Euler-Lagrange equation.

`\Eulerlagrange[⟨operand⟩]`

Like `\eulerlagrange` but uses Δ.

`\( \eulerlagrange \) or \( \eulerlagrange[x] \) \\` `\( \Eulerlagrange \) or \( \Eulerlagrange[x] \)`	$\frac{\partial \mathcal{L}}{\partial q_i} - \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\partial \mathcal{L}}{\partial \dot{q}_i}\right) = 0$ or $\frac{\partial \mathcal{L}}{\partial x} - \frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\partial \mathcal{L}}{\partial \dot{x}}\right) = 0$ $\frac{\Delta \mathcal{L}}{\Delta q_i} - \frac{\Delta}{\Delta t}\left(\frac{\Delta \mathcal{L}}{\Delta \dot{q}_i}\right) = 0$ or $\frac{\Delta \mathcal{L}}{\Delta x} - \frac{\Delta}{\Delta t}\left(\frac{\Delta \mathcal{L}}{\Delta \dot{x}}\right) = 0$

6.10 Other Useful Commands

`\asin`

Symbol for inverse sine and other inverse circular trig functions.

`\acos`

`\atan`

`\asec`

`\acsc`

`\acot`

`\( \asin, \acos, \atan, \asec, \acsc, \acot \)`	$\sin^{-1}, \cos^{-1}, \tan^{-1}, \sec^{-1}, \csc^{-1}, \cot^{-1}$

`\sech`

Hyperbolic and inverse hyperbolic functions not defined in LaTeX.

`\csch`

`\asinh`

`\acosh`

`\atanh`

`\asech`

`\acsch`

`\acoth`

```
\( \sech, \csch, \asinh, \acosh, \atanh, \asech, \acsch, \acoth \)
```

$\mathrm{sech}, \mathrm{csch}, \sinh^{-1}, \cosh^{-1}, \tanh^{-1}, \mathrm{sech}^{-1}, \mathrm{csch}^{-1}, \coth^{-1}$

`\sgn{⟨arg⟩}`

Signum function.

`\( \sgn \)`	sgn

`\dex`

Decimal exponentiation function (used in astrophysics).

`\( \dex \)`	dex

`\logb[⟨base⟩]`

Logarithm to an arbitrary base.

`\logb 8, \logb[2] 8`	$\log 8, \log_2 8$

`\cB`

Alternate symbol for magnetic field inspired by Tom Moore.

`\cB, \vect{\cB}`	$cB, \vec{cB}$

`\newpi`

Bob Palais' symbol for 2π.

`\newpi`	π

`\scripty{⟨kernel⟩}`

Command to get fonts in Griffiths' electrodynamics textbook.

`\scripty{r}`	$\scripty{r}$

\Lagr

Command to get symbol for Lagrangian.

`\Lagr`	$\mathcal{L}$

\flux[⟨*label*⟩]

Symbol for flux of a vector field.

`\flux, \flux[E]`	Φ, Φ_{E}

\circulation[⟨*label*⟩]

Symbol for circulation of a vector field.

`\circulation, \circulation[E]`	Γ, Γ_{E}

\inparens{⟨*arg*⟩}

Surrounds with argument with parentneses. A blank argument generates a placeholder.

`\inparens{\onehalf}, \inparens{-3}, \inparens{}`	$\left(\frac{1}{2}\right)$, (-3), $(\,\_\,)$

\absof{⟨*arg*⟩}

Absolute value function. A blank argument generates a placeholder.

`\absof{-4}, \absof{}`	$\lvert -4 \rvert$, $\lvert\,\_\,\rvert$

\magof{⟨*arg*⟩}

Magnitude of a quantity (lets you selectively use double bars even when the **singlemagbars** option is use when loading the package). A blank argument generates a placeholder.

`\magof{\vect{E}}, \magof{}`	$\left\lVert \vec{E} \right\rVert$, $\lVert\,\_\,\rVert$

\dimsof{⟨*arg*⟩}

Notation for showing the dimensions of a quantity. A blank argument generates a placeholder.

```
\( \dimsof{\vect{v}} = L \cdot T^{-1} \), \dimsof{}
```

$[\vec{v}] = L \cdot T^{-1}$, $[\,\_\,]$

\unitsof{⟨*arg*⟩}

Notation for showing the units of a quantity. I propose this notation and hope to propagate it because I could not find any standard notation for this same idea in other sources. A blank argument generates a placeholder.

`\unitsof{\vect{v}} = \velocityonlytradunit, \unitsof{}`	$[\vec{v}]_u = \mathrm{m/s}$, $[\ \_\ ]_u$

\Changein{⟨*arg*⟩}

Notation for *the change in a quantity*.

`\Changein{\vect{E}}`	$\Delta\vec{E}$

\xtento{⟨*exponent*⟩}[⟨*unit*⟩]

Command for scientific notation with an optional unit.

\timestento{⟨*exponent*⟩}[⟨*unit*⟩]

Another command for scientific notation with an optional unit.

`2.99\xtento{8}[\velocityonlytradunit] \\` `2.99\timestento{-4}`	2.99×10^{8} m/s 2.99×10^{-4}

\ee{⟨*mantissa*⟩}{⟨*exponent*⟩}

Command for scientific notation for computer code. Units are not used in computer code.

\EE{⟨*mantissa*⟩}{⟨*exponent*⟩}

Identical to \ee but gives capital letters.

`\ee{2.99}{8} \\` `\EE{2.99}{8}`	`2.99e8` `2.99E8`

\dms{⟨*deg*⟩}{⟨*min*⟩}{⟨*sec*⟩}

Command for formatting angles and time. Note that other packages may do this better.

\hms{⟨*deg*⟩}{⟨*min*⟩}{⟨*sec*⟩}

Like \dms but formats time.

`\dms{23}{34}{10.27} \\` `\hms{23}{34}{10.27}`	$23^{\circ}34'10.27''$ $23^{\mathrm{h}}34^{\mathrm{m}}10.27^{\mathrm{s}}$

\clockreading{⟨*hrs*⟩}{⟨*min*⟩}{⟨*sec*⟩}

Command for formatting a clock reading. Really an alias for \hms, but conceptually a very different idea that introductory textbooks don't do a good enough job at articulating.

`\clockreading{23}{34}{10.27}`	$23^{\mathrm{h}}34^{\mathrm{m}}10.27^{\mathrm{s}}$

\latitude{⟨*arg*⟩}

Command for formatting latitude, useful in astronomy.

\latitudeN{⟨*arg*⟩}

Command for formatting latitude with an N for north.

\latitudeS{⟨*arg*⟩}

Command for formatting latitude with an S for north.

`\latitude{+35}, \latitudeN{35}, \latitudeS{35}`	$+35°$, 35° N, 35° S

`\longitude{⟨arg⟩}`
Command for formatting longitude, useful in astronomy. Use `\longitudeE` or `\longitudeW` to include a letter.

`\longitudeE{⟨arg⟩}`
Command for formatting longitude with an E for east.

`\longitudeW{⟨arg⟩}`
Command for formatting longitude with an W for east.

`\longitude{-81}, \longitudeE{81}, \longitudeW{81}`	$-81°$, 81° E, 81° W

`\ssup{⟨kernel⟩}{⟨sup⟩}`
Command for typesetting text superscripts.

`\ssup{N}{contact}`	N^{contact}

`\ssub{⟨kernel⟩}{⟨sub⟩}`
Command for typesetting text subscripts.

`\ssub{N}{AB}`	N_{AB}

`\ssud{⟨sup⟩}{⟨sub⟩}`
Command for typesetting text superscripts and subscripts.

`\ssud{N}{contact}{AB}`	$N^{\text{contact}}_{\text{AB}}$

`\msub{⟨kernel⟩}{⟨sub⟩}`
Command for typesetting mathematical subscripts.

`\msub{R}{\alpha\beta}`	$R_{\alpha\beta}$

`\msud{⟨kernel⟩}{⟨sup⟩}{⟨sub⟩}`
Command for typesetting mathematical superscripts and subscripts.

`\msud{\Gamma}{\gamma}{\alpha\beta}`	$\Gamma^{\gamma}_{\alpha\beta}$

`\levicivita{⟨indices⟩}`
Command for Levi-Civita symbol.

`\levicivita{ijk}`	ε_{ijk}

`\kronecker{⟨indices⟩}`
Command for Kronecker delta symbol.

`\kronecker{ij}`	δ_{ij}

`\xaxis`

Command for coordinate axes.

`\yaxis`

`\zaxis`

`\xaxis, \yaxis, \zaxis`	x-axis, y-axis, z-axis

`\naxis[⟨axis⟩]`

Command for custom naming a coordinate axis.

`\naxis{t}`	t-axis

`\axis`

Suffix command for custom naming a coordinate axis. You are responsible for using math mode if necessary for the thing to which you apply the suffix.

`\(t\axis\)`	t-axis

`\xyplane`

Commands for naming coordinate planes. All combinations are defined.

`\yzplane`

`\zxplane`

`\yxplane`

`\zyplane`

`\xzplane`

```
\xyplane, \yzplane, \zxplane, \yxplane, \zyplane, \xzplane
```

xy-plane, yz-plane, zx-plane, yx-plane, zy-plane, xz-plane

`\plane`

Suffix command for custom naming a coordinate plane. You are responsible for using math mode if necessary for the thing to which you apply the suffix.

`\(xt\)\plane`	xt-plane

`\fsqrt{⟨arg⟩}`

Command for square root as a fractional exponent.

`\fsqrt{x}`	$x^{\frac{1}{2}}$

\cuberoot{⟨*arg*⟩}

Command for cube root of an argument.

\fcuberoot{⟨*arg*⟩}

Command for cube root of an argument as a fractional power.

```
\cuberoot{x} \\
\fcuberoot{x}
```

$\sqrt[3]{x}$
$x^{\frac{1}{3}}$

\fourthroot{⟨*arg*⟩}

Command for fourth root of an argument.

\ffourthroot{⟨*arg*⟩}

Command for fourth root of an argument as a fractional power.

```
\fourthroot{x} \\
\ffourthroot{x}
```

$\sqrt[4]{x}$
$x^{\frac{1}{4}}$

\fifthroot{⟨*arg*⟩}

Command for fifth root of an argument.

\ffifthroot{⟨*arg*⟩}

Command for fifth root of an argument as a fractional power.

```
\fifthroot{x} \\
\ffifthroot{x}
```

$\sqrt[5]{x}$
$x^{\frac{1}{5}}$

\relgamma{⟨*arg*⟩}

Expression for Lorentz factor.

\frelgamma{⟨*arg*⟩}

Expression for Lorentz factor with a fractional power.

```
\begin{mysolution*}
  \gamma &= \relgamma{\magvect{v}} \\
  \gamma &= \frelgamma{\magvect{v}}
\end{mysolution*}
```

$$\gamma = \frac{1}{\sqrt{1-\left(\frac{\|\vec{v}\|}{c}\right)^2}}$$

$$\gamma = \left(1-\frac{\|\vec{v}\|^2}{c^2}\right)^{-\frac{1}{2}}$$

\oosqrtomxs{⟨*arg*⟩}

Commands for **o**ne **o**ver **s**quare root **o**f **o**ne **m**inus **x** **s**quared. Say that out loud and you will see where the name comes from.

\oosqrtomx{⟨*arg*⟩}

Commands for **o**ne **o**ver **s**quare root **o**f **o**ne **m**inus **x**. Say that out loud and you will see where the name comes from.

\oomx{⟨*arg*⟩}

Commands for **o**ne **o**ver **s**quare root **o**f **o**ne **m**inus **x**. Say that out loud and you will see where the name comes from.

\oopx{⟨*arg*⟩}

Commands for **o**ne **o**ver **s**quare root **o**f **o**ne **p**lus **x**. Say that out loud and you will see where the name comes from.

```
\oosqrtomxs{0.22} \\
\oosqrtomx{0.22}  \\
\ooomx{0.22}      \\
\ooopx{0.11}
```

$\frac{1}{\sqrt{1-0.22^2}}$
$\frac{1}{\sqrt{1-0.22}}$
$\frac{1}{1-0.22}$
$\frac{1}{1+0.11}$

6.11 Custom Operators

The = operator is frequently misused. We need other operators for other cases to express conceptual relationships other than, say, mathematical equality. Some of these may seem strange to you but I have found them helpful.

\isequals

Command for *test-for-equality* operator.

```
5 \isequals 3
```

$5 \stackrel{?}{=} 3$

\wordoperator{⟨*firstline*⟩}{⟨*secondline*⟩}

Command for two lines of tiny text to be use as an operator without using mathematical symbols.

\pwordoperator{⟨*firstline*⟩}{⟨*secondline*⟩}

Like \wordoperator but puts parentheses around the operator.

```
\wordoperator{added}{to} \\
\pwordoperator{added}{to}
```

$\substack{\text{added}\\\text{to}}$
$\left(\substack{\text{added}\\\text{to}}\right)$

\definedas

Operator representing a definition.

\pdefinedas

Same as \definedas but puts parentheses around the operator.

\earlierthan

Operator useful for comparing times and clock readings.

\pearlierthan

Same as \earlierthan but puts parentheses around the operator.

\laterthan

Operator useful for comparing times and clock readings.

\platerthan

Same as \laterthan but puts parentheses around the operator.

\adjustedby

Operator useful for comparing times and clock readings.

\padjustedby

Same as \adjustedby but puts parentheses around the operator.

\forevery

Operator for conveying the idea of for every.

\pforevery

Same as \forevery but puts parentheses around the operator.

\associated

Operator representing a conceptual association.

\passociated

Same as \associated but puts parentheses around the operator.

```
\definedas     \\
\pdefinedas    \\
\earlierthan   \\
\pearlierthan  \\
\laterthan     \\
\platerthan    \\
\adjustedby    \\
\padjustedby   \\
\forevery      \\
\pforevery     \\
\associated    \\
\passociated
```

$\overset{\text{defined}}{\text{as}}$
$\left(\overset{\text{defined}}{\text{as}}\right)$
$\overset{\text{earlier}}{\text{than}}$
$\left(\overset{\text{earlier}}{\text{than}}\right)$
$\overset{\text{later}}{\text{than}}$
$\left(\overset{\text{later}}{\text{than}}\right)$
$\overset{\text{adjusted}}{\text{by}}$
$\left(\overset{\text{adjusted}}{\text{by}}\right)$
$\overset{\text{for}}{\text{every}}$
$\left(\overset{\text{for}}{\text{every}}\right)$
$\overset{\text{associated}}{\text{with}}$
$\left(\overset{\text{associated}}{\text{with}}\right)$

\defines

Command for *defines* or *defined by* operator.

```
\vect{p} \defines \(\gamma m\)\vect{v}
```

$\vec{p} \overset{\text{def}}{=} \gamma m \vec{v}$

\inframe[⟨*frame*⟩]

Command for operator indicating the coordinate representation of a vector in a particular reference frame denoted by a capital letter.

```
\vect{p} \inframe[S] \momentum{\mivector{1,2,3}}          \\
\vect{p} \inframe[S’] \momentum{\mivector{\sqrt{14},0,0}}
```

$\vec{p} \underset{S}{\longrightarrow} \langle 1,2,3\rangle\ \text{kg}\cdot\text{m/s}$

$\vec{p} \underset{S'}{\longrightarrow} \left\langle \sqrt{14},0,0\right\rangle\ \text{kg}\cdot\text{m/s}$

\associates

Command for *associated with* or *associates with* operator (for verbal concepts). This is conceptually different from the \associated or \passociated operators.

```
kinetic energy \associates velocity
```

kinetic energy $\xrightarrow{\text{assoc}}$ velocity

`\becomes`

Command for *becomes* operator.

```
\(\gamma m\)\vect{v} \becomes \(m\)\vect{v}
```

$\gamma m\vec{v} \xrightarrow{\text{becomes}} m\vec{v}$

`\rrelatedto{⟨leftoperation⟩}`

Command for left-to-right relationship.

```
(flux ratio) \rrelatedto{taking logarithm} (mag diff)
```

(flux ratio) $\xRightarrow{\text{taking logarithm}}$ (mag diff)

`\lrelatedto{⟨roperation⟩}`

Command for right-to-left relationship.

```
(flux ratio) \lrelatedto{exponentiation} (mag diff)
```

(flux ratio) $\xLeftarrow[\text{exponentiation}]{}$ (mag diff)

`\brelatedto{⟨leftoperation⟩}{⟨roperation⟩}`

Command for bidirectional relationship.

```
(mag diff) \brelatedto{taking logarithm}{exponentiation}(flux ratio)
```

(mag diff) $\xLeftrightarrow[\text{taking logarithm}]{\text{exponentiation}}$(flux ratio)

6.12 Commands Specific to *Matter & Interactions*

While these commands were inspired by *Matter & Interactions*, they can certainly be used in any introductory physics course.

`\momentumprinciple`

Expression for the momentum principle.

`\LHSmomentumprinciple`

Just the left hand side.

`\RHSmomentumprinciple`

Just the right hand side.

`\momentumprinciple \\`
`\LHSmomentumprinciple \\`
`\RHSmomentumprinciple`
	$\vec{p}_{\mathrm{sys,final}} = \vec{p}_{\mathrm{sys,initial}} + \vec{F}_{\mathrm{net,sys}}\Delta t$
	$\vec{p}_{\mathrm{sys,final}}$
	$\vec{p}_{\mathrm{sys,initial}} + \vec{F}_{\mathrm{net,sys}}\Delta t$

`\momentumprinciplediff`

Expression for the momentum principle in differential form.

`\momentumprinciplediff`	$\Delta\vec{p}_{\mathrm{sys}} = \vec{F}_{\mathrm{net,sys}}\Delta t$

`\energyprinciple`

Expression for the energy principle. Processes other than work and thermal energy transfer (e.g. radiation) are neglected.

`\LHSenergyprinciple`

Just the left hand side.

`\RHSenergyprinciple`

Just the right hand side.

`\energyprinciple \\`
`\LHSenergyprinciple \\`
`\RHSenergyprinciple`
	$E_{\mathrm{sys,final}} = E_{\mathrm{sys,initial}} + W + Q$
	$E_{\mathrm{sys,final}}$
	$E_{\mathrm{sys,initial}} + W + Q$

`\energyprinciplediff`

Expression for the energy principle in differential form.

`\energyprinciplediff`	$\Delta E_{\mathrm{sys}} = W + Q$

`\angularmomentumprinciple`

Expression for the angular momentum principle.

`\LHSangularmomentumprinciple`

Just the left hand side.

`\RHSangularmomentumprinciple`

Just the right hand side.

`\angularmomentumprinciple \\`
`\LHSangularmomentumprinciple \\`
`\RHSangularmomentumprinciple`
	$\vec{L}_{A,\mathrm{sys,final}} = \vec{L}_{A,\mathrm{sys,initial}} + \vec{\tau}_{A,\mathrm{net}}\Delta t$
	$\vec{L}_{A,\mathrm{sys,final}}$
	$\vec{L}_{A,\mathrm{sys,initial}} + \vec{\tau}_{A,\mathrm{net}}\Delta t$

`\angularmomentumprinciplediff`

Expression for the angular momentum principle in differential form.

`\angularmomentumprinciplediff`	$\Delta\vec{L}_{A,\mathrm{sys}} = \vec{\tau}_{A,\mathrm{net}}\Delta t$

`\gravitationalinteraction`

Expression for gravitational interaction.

`\gravitationalinteraction`	$G\frac{M_1M_2}{\lVert\vec{r}_{12}\rVert^2}(-\widehat{r}_{12})$

`\electricinteraction`

Expression for electric interaction.

`\electricinteraction`	$\frac{1}{4\pi\epsilon_0}\frac{Q_1Q_2}{\lVert\vec{r}_{12}\rVert^2}\widehat{r}_{12}$

`\springinteraction`

Expression for spring interaction.

`\springinteraction`	$k_s\lVert\vec{s}\rVert(-\widehat{s})$

`\gfieldofparticle`

Expression for a particle's gravitational field.

`\gfieldofparticle`	$G\frac{M}{\lVert\vec{r}\rVert^2}(-\widehat{r})$

`\Efieldofparticle`

Expression for a particle's electric field.

`\Efieldofparticle`	$\frac{1}{4\pi\epsilon_0}\frac{Q}{\lVert\vec{r}\rVert^2}\widehat{r}$

`\Bfieldofparticle`

Expression for a particle's magnetic field.

`\Bfieldofparticle`	$\frac{\mu_0}{4\pi}\frac{Q\lVert\vec{v}\rVert}{\lVert\vec{r}\rVert^2}\widehat{v}\times\widehat{r}$

In the commands that take an optional label, note how to specify initial and final values of quantities.

`\Esys[⟨label⟩]`

Symbol for system energy.

`\Esys, \Esys[final], \Esys[initial]`	E_{sys}, $E_{\text{sys,final}}$, $E_{\text{sys,initial}}$

`\Us[⟨label⟩]`

Symbol for spring potential energy.

`\Us, \Us[final], \Us[initial]`	U_s, $U_{s,\text{final}}$, $U_{s,\text{initial}}$

`\Ug[⟨label⟩]`

Symbol for gravitational potential energy.

`\Ug, \Ug[final], \Ug[initial]`	U_g, $U_{g,\text{final}}$, $U_{g,\text{initial}}$

`\Ue[⟨label⟩]`

Symbol for electric potential energy.

`\Ue, \Ue[final], \Ue[initial]`	U_e, $U_{e,\text{final}}$, $U_{e,\text{initial}}$

`\Ktrans[⟨label⟩]`

Symbol for translational kinetic energy.

`\Ktrans, \Ktrans[final], \Ktrans[initial]`	K_{trans}, $K_{\text{trans,final}}$, $K_{\text{trans,initial}}$

`\Krot[⟨label⟩]`

Symbol for rotational kinetic energy.

`\Krot, \Krot[final], \Krot[initial]`	K_{rot}, $K_{\text{rot,final}}$, $K_{\text{rot,initial}}$

`\Kvib[⟨label⟩]`

Symbol for vibrational kinetic energy.

`\Kvib, \Evib[final], \Evib[initial]`	K_{vib}, $E_{\text{vib,final}}$, $E_{\text{vib,initial}}$

`\Eparticle[⟨label⟩]`

Symbol for particle energy.

`\Eparticle, \Eparticle[final], \Eparticle[initial]`	E_{particle}, $E_{\text{particle,final}}$, $E_{\text{particle,initial}}$

`\Einternal[⟨label⟩]`

Symbol for internal energy.

`\Einternal, \Einternal[final], \Einternal[initial]`	E_{internal}, $E_{\text{internal,final}}$, $E_{\text{internal,initial}}$

`\Erest[⟨label⟩]`

Symbol for rest energy.

`\Erest, \Erest[final], \Erest[initial]`	E_{rest}, $E_{\text{rest,final}}$, $E_{\text{rest,initial}}$

`\Echem[⟨label⟩]`

Symbol for chemical energy.

`\Echem, \Echem[final], \Echem[initial]`	E_{chem}, $E_{\text{chem,final}}$, $E_{\text{chem,initial}}$

`\Etherm[⟨label⟩]`

Symbol for thermal energy.

`\Etherm, \Etherm[final], \Etherm[initial]`	E_{therm}, $E_{\text{therm,final}}$, $E_{\text{therm,initial}}$

\Evib[⟨*label*⟩]

Symbol for vibrational energy.

`\Evib, \Evib[final], \Evib[initial]`	E_{vib}, $E_{\text{vib,final}}$, $E_{\text{vib,initial}}$

\Ephoton[⟨*label*⟩]

Symbol for photon energy.

`\Ephoton, \Ephoton[final], \Ephoton[initial]`	E_{photon}, $E_{\text{photon,final}}$, $E_{\text{photon,initial}}$

\DEsys

Symbol for change in system energy.

`\DEsys`	ΔE_{sys}

\DUs

Symbol for change in spring potential energy.

`\DUs`	ΔU_s

\DUg

Symbol for change in gravitational potential energy.

`\DUg`	ΔU_g

\DUe

Symbol for change in electric potential energy.

`\DUe`	ΔU_e

\DKtrans

Symbol for change in translational kinetic energy.

`\DKtrans`	ΔK_{trans}

\DKrot

Symbol for change in rotational kinetic energy.

`\DKrot`	ΔK_{rot}

\DKvib

Symbol for change in vibrational kinetic energy.

`\DKvib`	ΔK_{vib}

`\DEparticle`

Symbol for change in particle energy.

`\DEparticle`	$\Delta E_{\text{particle}}$

`\DEinternal`

Symbol for change in internal energy.

`\DEinternal`	$\Delta E_{\text{internal}}$

`\DErest`

Symbol for change in rest energy.

`\DErest`	ΔE_{rest}

`\DEchem`

Symbol for change in chemical energy.

`\DEchem`	ΔE_{chem}

`\DEtherm`

Symbol for change in thermal energy.

`\DEtherm`	ΔE_{therm}

`\DEvib`

Symbol for change in vibrational energy.

`\DEvib`	ΔE_{vib}

`\DEphoton`

Symbol for change in photon energy.

`\DEphoton`	ΔE_{photon}

`\springpotentialenergy`

Expression for spring potential energy.

`\springpotentialenergy`	$\frac{1}{2}\,k_s\lVert\vec{s}\rVert^2$

`\finalspringpotentnialenergy`

Expression for final spring potential energy.

`\finalspringpotentialenergy`	$\left(\frac{1}{2}k_s\,\lVert\vec{s}\rVert^2\right)_{\text{final}}$

\initialspringpotentialenergy
Expression for initial spring potential energy.

`\initialspringpotentialenergy`	$\left(\frac{1}{2}k_s \lVert\vec{s}\rVert^2\right)_{\text{initial}}$

\electricpotentialenergy
Expression for electric potential energy.

`\electricpotentialenergy`	$\frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{\lVert\vec{r}_{12}\rVert}$

\finalelectricpotentialenergy
Expression for final electric potential energy.

`\finalelectricpotentialenergy`	$\left(\frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{\lVert\vec{r}_{12}\rVert}\right)_{\text{final}}$

\initialelectricpotentialenergy
Expression for initial electric potential energy.

`\initialelectricpotentialenergy`	$\left(\frac{1}{4\pi\epsilon_0}\frac{Q_1 Q_2}{\lVert\vec{r}_{12}\rVert}\right)_{\text{initial}}$

\gravitationalpotentialenergy
Expression for gravitational potential energy.

`\gravitationalpotentialenergy`	$-G\frac{M_1 M_2}{\lVert\vec{r}_{12}\rVert}$

\finalgravitationalpotentialenergy
Expression for final gravitational potential energy.

`\finalgravitationalpotentialenergy`	$\left(-G\frac{M_1 M_2}{\lVert\vec{r}_{12}\rVert}\right)_{\text{final}}$

\initialgravitationalpotentialenergy
Expression for initial gravitational potential energy.

`\initialgravitationalpotentialenergy`	$\left(-G\frac{M_1 M_2}{\lVert\vec{r}_{12}\rVert}\right)_{\text{initial}}$

\ks
Symbol for spring stiffness.

`\ks`	k_s

\Fnet
Various symbols for net force.

`\Fnet, \Fnetext, \Fnetsys, \Fsub{ball,bat}`	$\vec{F}_{\mathrm{net}}$, $\vec{F}_{\mathrm{net,ext}}$, $\vec{F}_{\mathrm{net,sys}}$, $\vec{F}_{\mathrm{ball,bat}}$

`\Tnet`

Various symbols for net torque.

`\Tnet, \Tnetext, \Tnetsys, \Tsub{ball}`	$\vec{\tau}_{A,\mathrm{net}}$, $\vec{\tau}_{A,\mathrm{net,ext}}$, $\vec{\tau}_{A,\mathrm{net,sys}}$, $\vec{\tau}_{A,\mathrm{ball}}$

`\Ltotal`

Various symbols for total angular momentum.

`\Ltotal, \Lsys, \Lsub{ball}`	$\vec{L}_{A,\mathrm{total}}$, $\vec{L}_{A,\mathrm{sys}}$, $\vec{L}_{A,\mathrm{ball}}$

`\LHSmaxwelliint[`⟨*surfacename*⟩`]`

Left hand side of Maxwell's first equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\LHSmaxwelliint   \\
  &\LHSmaxwelliint[S]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{E} \cdot \widehat{n}\,\mathrm{d}A$$
$$\oiint_{S} \vec{E} \cdot \widehat{n}\,\mathrm{d}A$$

`\RHSmaxwelliint`

Right hand side of Maxwell's first equation in integral form.

```
\[ \RHSmaxwelliint \]
```

$$\frac{Q_{e,\mathrm{net}}}{\epsilon_0}$$

`\RHSmaxwelliinta[`⟨*volumename*⟩`]`

Alternate form of right hand side of Maxwell's first equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwelliinta          \\
  &\RHSmaxwelliinta[\upsilon]
\end{mysolution*}
```

$$\frac{1}{\epsilon_0}\iiint_V \rho_e\,\mathrm{d}V$$
$$\frac{1}{\epsilon_0}\iiint_\upsilon \rho_e\,\mathrm{d}V$$

`\RHSmaxwelliintfree`

Right hand side of Maxwell's first equation in integral form in free space.

```
\[ \RHSmaxwelliintfree \]
```

$$0$$

`\maxwelliint[`⟨*surfacename*⟩`]`

Maxwell's first equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\maxwelliint    \\
  &\maxwelliint[S]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{E} \cdot \widehat{n} \,\mathrm{d}A = \frac{Q_{e,\text{net}}}{\epsilon_0}$$
$$\oiint_{S} \vec{E} \cdot \widehat{n} \,\mathrm{d}A = \frac{Q_{e,\text{net}}}{\epsilon_0}$$

\maxwelliinta[⟨*surfacename*⟩][⟨*volumename*⟩]

Alternate form of Maxwell's first equation in integral form. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwelliinta              \\
  &\maxwelliinta[S][\upsilon]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{E} \cdot \widehat{n} \,\mathrm{d}A = \frac{1}{\epsilon_0} \iiint_V \rho_e \,\mathrm{d}V$$
$$\oiint_{S} \vec{E} \cdot \widehat{n} \,\mathrm{d}A = \frac{1}{\epsilon_0} \iiint_\upsilon \rho_e \,\mathrm{d}V$$

\maxwelliintfree[⟨*surfacename*⟩]

Maxwell's first equation in integral form in free space. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\maxwelliintfree    \\
  &\maxwelliintfree[S]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{E} \cdot \widehat{n} \,\mathrm{d}A = 0$$
$$\oiint_{S} \vec{E} \cdot \widehat{n} \,\mathrm{d}A = 0$$

\LHSmaxwelliiint[⟨*surfacename*⟩]

Left hand side of Maxwell's second equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\LHSmaxwelliiint    \\
  &\LHSmaxwelliiint[S]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{B} \cdot \widehat{n} \,\mathrm{d}A$$
$$\oiint_{S} \vec{B} \cdot \widehat{n} \,\mathrm{d}A$$

\RHSmaxwelliiint

Right hand side of Maxwell's second equation in integral form.

```
\[ \RHSmaxwelliiint \]
```

$$0$$

\RHSmaxwelliiintm

Right hand side of Maxwell's second equation in integral form with magnetic monopoles.

```
\[ \RHSmaxwelliiintm \]
```

$$\mu_0 Q_{m,\text{net}}$$

\RHSmaxwelliiintma[⟨*volumename*⟩]

Alternate form of right hand side of Maxwell's second equation in integral form with magnetic monopoles. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwelliiiintma            \\
  &\RHSmaxwelliiiintma[\upsilon]
\end{mysolution*}
```

$$\mu_0 \iiint_V \rho_m \, \mathrm{d}V$$
$$\mu_0 \iiint_\upsilon \rho_m \, \mathrm{d}V$$

`\RHSmaxwelliiiintfree`

Right hand side of Maxwell's second equation in integral form in free space.

```
\[ \RHSmaxwelliiiintfree \]
```

$$0$$

`\maxwelliiint[⟨surfacename⟩]`

Maxwell's second equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\maxwelliiint    \\
  &\maxwelliiint[S]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{B} \cdot \widehat{n} \, \mathrm{d}A = 0$$
$$\oiint_S \vec{B} \cdot \widehat{n} \, \mathrm{d}A = 0$$

`\maxwelliiintm[⟨surfacename⟩]`

Maxwell's second equation in integral form with magnetic monopoles. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\maxwelliiintm    \\
  &\maxwelliiintm[S]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{B} \cdot \widehat{n} \, \mathrm{d}A = \mu_0 Q_{m,\mathrm{net}}$$
$$\oiint_S \vec{B} \cdot \widehat{n} \, \mathrm{d}A = \mu_0 Q_{m,\mathrm{net}}$$

`\maxwelliiintma[⟨surfacename⟩][⟨volumename⟩]`

Alternate form of Maxwell's second equation in integral form with magnetic monopoles. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwelliiintma            \\
  &\maxwelliiintma[S][\upsilon]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{B} \cdot \widehat{n} \, \mathrm{d}A = \mu_0 \iiint_V \rho_m \, \mathrm{d}V$$
$$\oiint_S \vec{B} \cdot \widehat{n} \, \mathrm{d}A = \mu_0 \iiint_\upsilon \rho_m \, \mathrm{d}V$$

`\maxwelliiintfree[⟨surfacename⟩]`

Maxwell's second equation in integral form in free space. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\maxwelliiintfree    \\
  &\maxwelliiintfree[S]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{B} \cdot \widehat{n} \, \mathrm{d}A = 0$$
$$\oiint_S \vec{B} \cdot \widehat{n} \, \mathrm{d}A = 0$$

\LHSmaxwelliiiint[⟨*boundaryname*⟩]

Left hand side of Maxwell's third equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\LHSmaxwelliiiint    \\
  &\LHSmaxwelliiiint[C]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{E}\cdot\widehat{t}\,\mathrm{d}\ell$$
$$\oint_{C} \vec{E}\cdot\widehat{t}\,\mathrm{d}\ell$$

\RHSmaxwelliiiint[⟨*surfacename*⟩]

Right hand side of Maxwell's third equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwelliiiint    \\
  &\RHSmaxwelliiiint[S]
\end{mysolution*}
```

$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega} \vec{B}\cdot\widehat{n}\,\mathrm{d}A$$
$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S} \vec{B}\cdot\widehat{n}\,\mathrm{d}A$$

\RHSmaxwelliiiintm[⟨*surfacename*⟩]

Right hand side of Maxwell's third equation in integral form with magnetic monopoles. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwelliiiintm    \\
  &\RHSmaxwelliiiintm[S]
\end{mysolution*}
```

$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega} \vec{B}\cdot\widehat{n}\,\mathrm{d}A-\mu_0 I_{m,\text{net}}$$
$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S} \vec{B}\cdot\widehat{n}\,\mathrm{d}A-\mu_0 I_{m,\text{net}}$$

\RHSmaxwelliiiintma[⟨*surfacename*⟩]

Alternate form of right hand side of Maxwell's third equation in integral form with magnetic monopoles. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwelliiiintma    \\
  &\RHSmaxwelliiiintma[S]
\end{mysolution*}
```

$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega} \vec{B}\cdot\widehat{n}\,\mathrm{d}A-\mu_0\iint_{\Omega} \vec{J}_m\cdot\widehat{n}\,\mathrm{d}A$$
$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S} \vec{B}\cdot\widehat{n}\,\mathrm{d}A-\mu_0\iint_{S} \vec{J}_m\cdot\widehat{n}\,\mathrm{d}A$$

\RHSmaxwelliiiintfree[⟨*surfacename*⟩]

Right hand side of Maxwell's third equation in integral form in free space. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwelliiiintfree    \\
  &\RHSmaxwelliiiintfree[S]
\end{mysolution*}
```

$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega} \vec{B}\cdot\widehat{n}\,\mathrm{d}A$$
$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S} \vec{B}\cdot\widehat{n}\,\mathrm{d}A$$

\maxwelliiiint[⟨*boundaryname*⟩][⟨*surfacename*⟩]

Maxwell's third equation in integral form. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwelliiiint         \\
  &\maxwelliiiint[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{E} \cdot \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{dt}} \iint_{\Omega} \vec{B} \cdot \hat{n}\,\mathrm{d}A$$
$$\oint_{C} \vec{E} \cdot \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{dt}} \iint_{S} \vec{B} \cdot \hat{n}\,\mathrm{d}A$$

\maxwelliiiintm[⟨*boundaryname*⟩][⟨*surfacename*⟩]

Maxwell's third equation in integral form with magnetic monopoles. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwelliiiintm        \\
  &\maxwelliiiintm[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{E} \cdot \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{dt}} \iint_{\Omega} \vec{B} \cdot \hat{n}\,\mathrm{d}A - \mu_0 I_{m,\mathrm{net}}$$
$$\oint_{C} \vec{E} \cdot \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{dt}} \iint_{S} \vec{B} \cdot \hat{n}\,\mathrm{d}A - \mu_0 I_{m,\mathrm{net}}$$

\maxwelliiiintma[⟨*boundaryname*⟩][⟨*surfacename*⟩]

Alternate form of Maxwell's third equation in integral form with magnetic monopoles. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwelliiiintma        \\
  &\maxwelliiiintma[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{E} \cdot \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{dt}} \iint_{\Omega} \vec{B} \cdot \hat{n}\,\mathrm{d}A - \mu_0 \iint_{\Omega} \vec{J}_m \cdot \hat{n}\,\mathrm{d}A$$
$$\oint_{C} \vec{E} \cdot \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{dt}} \iint_{S} \vec{B} \cdot \hat{n}\,\mathrm{d}A - \mu_0 \iint_{S} \vec{J}_m \cdot \hat{n}\,\mathrm{d}A$$

\maxwelliiiintfree[⟨*boundaryname*⟩][⟨*surfacename*⟩]

Maxwell's third equation in integral form in free space. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwelliiiintfree        \\
  &\maxwelliiiintfree[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{E} \cdot \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{dt}} \iint_{\Omega} \vec{B} \cdot \hat{n}\,\mathrm{d}A$$
$$\oint_{C} \vec{E} \cdot \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{dt}} \iint_{S} \vec{B} \cdot \hat{n}\,\mathrm{d}A$$

\LHSmaxwellivint[⟨*boundaryname*⟩]

Left hand side of Maxwell's fourth equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\LHSmaxwellivint     \\
  &\LHSmaxwellivint[C]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{B} \cdot \hat{t}\,\mathrm{d}\ell$$
$$\oint_{C} \vec{B} \cdot \hat{t}\,\mathrm{d}\ell$$

\RHSmaxwellivint[⟨*surfacename*⟩]

Right hand side of Maxwell's fourth equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwellivint     \\
  &\RHSmaxwellivint[S]
\end{mysolution*}
```

$$\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_\Omega \vec{E}\cdot\widehat{n}\,\mathrm{d}A+\mu_0 I_{e,\mathrm{net}}$$
$$\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_S \vec{E}\cdot\widehat{n}\,\mathrm{d}A+\mu_0 I_{e,\mathrm{net}}$$

\RHSmaxwellivinta[⟨*surfacename*⟩]

Alternate form of right hand side of Maxwell's fourth equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwellivinta     \\
  &\RHSmaxwellivinta[S]
\end{mysolution*}
```

$$\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_\Omega \vec{E}\cdot\widehat{n}\,\mathrm{d}A+\mu_0\iint_\Omega \vec{J}_e\cdot\widehat{n}\,\mathrm{d}A$$
$$\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_S \vec{E}\cdot\widehat{n}\,\mathrm{d}A+\mu_0\iint_S \vec{J}_e\cdot\widehat{n}\,\mathrm{d}A$$

\RHSmaxwellivintfree[⟨*surfacename*⟩]

Right hand side of Maxwell's fourth equation in integral form in free space. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwellivintfree     \\
  &\RHSmaxwellivintfree[S]
\end{mysolution*}
```

$$\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_\Omega \vec{E}\cdot\widehat{n}\,\mathrm{d}A$$
$$\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_S \vec{E}\cdot\widehat{n}\,\mathrm{d}A$$

\maxwellivint[⟨*boundaryname*⟩][⟨*surfacename*⟩]

Maxwell's fourth equation in integral form. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwellivint       \\
  &\maxwellivint[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega}\vec{B}\cdot\widehat{t}\,\mathrm{d}\ell=\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_\Omega \vec{E}\cdot\widehat{n}\,\mathrm{d}A+\mu_0 I_{e,\mathrm{net}}$$
$$\oint_C\vec{B}\cdot\widehat{t}\,\mathrm{d}\ell=\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_S \vec{E}\cdot\widehat{n}\,\mathrm{d}A+\mu_0 I_{e,\mathrm{net}}$$

\maxwellivinta[⟨*boundaryname*⟩][⟨*surfacename*⟩]

Alternate form of Maxwell's fourth equation in integral form. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwellivinta       \\
  &\maxwellivinta[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega}\vec{B}\cdot\widehat{t}\,\mathrm{d}\ell=\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_\Omega \vec{E}\cdot\widehat{n}\,\mathrm{d}A+\mu_0\iint_\Omega \vec{J}_e\cdot\widehat{n}\,\mathrm{d}A$$
$$\oint_C\vec{B}\cdot\widehat{t}\,\mathrm{d}\ell=\mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_S \vec{E}\cdot\widehat{n}\,\mathrm{d}A+\mu_0\iint_S \vec{J}_e\cdot\widehat{n}\,\mathrm{d}A$$

\maxwellivintfree[⟨*boundaryname*⟩][⟨*surfacename*⟩]

Maxwell's fourth equation in integral form in free space. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwellivintfree          \\
  &\maxwellivintfree[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{B}\cdot\hat{t}\,\mathrm{d}\ell = \mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega} \vec{E}\cdot\hat{n}\,\mathrm{d}A$$
$$\oint_{C} \vec{B}\cdot\hat{t}\,\mathrm{d}\ell = \mu_0\epsilon_0\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S} \vec{E}\cdot\hat{n}\,\mathrm{d}A$$

\LHSmaxwellidif

Left hand side of Maxwell's first equation in differential form.

```
\[ \LHSmaxwellidif \]
```

$$\boldsymbol{\nabla}\bullet\vec{E}$$

\RHSmaxwellidif

Right hand side of Maxwell's first equation in differential form.

```
\[ \RHSmaxwellidif \]
```

$$\frac{\rho_e}{\epsilon_0}$$

\RHSmaxwellidiffree

Right hand side of Maxwell's first equation in differential form in free space.

```
\[ \RHSmaxwellidiffree \]
```

$$0$$

\maxwellidif

Maxwell's first equation in differential form.

```
\[ \maxwellidif \]
```

$$\boldsymbol{\nabla}\bullet\vec{E} = \frac{\rho_e}{\epsilon_0}$$

\maxwellidiffree

Maxwell's first equation in differential form in free space.

```
\[ \maxwellidiffree \]
```

$$\boldsymbol{\nabla}\bullet\vec{E} = 0$$

\LHSmaxwelliidif

Left hand side of Maxwell's second equation in differential form.

```
\[ \LHSmaxwelliidif \]
```

$$\boldsymbol{\nabla}\bullet\vec{B}$$

\RHSmaxwelliidif

Right hand side of Maxwell's second equation in differential form.

```
\[ \RHSmaxwelliidif \]
```

$$0$$

\RHSmaxwelliidifm

Right hand side of Maxwell's second equation in differential form with magnetic monopoles.

```
\[ \RHSmaxwelliidifm \]
```

$$\mu_0\rho_m$$

\RHSmaxwelliidiffree
Right hand side of Maxwell's second equation in differential form in free space.

`\[ \RHSmaxwelliidiffree \]`	0

\maxwelliidif
Maxwell's second equation in differential form.

`\[ \maxwelliidif \]`	$\boldsymbol{\nabla} \bullet \vec{B} = 0$

\maxwelliidifm
Maxwell's second equation in differential form with magnetic monopoles.

`\[ \maxwelliidifm \]`	$\boldsymbol{\nabla} \bullet \vec{B} = \mu_0 \rho_m$

\maxwellidiiffree
Maxwell's second equation in differential form in free space.

`\[ \maxwelliidiffree \]`	$\boldsymbol{\nabla} \bullet \vec{B} = 0$

\LHSmaxwelliiidif
Left hand side of Maxwell's third equation in differential form.

`\[ \LHSmaxwelliiidif \]`	$\boldsymbol{\nabla} \times \vec{E}$

\RHSmaxwelliiidif
Right hand side of Maxwell's third equation in differential form.

`\[ \RHSmaxwelliiidif \]`	$-\dfrac{\partial \vec{B}}{\partial t}$

\RHSmaxwelliiidifm
Right hand side of Maxwell's third equation in differential form with magnetic monopoles.

`\[ \RHSmaxwelliiidifm \]`	$-\dfrac{\partial \vec{B}}{\partial t} - \mu_0 \vec{J}_m$

\RHSmaxwelliiidiffree
Right hand side of Maxwell's third equation in differential form in free space.

`\[ \RHSmaxwelliiidiffree \]`	$-\dfrac{\partial \vec{B}}{\partial t}$

\maxwelliiidif
Maxwell's third equation in differential form.

`\[ \maxwelliiidif \]`	$$\nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$

`\maxwelliiidifm`
Maxwell's third equation in differential form with magnetic monopoles.

`\[ \maxwelliiidifm \]`	$$\nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t} - \mu_0\vec{J}_m$$

`\maxwelliiidiffree`
Maxwell's third equation in differential form in free space.

`\[ \maxwelliiidiffree \]`	$$\nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$

`\LHSmaxwellivdif`
Left hand side of Maxwell's fourth equation in differential form.

`\[ \LHSmaxwellivdif \]`	$$\nabla\times\vec{B}$$

`\RHSmaxwellivdif`
Right hand side of Maxwell's fourth equation in differential form.

`\[ \RHSmaxwellivdif \]`	$$\mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t} + \mu_0\vec{J}_e$$

`\RHSmaxwellivdiffree`
Right hand side of Maxwell's fourth equation in differential form in free space.

`\[ \RHSmaxwellivdiffree \]`	$$\mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t}$$

`\maxwellivdif`
Maxwell's fourth equation in differential form.

`\[ \maxwellivdif \]`	$$\nabla\times\vec{B} = \mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t} + \mu_0\vec{J}_e$$

`\maxwellivdiffree`
Maxwell's fourth equation in differential form in free space.

`\[ \maxwellivdiffree \]`	$$\nabla\times\vec{B} = \mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t}$$

`\RHSlorentzforce`
Right hand side of Lorentz force.

```
\[ \RHSlorentzforce \]
```

$$q_e\left(\vec{E}+\vec{v}\times\vec{B}\right)$$

\RHSlorentzforcem

Right hand side of Lorentz force with magnetic monopoles.

```
\[ \RHSlorentzforcem \]
```

$$q_e\left(\vec{E}+\vec{v}\times\vec{B}\right)+q_m\left(\vec{B}-\vec{v}\times\frac{\vec{E}}{c^2}\right)$$

6.13 VPython and GlowScript Code

There are three ways to deal with VPython[2] and GlowScript[3] code. With very few exceptions, VPython code and GlowScript code are identical. The commands with **vpython** in their names can handle both, but for semantic completeness there are corresponding commands with **glowscript** in their names. Because Classic VPython will no longer be developed, the first line of all VPython programs not used in GlowScript will conform to Jupyter syntax.

\vpythonline{⟨*vpythoncode*⟩}

Command for a single line of VPython or GlowScript code used inline.

```
\vpythonline{from vpython import *}
```

from vpython import *

\glowscriptline{⟨*glowscriptcode*⟩}

Command for a single line of GlowScript code used inline. Note that with very few exceptions, GlowScript code is identical to VPython code.

```
\glowscriptline{xyplane = box(pos=vector(0,0,0),length=10,width=10,height=0.05)}
```

xyplane = **box**(**pos**=**vector**(0,0,0),**length**=10,**width**=10,**height**=0.05)

\begin{vpythonblock}[⟨*caption*⟩]
⟨*environment content*⟩
\end{vpythonblock}

Environment for a block of VPython or GlowScript code.

[2]See the VPython home page at https://vpython.org/ for more information.
[3]See the GlowScript home page at https://glowscript.org/ for more information.

```
\begin{vpythonblock}[Example VPython Listing]
  from vpython import *

  sphere(pos=vector(1,2,3),color=color.green)
  # create a named arrow
  MyArrow=arrow(pos=earth.pos,axis=fscale*Fnet,color=color.green)
  print ("arrow.pos = "), arrow.pos
\end{vpythonblock}
```

```
from vpython import *

sphere(pos=vector(1,2,3),color=color.green)
# create a named arrow
MyArrow=arrow(pos=earth.pos,axis=fscale*Fnet,color=color.green)
print ("arrow.pos␣=␣"), arrow.pos
```

Listing 1: Example VPython Listing

\begin{glowscriptblock}[⟨*caption*⟩]
⟨*environment content*⟩
\end{glowscriptblock}

Environment for a block of GlowScript code.

```
\begin{glowscriptblock}[Example GlowScript Listing]
GlowScript 2.3 VPython

Aarr = arrow(pos=vector(0,0,0),axis=A,color=color.red)
label(pos=Aarr.axis,text='A')
Barr = arrow(pos=vector(0,0,0),axis=B,color=color.blue)
label(pos=Barr.axis,text='B')
Carr = arrow(pos=vector(0,0,0),axis=C,color=color.green)
label(pos=Carr.axis,text='C')
\end{glowscriptblock}
```

```
GlowScript 2.3 VPython

Aarr = arrow(pos=vector(0,0,0),axis=A,color=color.red)
label(pos=Aarr.axis,text='A')
Barr = arrow(pos=vector(0,0,0),axis=B,color=color.blue)
label(pos=Barr.axis,text='B')
Carr = arrow(pos=vector(0,0,0),axis=C,color=color.green)
label(pos=Carr.axis,text='C')
```

Listing 2: Example GlowScript Listing

\vpythonfile[⟨*caption*⟩]⟨*filename*⟩

Typesets a file in the current directory containing VPython code. The listing will begin on a new page.

\glowscriptfile[⟨*caption*⟩]⟨*filename*⟩

Functionally identical to \vpythonfile.

```
\vpythonfile[vdemo.py]{vdemo.py}
```

```python
#
from vpython import *

G = 6.7e-11

# create objects
giant = sphere(pos=vector(-1e11,0,0),radius=2e10,mass=2e30,color=color.red)
giant.p = vector(0,0,-1e4) * giant.mass
dwarf = sphere(pos=vector(1.5e11,0,0),radius=1e10,mass=1e30,color=color.yellow)
dwarf.p = -giant.p

for a in [giant,dwarf]:
  a.orbit = curve(color=a.color,radius=2e9)

dt = 86400
while 1:
  rate(100)
  dist = dwarf.pos - giant.pos
  force = G * giant.mass * dwarf.mass * dist / mag(dist)**3
  giant.p = giant.p + force*dt
  dwarf.p = dwarf.p - force*dt
  for a in [giant,dwarf]:
    a.pos = a.pos + a.p/a.mass * dt
    a.orbit.append(pos=a.pos)
```

Listing 3: vdemo.py

6.14 Boxes and Environments

`\emptyanswer[⟨wdth⟩][⟨hght⟩]`

Typesets empty space for filling answer boxes, so there is nothing to see.

```
\emptyanswer[0.75][0.2]
```

```
\begin{activityanswer}[⟨bgclr⟩][⟨frmclr⟩][⟨txtclr⟩][⟨wdth⟩][⟨hght⟩]
 ⟨environment content⟩
\end{activityanswer}
```

Main environment for typesetting boxed answers.

```
\begin{activityanswer}
  Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
  Morbi commodo, ipsum sed pharetra gravida, orci magna
  rhoncus neque, id pulvinar odio lorem non turpis. Nullam
  sit amet enim.
\end{activityanswer}
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

\begin{adjactivityanswer}[⟨*bgclr*⟩][⟨*frmclr*⟩][⟨*txtclr*⟩][⟨*wdth*⟩][⟨*hght*⟩]
⟨*environment content*⟩
\end{adjactivityanswer}

Like activityanswer→ P. 106 but adjusts vertically to tightly surround text.

```
\begin{adjactivityanswer}
  Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi
  commodo, ipsum sed pharetra gravida, orci magna rhoncus neque,
  id pulvinar odio lorem non turpis. Nullam sit amet enim.
  Suspendisse id velit vitae ligula volutpat condimentum. Aliquam
  erat volutpat. Sed quis velit. Nulla facilisi. Nulla libero.
  Vivamus pharetra posuere sapien. Nam consectetuer. Sed aliquam,
  nunc eget euismod ullamcorper, lectus nunc ullamcorper orci,
  fermentum bibendum enim nibh eget ipsum. Donec porttitor ligula
  eu dolor. Maecenas vitae nulla consequat libero cursus venenatis.
  Nam magna enim, accumsan eu, blandit sed, blandit a, eros.
\end{adjactivityanswer}
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim. Suspendisse id velit vitae ligula volutpat condimentum. Aliquam erat volutpat. Sed quis velit. Nulla facilisi. Nulla libero. Vivamus pharetra posuere sapien. Nam consectetuer. Sed aliquam, nunc eget euismod ullamcorper, lectus nunc ullamcorper orci, fermentum bibendum enim nibh eget ipsum. Donec porttitor ligula eu dolor. Maecenas vitae nulla consequat libero cursus venenatis. Nam magna enim, accumsan eu, blandit sed, blandit a, eros.

\emptybox[⟨*txt*⟩][⟨*bgclr*⟩][⟨*frmclr*⟩][⟨*txtclr*⟩][⟨*wdth*⟩][⟨*hght*⟩]

Provides a fixed-size box with optional text.

```
\emptybox[Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque,
id pulvinar odio lorem non turpis. Nullam sit amet enim.]
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

`\adjemptybox[⟨txt⟩][⟨bgclr⟩][⟨frmclr⟩][⟨txtclr⟩][⟨wdth⟩][⟨hght⟩]`

Like `\emptybox` → P. 107 but adjusts vertically to tightly surround text.

```
\adjemptybox[Lorem ipsum dolor sit amet, consectetuer adipiscing
elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus
neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.]
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

`\answerbox[⟨txt⟩][⟨bgclr⟩][⟨frmclr⟩][⟨txtclr⟩][⟨wdth⟩][⟨hght⟩]`

Wrapper for `\emptybox` → P. 107.

```
\answerbox[Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque,
id pulvinar odio lorem non turpis. Nullam sit amet enim.]
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

`\adjanswerbox[⟨txt⟩][⟨bgclr⟩][⟨frmclr⟩][⟨txtclr⟩][⟨wdth⟩][⟨hght⟩]`

Wrapper for `\adjemptybox`.

```
\adjanswerbox[Lorem ipsum dolor sit amet, consectetuer adipiscing
elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus
neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.]
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

`\smallanswerbox`[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 0.10 that of current `\textheight` and width 0.90 that of current `\linewidth`.

```
\smallanswerbox[][red]
```

`\mediumanswerbox`[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 0.20 that of current `\textheight` and width 0.90 that of current `\linewidth`.

```
\mediumanswerbox[][lightgray]
```

`\largeanswerbox`[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 0.25 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\largeanswerbox[][lightgray]
```

`\largeranswerbox[⟨txt⟩][⟨bgclr⟩]`

Answer box with height 0.33 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\largeranswerbox[][lightgray]
```

`\hugeanswerbox[⟨txt⟩][⟨bgclr⟩]`

Answer box with height 0.50 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\hugeanswerbox[][lightgray]
```

`\hugeranswerbox[⟨txt⟩][⟨bgclr⟩]`

Answer box with height 0.75 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\hugeranswerbox[][lightgray]
```

`\fullpageanswerbox[⟨txt⟩][⟨bgclr⟩]`

Answer box with height 1.00 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\fullpageanswerbox[][lightgray]
```

`\smallanswerform[⟨name⟩][⟨prompt⟩]`

Editable answer form with height 0.10 that of current `\textheight` and width 0.90 that of current `\linewidth`. The first argument isn't really optional, and *must* be different for each form used. Content can be typed in the box and saved with a PDF editor or viewer that supports PDF forms.

```
\smallanswerform[a1][Type your response here.]
```

Type your response here.

`\mediumanswerform[⟨name⟩][⟨prompt⟩]`

Editable answer form with height 0.20 that of current `\textheight` and width 0.90 that of current `\linewidth`. The first argument isn't really optional, and **must** be different for each form used. Content can be typed in the box and saved with a PDF editor or viewer that supports PDF forms.

```
\mediumanswerform[a1][Type your response here.]
```

Type your response here.

`\largeanswerform[⟨name⟩][⟨prompt⟩]`

Editable answer form with height 0.25 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\largeanswerform[a1][Type your response here.]
```

`\largeranswerform[⟨name⟩][⟨prompt⟩]`

Editable answer form with height 0.33 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\largeranswerform[a1][Type your response here.]
```

`\hugeanswerform[⟨name⟩][⟨prompt⟩]`

Editable answer form with height 0.50 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\hugeanswerform[a1][Type your response here.]
```

`\hugeranswerform[⟨name⟩][⟨prompt⟩]`

Editable answer form with height 0.75 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\hugeranswerform[a1][Type your response here.]
```

`\fullpageanswerform[⟨name⟩][⟨prompt⟩]`

Editable answer form with height 1.00 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\fullpageanswerform[a1][Type your response here.]
```

\begin{miinstructornote}
⟨*environment content*⟩
\end{miinstructornote}

Environment for highlighting notes to instructors.

```
\begin{miinstructornote}
  Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
  enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
  neque dolor, adipiscing sed, consectetuer et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetuer in, blandit sed,
  suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
  mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
  purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
  Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
  interdum sapien.
\end{miinstructornote}
```

INSTRUCTOR NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetuer et, lacinia sit amet, quam. Suspendisse wisi quam, consectetuer in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

\begin{mistudentnote}
⟨*environment content*⟩
\end{mistudentnote}

Environment for highlighting notes to students.

```
\begin{mistudentnote}
  Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
  enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
  neque dolor, adipiscing sed, consectetuer et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetuer in, blandit sed,
  suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
  mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
  purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
  Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
  interdum sapien.
\end{mistudentnote}
```

STUDENT NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetuer et, lacinia sit amet, quam. Suspendisse wisi quam, consectetuer in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

```
\begin{miderivation}
  ⟨environment content⟩
\end{miderivation}
```

Environment for mathematical derivations based on the `align` environment. See `mysolution` → P. 117 for how to handle long lines in this environment. Note that using this environment resets the counter for equation numbering. If you want continuous numbering throughout your document, use the `align` environment.

```
\begin{miderivation*}
  ⟨environment content⟩
\end{miderivation*}
```

Like `miderivation` but suppresses line numbers.

```
\begin{miderivation}
  \gamma        &= \relgamma{\magvect{v}} && \text{given}                \\
  \gamma\squared &= \ooomx{\inparens{\frac{\magvect{v}}{c}}\squared}
    &&\text{square both sides}                                          \\
  \frac{1}{\gamma\squared} &= 1-\inparens{\frac{\magvect{v}}{c}}\squared
    &&\text{reciprocal of both sides}                                   \\
  \inparens{\frac{\magvect{v}}{c}}\squared &= 1-\frac{1}{\gamma\squared}
    &&\text{rearrange}                                                  \\
  \frac{\magvect{v}}{c} &= \sqrt{1-\frac{1}{\gamma\squared}}
    &&\text{square root of both sides}
\end{miderivation}
```

DERIVATION

$$\gamma = \frac{1}{\sqrt{1-\left(\frac{\|\vec{v}\|}{c}\right)^2}} \qquad \text{given} \qquad (1)$$

$$\gamma^2 = \frac{1}{1-\left(\frac{\|\vec{v}\|}{c}\right)^2} \qquad \text{square both sides} \qquad (2)$$

$$\frac{1}{\gamma^2} = 1-\left(\frac{\|\vec{v}\|}{c}\right)^2 \qquad \text{reciprocal of both sides} \qquad (3)$$

$$\left(\frac{\|\vec{v}\|}{c}\right)^2 = 1-\frac{1}{\gamma^2} \qquad \text{rearrange} \qquad (4)$$

$$\frac{\|\vec{v}\|}{c} = \sqrt{1-\frac{1}{\gamma^2}} \qquad \text{square root of both sides} \qquad (5)$$

\begin{**mistandard**}
⟨*environment content*⟩
\end{**mistandard**}

Environment for standards for standards-based grading.

```
\begin{mistandard}
  I can create a standard which reflects deep student learning.
\end{mistandard}
```

STANDARD

I can create a standard which reflects deep student learning.

\begin{**bwinstructornote**}
⟨*environment content*⟩
\end{**bwinstructornote**}

Like miinstructornote →P. 112 but in black and grey.

```
\begin{bwinstructornote}
  Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
  enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
  neque dolor, adipiscing sed, consectetuer et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetuer in, blandit sed,
  suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
  mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
  purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
  Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
  interdum sapien.
\end{bwinstructornote}
```

INSTRUCTOR NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetuer et, lacinia sit amet, quam. Suspendisse wisi quam, consectetuer in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

`\begin{bwstudentnote}`
  ⟨*environment content*⟩
`\end{bwstudentnote}`

Like `mistudentnote` → P. 112 but in black and grey.

```
\begin{bwstudentnote}
  Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
  enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
  neque dolor, adipiscing sed, consectetuer et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetuer in, blandit sed,
  suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
  mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
  purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
  Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
  interdum sapien.
\end{bwstudentnote}
```

STUDENT NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetuer et, lacinia sit amet, quam. Suspendisse wisi quam, consectetuer in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

```
\begin{bwderivation}
  ⟨environment content⟩
\end{bwderivation}
```

Like `miderivation`→ P. 113 but in black and grey. See `mysolution`→ P. 117 for how to handle long lines in this environment.

```
\begin{bwderivation*}
  ⟨environment content⟩
\end{bwderivation*}
```

Like `bwderivation` but suppresses line numbers.

```
\begin{bwderivation}
  \gamma &= \relgamma{\magvect{v}} && \text{given}                    \\
  \gamma\squared &= \ooomx{\inparens{\frac{\magvect{v}}{c}}\squared}
    &&\text{square both sides}                                         \\
  \frac{1}{\gamma\squared} &= 1-\inparens{\frac{\magvect{v}}{c}}\squared
    &&\text{reciprocal of both sides}                                  \\
  \inparens{\frac{\magvect{v}}{c}}\squared &= 1-\frac{1}{\gamma\squared}
    &&\text{rearrange}                                                 \\
  \frac{\magvect{v}}{c}&=\sqrt{1-\frac{1}{\gamma\squared}}
    &&\text{square root of both sides}
\end{bwderivation}
```

DERIVATION

$$\gamma = \frac{1}{\sqrt{1-\left(\frac{\|\vec{v}\|}{c}\right)^2}} \qquad \text{given} \qquad (1)$$

$$\gamma^2 = \frac{1}{1-\left(\frac{\|\vec{v}\|}{c}\right)^2} \qquad \text{square both sides} \qquad (2)$$

$$\frac{1}{\gamma^2} = 1-\left(\frac{\|\vec{v}\|}{c}\right)^2 \qquad \text{reciprocal of both sides} \qquad (3)$$

$$\left(\frac{\|\vec{v}\|}{c}\right)^2 = 1-\frac{1}{\gamma^2} \qquad \text{rearrange} \qquad (4)$$

$$\frac{\|\vec{v}\|}{c} = \sqrt{1-\frac{1}{\gamma^2}} \qquad \text{square root of both sides} \qquad (5)$$

```
\begin{bwstandard}
  ⟨environment content⟩
\end{bwstandard}
```

Like `mistandard`→ P. 114 but in black and grey.

```
\begin{bwstandard}
  I can create a standard which reflects deep student learning.
\end{bwstandard}
```

STANDARD

I can create a standard which reflects deep student learning.

```
\begin{mysolution}
  ⟨environment content⟩
\end{mysolution}
```

Alias for simple environment for mathematical derivations based on the `align` environment. The second example shows how to handle long lines for this and the derivation environments.

```
\begin{mysolution*}
  ⟨environment content⟩
\end{mysolution*}
```

Like `mysolution` but suppresses line numbers.

```latex
\begin{mysolution}
  \gamma &= \relgamma{\magvect{v}}
    && \text{given}                                                    \\
  \gamma\squared &= \ooomx{\inparens{\frac{\magvect{v}}{c}}\squared}
    &&\text{square both sides}                                         \\
  \frac{1}{\gamma\squared} &= 1-\inparens{\frac{\magvect{v}}{c}}\squared
    &&\text{reciprocal of both sides}                                  \\
  \inparens{\frac{\magvect{v}}{c}}\squared &= 1-\frac{1}{\gamma\squared}
    &&\text{rearrange}                                                 \\
  \frac{\magvect{v}}{c} &= \sqrt{1-\frac{1}{\gamma\squared}}
    &&\text{square root of both sides}
\end{mysolution}
\begin{mysolution*}
  \vect{E} &= \electricfield{\mivector{1,2,3}} + \electricfield{\mivector{2,4,6}}
    \nonumber                                                              \\
  &\hphantom{{}=\electricfield{\mivector{1,1,1}}+\electricfield{\mivector{3,5,6}}
    &&\text{superposition}                                                 \\
  \vect{E} &= \electricfield{\mivector{2,3,4}} + \electricfield{\mivector{2,4,6}}
    \nonumber                                                              \\
  &+ \electricfield{\mivector{1,1,1}} +\electricfield{\mivector{3,5,6}}
    &&\text{superposition again}                                           \\
  \vect{E} &= \electricfield{\mivector{2,3,4}} + \electricfield{\mivector{2,4,6}}
    \nonumber                                                              \\
  &\quad + \electricfield{\mivector{1,1,1}} +\electricfield{\mivector{3,5,6}}
    && \text{more superposition}
\end{mysolution*}
```

$$\gamma = \frac{1}{\sqrt{1-\left(\frac{\|\vec{v}\|}{c}\right)^2}} \qquad \text{given} \tag{1}$$

$$\gamma^2 = \frac{1}{1-\left(\frac{\|\vec{v}\|}{c}\right)^2} \qquad \text{square both sides} \tag{2}$$

$$\frac{1}{\gamma^2} = 1-\left(\frac{\|\vec{v}\|}{c}\right)^2 \qquad \text{reciprocal of both sides} \tag{3}$$

$$\left(\frac{\|\vec{v}\|}{c}\right)^2 = 1-\frac{1}{\gamma^2} \qquad \text{rearrange} \tag{4}$$

$$\frac{\|\vec{v}\|}{c} = \sqrt{1-\frac{1}{\gamma^2}} \qquad \text{square root of both sides} \tag{5}$$

$$\begin{aligned}
\vec{E} &= \langle 1,2,3\rangle\ \mathrm{N/C} + \langle 2,4,6\rangle\ \mathrm{N/C} \\
&\hphantom{{}=\langle 1,1,1\rangle\ \mathrm{N/C}} + \langle 3,5,6\rangle\ \mathrm{N/C} && \text{superposition} \\
\vec{E} &= \langle 2,3,4\rangle\ \mathrm{N/C} + \langle 2,4,6\rangle\ \mathrm{N/C} \\
&+ \langle 1,1,1\rangle\ \mathrm{N/C} + \langle 3,5,6\rangle\ \mathrm{N/C} && \text{superposition again} \\
\vec{E} &= \langle 2,3,4\rangle\ \mathrm{N/C} + \langle 2,4,6\rangle\ \mathrm{N/C} \\
&\quad + \langle 1,1,1\rangle\ \mathrm{N/C} + \langle 3,5,6\rangle\ \mathrm{N/C} && \text{more superposition}
\end{aligned}$$

\begin{problem}{⟨*problemname*⟩}
⟨*environment content*⟩
\end{problem}

Creates a simple environment for problem solutions. This environment is mainly for students. Each new problem starts on a new page in an effort to force organization upon students. The environment also creates a new `enumerate` environment called `parts` for which labels are alphabetic, reflecting the organization of multipart textbook problems. The `\item` command is renamed `\problempart` to, again, help with organization for newcomers to LaTeX. A typical example would be structured as follows.

```
\begin{problem}{Chapter 2 Problem 1}
This problem has two parts.
\begin{parts}
  \problempart
  This is the first part
  \problempart
  This is the second part
\end{parts}
\end{problem}
```

Chapter 2 Problem 1

This problem has two parts.

(a) This is the first part

(b) This is the second part

\reason{⟨*text*⟩}

In a `mysolution` → P. 117 environment, this aligns the text arguments with the end of the longest line and nicely handles line wrapping. Make sure your margins are narrow enough. You may need to experiment.

```
\begin{mysolution}
  c^2 &= a^2 + b^2 && \reason{given}      \\
  a^2 &= c^2 - b^2 && \reason{Rearrange, and add some extra text just for fun.} \\
  a &= \sqrt{c^2 - b^2} && \reason{Take square root of both sides.}
\end{mysolution}
```

$$c^2 = a^2 + b^2 \qquad \text{given} \tag{1}$$

$$a^2 = c^2 - b^2 \qquad \text{Rearrange, and add some extra text just for fun.} \tag{2}$$

$$a = \sqrt{c^2 - b^2} \qquad \text{Take square root of both sides.} \tag{3}$$

6.15 Miscellaneous Commands

`\checkpoint`

Centered checkpoint for student discussion.

```
\checkpoint
```

|——— CHECKPOINT ———|

`\image[⟨scaleorsizes⟩]{⟨imagefilename⟩}{⟨caption⟩}{⟨label⟩}`

Centered figure displayed actual size with caption. The optional argument can be a scale factor (with 1 being the original image size), explicit `width` and/or `height` parameters, or even an `angle` for rotating the image. Be sure to give each image a unique label. This allows you to refer back to the image subsequently just by using the label.

```
\image{sampleimage.pdf}{An image shown actual size.}{img-label1}
\image[scale=1.5]{sampleimage.pdf}{An image scaled by 1.5 times.}{img-label2}
\image[height=1cm,width=2cm]{sampleimage.pdf}{An image resized.}{img-label3}
\image[width=0.8\textwidth]{sampleimage.pdf}{An image 80 percent the text width.}{img-label4}
\image[angle=45]{sampleimage.pdf}{An image actual size, rotated.}{img-label5}
```

`\sneakyone{⟨thing⟩}`

Shows argument as a sneaky one.

```
\sneakyone{\frac{\m}{\m}}
```

$\cancelto{1}{\frac{m}{m}}$

`\parallelto{⟨thing⟩}`

A better looking parallel symbol whose height is the same as the perpendicular symbol's height.

```
\(\vect{A}_{\parallelto\vect{B}}\) and ⤸
    ⤷\(\vect{A}_{\perpendicularto\vect{B}}\)
```

$\vec{A}_{\parallel\vec{B}}$ and $\vec{A}_{\perp\vec{B}}$

`\perpendicularto{⟨thing⟩}`

An alias for the perpendicular symbol.

```
\(\vect{A}_{\parallelto\vect{B}}\) and ⤸
    ⤷\(\vect{A}_{\perpendicularto\vect{B}}\)
```

$\vec{A}_{\parallel\vec{B}}$ and $\vec{A}_{\perp\vec{B}}$

`\qed`

Command for QED symbol.

```
\qed
```

Q.E.D.

7 Source Code

Note the packages that must be present.

```
\RequirePackage{amsmath}
\RequirePackage{amssymb}
\RequirePackage{array}
\RequirePackage{cancel}
\RequirePackage[dvipsnames]{xcolor}
\RequirePackage{enumitem}
\RequirePackage{environ}
\RequirePackage{esint}
\RequirePackage[g]{esvect}
\RequirePackage{etoolbox}
\RequirePackage{filehook}
\RequirePackage{extarrows}
\RequirePackage{float}
\RequirePackage[T1]{fontenc}
\RequirePackage{graphicx}
\RequirePackage{epstopdf}
\RequirePackage{textcomp}
\RequirePackage{letltxmacro}
\RequirePackage{listings}
\RequirePackage{mathtools}
\RequirePackage[framemethod=TikZ]{mdframed}
\RequirePackage{stackengine}
\RequirePackage{suffix}
\RequirePackage{tensor}
\RequirePackage{xargs}
\RequirePackage{xparse}
\RequirePackage{xspace}
\RequirePackage{ifthen}
\RequirePackage{calligra}
\RequirePackage[hypertexnames=false]{hyperref}
\hypersetup{colorlinks=true,urlcolor=blue}
\DeclareMathAlphabet{\mathcalligra}{T1}{calligra}{m}{n}
\DeclareFontShape{T1}{calligra}{m}{n}{<->s*[2.2]callig15}{}
\DeclareGraphicsRule{.tif}{png}{.png}{`convert #1 `basename #1 .tif`.png}
\DeclareMathAlphabet{\mathpzc}{OT1}{pzc}{m}{it}
\usetikzlibrary{shadows}
\definecolor{vbgcolor}{rgb}{1,1,1}           % background for code listings
\definecolor{vshadowcolor}{rgb}{0.5,0.5,0.5} % shadow for code listings
\lstdefinestyle{vpython}{%                   % style for code listings
  language=Python,%                          % select language
  morekeywords={__future__,division,append,  % VPython/GlowScript specific keywords
  arange,arrow,astuple,axis,background,black,blue,cyan,green,%
  magenta,orange,red,white,yellow,border,box,color,comp,%
  cone,convex,cross,curve,cylinder,degrees,diff_angle,dot,ellipsoid,extrusion,faces,%
  font,frame,graphs,headlength,height,headwidth,helix,index,interval,label,length,%
  line,linecolor,mag,mag2,make_trail,material,norm,normal,objects,opacity,points,pos,%
```

```
  print,print_function,proj,pyramid,radians,radius,rate,retain,ring,rotate,scene,%
  shaftwidth,shape,sign,size,space,sphere,text,trail_object,trail_type,True,twist,up,%
  vector,visual,width,offset,yoffset,GlowScript,VPython,vpython,trail_color,%
  trail_radius,pps,clear,False,CoffeeScript,graph,gdisplay,canvas,pause,vec,clone,%
  compound,vertex,triangle,quad,attach_trail,attach_arrow,textures,bumpmaps,%
  print_options,get_library,read_local_file},%
  captionpos=b,%                         % position caption
  frame=shadowbox,%                      % shadowbox around listing
  rulesepcolor=\color{vshadowcolor},%    % shadow color
  basicstyle=\footnotesize,%             % basic font for code listings
  commentstyle=\bfseries\color{red},     % font for comments
  keywordstyle=\bfseries\color{blue},%   % font for keywords
  showstringspaces=true,%                % show spaces in strings
  stringstyle=\bfseries\color{green},%   % color for strings
  numbers=left,%                         % where to put line numbers
  numberstyle=\tiny,%                    % set to 'none' for no line numbers
  xleftmargin=20pt,%                     % extra left margin
  backgroundcolor=\color{vbgcolor},%     % some people find this annoying
  upquote=true,%                         % how to typeset quotes
  breaklines=true}%                      % break long lines
\definecolor{formcolor}{gray}{0.90}      % color for form background
\newcolumntype{C}[1]{>{\centering}m{#1}}
\newboolean{@optromanvectors}
\newboolean{@optboldvectors}
\newboolean{@optsinglemagbars}
\newboolean{@optbaseunits}
\newboolean{@optdrvdunits}
\newboolean{@optapproxconsts}
\newboolean{@optuseradians}
\setboolean{@optromanvectors}{false}    % this is where you set the default option
\setboolean{@optboldvectors}{false}     % this is where you set the default option
\setboolean{@optsinglemagbars}{false}   % this is where you set the default option
\setboolean{@optbaseunits}{false}       % this is where you set the default option
\setboolean{@optdrvdunits}{false}       % this is where you set the default option
\setboolean{@optapproxconsts}{false}    % this is where you set the default option
\setboolean{@optuseradians}{false}      % this is where you set the default option
\DeclareOption{romanvectors}{\setboolean{@optromanvectors}{true}}
\DeclareOption{boldvectors}{\setboolean{@optboldvectors}{true}}
\DeclareOption{singlemagbars}{\setboolean{@optsinglemagbars}{true}}
\DeclareOption{baseunits}{\setboolean{@optbaseunits}{true}}
\DeclareOption{drvdunits}{\setboolean{@optdrvdunits}{true}}
\DeclareOption{approxconsts}{\setboolean{@optapproxconsts}{true}}
\DeclareOption{useradians}{\setboolean{@optuseradians}{true}}
\ProcessOptions\relax
```

```
\newcommand*{\mandiversion}{\ifmmode%
    2.7.1\mbox{ dated }2018/01/15%
  \else%
    2.7.1 dated 2018/01/15%
  \fi
```

```
  }%
\typeout{                                                   }
\typeout{mandi: You're using mandi version \mandiversion.}
```

This block of code fixes a conflict with the amssymb package.

```
\@ifpackageloaded{amssymb}{%
  \csundef{square}
  \typeout{mandi: Package amssymb detected. Its \protect\square\space
  has been redefined.}
}{%
  \typeout{mandi: Package amssymb not detected.}
}%
```

This block of code defines unit names and symbols.

```
\newcommand*{\per}{\ensuremath{/}}
\newcommand*{\usk}{\ensuremath{\cdot}}
\newcommand*{\unit}[2]{\ensuremath{{#1}\;{#2}}}
\newcommand*{\ampere}{\ensuremath{\mathrm{A}}}
\newcommand*{\arcminute}{\ensuremath{'}}
\newcommand*{\arcsecond}{\ensuremath{''}}
\newcommand*{\atomicmassunit}{\ensuremath{\mathrm{u}}}
\newcommand*{\candela}{\ensuremath{\mathrm{cd}}}
\newcommand*{\coulomb}{\ensuremath{\mathrm{C}}}
\newcommand*{\degree}{\ensuremath{^{\circ}}}
\newcommand*{\electronvolt}{\ensuremath{\mathrm{eV}}}
\newcommand*{\eV}{\electronvolt}
\newcommand*{\farad}{\ensuremath{\mathrm{F}}}
\newcommand*{\henry}{\ensuremath{\mathrm{H}}}
\newcommand*{\hertz}{\ensuremath{\mathrm{Hz}}}
\newcommand*{\hour}{\ensuremath{\mathrm{h}}}
\newcommand*{\joule}{\ensuremath{\mathrm{J}}}
\newcommand*{\kelvin}{\ensuremath{\mathrm{K}}}
\newcommand*{\kilogram}{\ensuremath{\mathrm{kg}}}
\newcommand*{\metre}{\ensuremath{\mathrm{m}}}
\newcommand*{\minute}{\ensuremath{\mathrm{min}}}
\newcommand*{\mole}{\ensuremath{\mathrm{mol}}}
\newcommand*{\newton}{\ensuremath{\mathrm{N}}}
\newcommand*{\ohm}{\ensuremath{\Omega}}
\newcommand*{\pascal}{\ensuremath{\mathrm{Pa}}}
\newcommand*{\radian}{\ensuremath{\mathrm{rad}}}
\newcommand*{\second}{\ensuremath{\mathrm{s}}}
\newcommand*{\siemens}{\ensuremath{\mathrm{S}}}
\newcommand*{\steradian}{\ensuremath{\mathrm{sr}}}
\newcommand*{\tesla}{\ensuremath{\mathrm{T}}}
\newcommand*{\volt}{\ensuremath{\mathrm{V}}}
\newcommand*{\watt}{\ensuremath{\mathrm{W}}}
\newcommand*{\weber}{\ensuremath{\mathrm{Wb}}}
\newcommand*{\C}{\coulomb}
\newcommand*{\F}{\farad}
```

```
%\H is already defined as a LaTeX accent
\newcommand*{\J}{\joule}
\newcommand*{\N}{\newton}
\newcommand*{\Pa}{\pascal}
\newcommand*{\rad}{\radian}
\newcommand*{\sr}{\steradian}
%\S is already defined as a LaTeX symbol
\newcommand*{\T}{\tesla}
\newcommand*{\V}{\volt}
\newcommand*{\W}{\watt}
\newcommand*{\Wb}{\weber}
\newcommand*{\square}[1]{\ensuremath{{#1}^2}}               % prefix   2
\newcommand*{\cubic}[1]{\ensuremath{{#1}^3}}                % prefix   3
\newcommand*{\quartic}[1]{\ensuremath{{#1}^4}}              % prefix   4
\newcommand*{\reciprocal}[1]{\ensuremath{{#1}^{-1}}}        % prefix  -1
\newcommand*{\reciprocalsquare}[1]{\ensuremath{{#1}^{-2}}}  % prefix  -2
\newcommand*{\reciprocalcubic}[1]{\ensuremath{{#1}^{-3}}}   % prefix  -3
\newcommand*{\reciprocalquartic}[1]{\ensuremath{{#1}^{-4}}} % prefix  -4
\newcommand*{\squared}{\ensuremath{^2}}                     % postfix  2
\newcommand*{\cubed}{\ensuremath{^3}}                       % postfix  3
\newcommand*{\quarted}{\ensuremath{^4}}                     % postfix  4
\newcommand*{\reciprocaled}{\ensuremath{^{-1}}}             % postfix -1
\newcommand*{\reciprocalsquared}{\ensuremath{^{-2}}}        % postfix -2
\newcommand*{\reciprocalcubed}{\ensuremath{^{-3}}}          % postfix -3
\newcommand*{\reciprocalquarted}{\ensuremath{^{-4}}}        % postfix -4
```

Define a new named physics quantity or physical constant and commands for selecting units. My thanks to Ulrich Diez for contributing this code.

```
\newcommand*\mi@exchangeargs[2]{#2#1}%
\newcommand*\mi@name{}%
\long\def\mi@name#1#{\romannumeral0\mi@innername{#1}}%
\newcommand*\mi@innername[2]{%
  \expandafter\mi@exchangeargs\expandafter{\csname#2\endcsname}{#1}}%
\begingroup
\@firstofone{%
  \endgroup
  \newcommand*\mi@forkifnull[3]{%
    \romannumeral\iffalse{\fi\expandafter\@secondoftwo\expandafter%
    {\expandafter{\string#1}\expandafter\@secondoftwo\string}%
    \expandafter\@firstoftwo\expandafter{\iffalse}\fi0 #3}{0 #2}}}%
\newcommand*\selectbaseunit[3]{#1}
\newcommand*\selectdrvdunit[3]{#2}
\newcommand*\selecttradunit[3]{#3}
\newcommand*\selectunit{}
\newcommand*\perpusebaseunit{\let\selectunit=\selectbaseunit}
\newcommand*\perpusedrvdunit{\let\selectunit=\selectdrvdunit}
\newcommand*\perpusetradunit{\let\selectunit=\selecttradunit}
\newcommand*\hereusebaseunit[1]{%
  \begingroup\perpusebaseunit#1\endgroup}%
\newcommand*\hereusedrvdunit[1]{%
```

```
  \begingroup\perpusedrvdunit#1\endgroup}%
\newcommand*\hereusetradunit[1]{%
  \begingroup\perpusetradunit#1\endgroup}%
\newenvironment{usebaseunit}{\perpusebaseunit}{}%
\newenvironment{usedrvdunit}{\perpusedrvdunit}{}%
\newenvironment{usetradunit}{\perpusetradunit}{}%
\newcommand*\newphysicsquantity{\definephysicsquantity{\newcommand}}
\newcommand*\redefinephysicsquantity{\definephysicsquantity{\renewcommand}}
\newcommandx*\definephysicsquantity[5][4=,5=]{%
  \innerdefinewhatsoeverquantityfork{#3}{#4}{#5}{#1}{#2}{}{[1]}{##1}}%
\newcommand*\newphysicsconstant{\definephysicsconstant{\newcommand}}
\newcommand*\redefinephysicsconstant{\definephysicsconstant{\renewcommand}}
\newcommandx*\definephysicsconstant[7][6=,7=]{%
  \innerdefinewhatsoeverquantityfork{#5}{#6}{#7}{#1}{#2}{#3}{}{#4}}%
\newcommand*\innerdefinewhatsoeverquantityfork[3]{%
  \expandafter\innerdefinewhatsoeverquantity\romannumeral0%
  \mi@forkifnull{#3}{\mi@forkifnull{#2}{{#1}}{{#2}}{#1}}%
                {\mi@forkifnull{#2}{{#1}}{{#2}}{#3}}{#1}}%
\newcommand*\innerdefinewhatsoeverquantity[8]{%
  \mi@name#4{#5}#7{\unit{#8}{\selectunit{#3}{#1}{#2}}}%
  \mi@name#4{#5baseunit}#7{\unit{#8}{#3}}%
  \mi@name#4{#5drvdunit}#7{\unit{#8}{#1}}%
  \mi@name#4{#5tradunit}#7{\unit{#8}{#2}}%
  \mi@name#4{#5onlyunit}{\selectunit{#3}{#1}{#2}}%
  \mi@name#4{#5onlybaseunit}{\ensuremath{#3}}%
  \mi@name#4{#5onlydrvdunit}{\ensuremath{#1}}%
  \mi@name#4{#5onlytradunit}{\ensuremath{#2}}%
  \mi@name#4{#5value}#7{\ensuremath{#8}}%
  \mi@forkifnull{#7}{%
    \ifx#4\renewcommand\mi@name\let{#5mathsymbol}=\relax\fi
    \mi@name\newcommand*{#5mathsymbol}{\ensuremath{#6}}}{}}%
```

This block of code processes the options.

```
\ifthenelse{\boolean{@optboldvectors}}
  {\typeout{mandi: You'll get bold vectors.}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\typeout{mandi: You'll get Roman vectors.}}
   {\typeout{mandi: You'll get italic vectors.}}}
\ifthenelse{\boolean{@optsinglemagbars}}
  {\typeout{mandi: You'll get single magnitude bars.}}
  {\typeout{mandi: You'll get double magnitude bars.}}
\ifthenelse{\boolean{@optbaseunits}}
  {\perpusebaseunit %
   \typeout{mandi: You'll get base units.}}
  {\ifthenelse{\boolean{@optdrvdunits}}
     {\perpusedrvdunit %
      \typeout{mandi: You'll get derived units.}}
     {\perpusetradunit %
      \typeout{mandi: You'll get traditional units.}}}
\ifthenelse{\boolean{@optapproxconsts}}
```

```
  {\typeout{mandi: You’ll get approximate constants.}}
  {\typeout{mandi: You’ll get precise constants.}}
\ifthenelse{\boolean{@optuseradians}}
  {\typeout{mandi: You’ll get radians in ang mom, ang impulse, and torque.}}
  {\typeout{mandi: You won’t get radians in ang mom, ang impulse, and torque.}}
\typeout{                                                  }
```

This is a utility command for picking constants.

```
\ifthenelse{\boolean{@optapproxconsts}}
  {\newcommand*{\mi@p}[2]{#1}} % approximate value
  {\newcommand*{\mi@p}[2]{#2}} % precise value
```

SI base unit of length or spatial displacement

```
\newcommand*{\m}{\metre}
```

SI base unit of mass

```
\newcommand*{\kg}{\kilogram}
```

SI base unit of time or temporal displacement

```
\newcommand*{\s}{\second}
```

SI base unit of electric current

```
\newcommand*{\A}{\ampere}
```

SI base unit of thermodynamic temperature

```
\newcommand*{\K}{\kelvin}
```

SI base unit of amount

```
\newcommand*{\mol}{\mole}
```

SI base unit of luminous intensity

```
\newcommand*{\cd}{\candela}
```

```
\newcommand*{\dimdisplacement}{\ensuremath{\mathrm{L}}}
\newcommand*{\dimmass}{\ensuremath{\mathrm{M}}}
\newcommand*{\dimduration}{\ensuremath{\mathrm{T}}}
\newcommand*{\dimcurrent}{\ensuremath{\mathrm{I}}}
\newcommand*{\dimtemperature}{\ensuremath{\mathrm{\Theta}}}
\newcommand*{\dimamount}{\ensuremath{\mathrm{N}}}
\newcommand*{\dimluminous}{\ensuremath{\mathrm{J}}}
\newcommand*{\infeet}[1]{\unit{#1}{\mathrm{ft}}}
\newcommand*{\infeetpersecond}[1]{\unit{#1}{\mathrm{ft}\per\s}}
\newcommand*{\infeetpersecondsquared}[1]{\unit{#1}{\mathrm{ft}\per\s\squared}}
\newcommand*{\indegrees}[1]{\unit{#1}{\mkern-\thickmuskip\degree}}
\newcommand*{\inFarenheit}[1]{\unit{#1}{\mkern-\thickmuskip\degree\mathrm{F}}}
```

```
\newcommand*{\inCelsius}[1]{\unit{#1}{\mkern-\thickmuskip\degree\mathrm{C}}}
\newcommand*{\inarcminutes}[1]{\unit{#1}{\mkern-\thickmuskip\arcminute}}
\newcommand*{\inarcseconds}[1]{\unit{#1}{\mkern-\thickmuskip\arcsecond}}
\newcommand*{\ineV}[1]{\unit{#1}{\electronvolt}}
\newcommand*{\ineVocs}[1]{\unit{#1}{\mathrm{eV}\per c^2}}
\newcommand*{\ineVoc}[1]{\unit{#1}{\mathrm{eV}\per c}}
\newcommand*{\inMeV}[1]{\unit{#1}{\mathrm{MeV}}}
\newcommand*{\inMeVocs}[1]{\unit{#1}{\mathrm{MeV}\per c^2}}
\newcommand*{\inMeVoc}[1]{\unit{#1}{\mathrm{MeV}\per c}}
\newcommand*{\inGeV}[1]{\unit{#1}{\mathrm{GeV}}}
\newcommand*{\inGeVocs}[1]{\unit{#1}{\mathrm{GeV}\per c^2}}
\newcommand*{\inGeVoc}[1]{\unit{#1}{\mathrm{GeV}\per c}}
\newcommand*{\inamu}[1]{\unit{#1}{\mathrm{u}}}
\newcommand*{\ingram}[1]{\unit{#1}{\mathrm{g}}}
\newcommand*{\ingrampercubiccm}[1]{\unit{#1}{\mathrm{g}\per\cubic\mathrm{cm}}}
\newcommand*{\inAU}[1]{\unit{#1}{\mathrm{AU}}}
\newcommand*{\inly}[1]{\unit{#1}{\mathrm{ly}}}
\newcommand*{\incyr}[1]{\unit{#1}{c\usk\mathrm{year}}}
\newcommand*{\inpc}[1]{\unit{#1}{\mathrm{pc}}}
\newcommand*{\insolarL}[1]{\unit{#1}{\Lsolar}}
\newcommand*{\insolarT}[1]{\unit{#1}{\Tsolar}}
\newcommand*{\insolarR}[1]{\unit{#1}{\Rsolar}}
\newcommand*{\insolarM}[1]{\unit{#1}{\Msolar}}
\newcommand*{\insolarF}[1]{\unit{#1}{\Fsolar}}
\newcommand*{\insolarf}[1]{\unit{#1}{\fsolar}}
\newcommand*{\insolarMag}[1]{\unit{#1}{\Magsolar}}
\newcommand*{\insolarmag}[1]{\unit{#1}{\magsolar}}
\newcommand*{\insolarD}[1]{\unit{#1}{\Dsolar}}
\newcommand*{\insolard}[1]{\unit{#1}{\dsolar}}
\newcommand*{\velocityc}[1]{\ensuremath{#1c}}
\newcommand*{\lorentz}[1]{\ensuremath{#1}}
\newcommand*{\speed}{\velocity}
\newphysicsquantity{displacement}%
  {\m}%
  [\m]%
  [\m]
\newphysicsquantity{mass}%
  {\kg}%
  [\kg]%
  [\kg]
\newphysicsquantity{duration}%
  {\s}%
  [\s]%
  [\s]
\newphysicsquantity{current}%
  {\A}%
  [\A]%
  [\A]
\newphysicsquantity{temperature}%
  {\K}%
```

```
  [\K]%
  [\K]
\newphysicsquantity{amount}%
  {\mol}%
  [\mol]%
  [\mol]
\newphysicsquantity{luminous}%
  {\cd}%
  [\cd]%
  [\cd]
\newphysicsquantity{planeangle}%
  {\m\usk\reciprocal\m}%
  [\rad]%
  [\rad]
\newphysicsquantity{solidangle}%
  {\m\squared\usk\reciprocalsquare\m}%
  [\sr]%
  [\sr]
\newphysicsquantity{velocity}%
  {\m\usk\reciprocal\s}%
  [\m\usk\reciprocal\s]%
  [\m\per\s]
\newphysicsquantity{acceleration}%
  {\m\usk\s\reciprocalsquared}%
  [\N\per\kg]%
  [\m\per\s\squared]
\newphysicsquantity{gravitationalfield}%
  {\m\usk\s\reciprocalsquared}%
  [\N\per\kg]%
  [\N\per\kg]
\newphysicsquantity{gravitationalpotential}%
  {\square\m\usk\reciprocalsquare\s}%
  [\J\per\kg]%
  [\J\per\kg]
\newphysicsquantity{momentum}%
  {\m\usk\kg\usk\reciprocal\s}%
  [\N\usk\s]%
  [\kg\usk\m\per\s]
\newphysicsquantity{impulse}%
  {\m\usk\kg\usk\reciprocal\s}%
  [\N\usk\s]%
  [\N\usk\s]
\newphysicsquantity{force}%
  {\m\usk\kg\usk\s\reciprocalsquared}%
  [\N]%
  [\N]
\newphysicsquantity{springstiffness}%
  {\kg\usk\s\reciprocalsquared}%
  [\N\per\m]%
  [\N\per\m]
```

```
\newphysicsquantity{springstretch}%
  {\m}%
  []%
  []
\newphysicsquantity{area}%
  {\m\squared}%
  []%
  []
\newphysicsquantity{volume}%
  {\cubic\m}%
  []%
  []
\newphysicsquantity{linearmassdensity}%
  {\reciprocal\m\usk\kg}%
  [\kg\per\m]%
  [\kg\per\m]
\newphysicsquantity{areamassdensity}%
  {\m\reciprocalsquared\usk\kg}%
  [\kg\per\m\squared]%
  [\kg\per\m\squared]
\newphysicsquantity{volumemassdensity}%
  {\m\reciprocalcubed\usk\kg}%
  [\kg\per\m\cubed]%
  [\kg\per\m\cubed]
\newphysicsquantity{youngsmodulus}%
  {\reciprocal\m\usk\kg\usk\s\reciprocalsquared}%
  [\N\per\m\squared]%
  [\Pa]
\newphysicsquantity{stress}%
  {\reciprocal\m\usk\kg\usk\s\reciprocalsquared}%
  [\N\per\m\squared]%
  [\Pa]
\newphysicsquantity{pressure}%
  {\reciprocal\m\usk\kg\usk\s\reciprocalsquared}%
  [\N\per\m\squared]%
  [\Pa]
\newphysicsquantity{strain}%
  {}%
  []%
  []
\newphysicsquantity{work}%
  {\m\squared\usk\kg\usk\s\reciprocalsquared}%
  [\N\usk\m]%
  [\J]
\newphysicsquantity{energy}%
  {\m\squared\usk\kg\usk\s\reciprocalsquared}%
  [\N\usk\m]%
  [\J]
\newphysicsquantity{power}%
  {\m\squared\usk\kg\usk\s\reciprocalcubed}%
```

```
  [\J\per\s]%
  [\W]
\newphysicsquantity{specificheatcapacity}%
  {\J\per\K\usk\kg}%
  [\J\per\K\usk\kg]%
  [\J\per\K\usk\kg]
\newphysicsquantity{angularvelocity}%
  {\rad\usk\reciprocal\s}%
  [\rad\per\s]%
  [\rad\per\s]
\newphysicsquantity{angularacceleration}%
  {\rad\usk\s\reciprocalsquared}%
  [\rad\per\s\squared]%
  [\rad\per\s\squared]
\newphysicsquantity{momentofinertia}%
  {\m\squared\usk\kg}%
  [\m\usk\kg\squared]%
  [\J\usk\s\squared]
\ifthenelse{\boolean{@optuseradians}}
  {%
  \newphysicsquantity{angularmomentum}%
    {\m\squared\usk\kg\usk\reciprocal\s\usk\reciprocal\rad}%
    [\N\usk\m\usk\s\per\rad]%
    [\m\squared\usk\kg\usk\reciprocal\s\usk\reciprocal\rad]
  \newphysicsquantity{angularimpulse}%
    {\m\squared\usk\kg\usk\reciprocal\s\usk\reciprocal\rad}%
    [\N\usk\m\usk\s\per\rad]%
    [\J\usk\s\per\rad]
  \newphysicsquantity{torque}%
    {\m\squared\usk\kg\usk\s\reciprocalsquared\usk\reciprocal\rad}%
    [\N\usk\m\per\rad]%
    [\J\per\rad]
  }%
  {%
  \newphysicsquantity{angularmomentum}%
    {\m\squared\usk\kg\usk\reciprocal\s}%
    [\N\usk\m\usk\s]%
    [\m\squared\usk\kg\usk\reciprocal\s]
  \newphysicsquantity{angularimpulse}%
    {\m\squared\usk\kg\usk\reciprocal\s}%
    [\N\usk\m\usk\s]%
    [\J\usk\s]
  \newphysicsquantity{torque}%
    {\m\squared\usk\kg\usk\s\reciprocalsquared}%
    [\N\usk\m]%
    [\J]
  }%
\newphysicsquantity{entropy}%
  {\m\squared\usk\kg\usk\s\reciprocalsquared\usk\reciprocal\K}%
  [\J\per\K]%
```

```
  [\J\per\K]
\newphysicsquantity{wavelength}%
  {\m}%
  [\m]%
  [\m]
\newphysicsquantity{wavenumber}%
  {\reciprocal\m}%
  [\per\m]%
  [\per\m]
\newphysicsquantity{frequency}%
  {\reciprocal\s}%
  [\hertz]%
  [\hertz]
\newphysicsquantity{angularfrequency}%
  {\rad\usk\reciprocal\s}%
  [\rad\per\s]%
  [\rad\per\s]
\newphysicsquantity{charge}%
  {\A\usk\s}%
  [\C]%
  [\C]
\newphysicsquantity{permittivity}%
  {\m\reciprocalcubed\usk\reciprocal\kg\usk\s\reciprocalquarted\usk\A\squared}%
  [\F\per\m]%
  [\C\squared\per\N\usk\m\squared]
\newphysicsquantity{permeability}%
  {\m\usk\kg\usk\s\reciprocalsquared\usk\A\reciprocalsquared}%
  [\henry\per\m]%
  [\T\usk\m\per\A]
\newphysicsquantity{electricfield}%
  {\m\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}%
  [\V\per\m]%
  [\N\per\C]
\newphysicsquantity{electricdipolemoment}%
  {\m\usk\s\usk\A}%
  [\C\usk\m]%
  [\C\usk\m]
\newphysicsquantity{electricflux}%
  {\m\cubed\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}%
  [\V\usk\m]%
  [\N\usk\m\squared\per\C]
\newphysicsquantity{magneticfield}%
  {\kg\usk\s\reciprocalsquared\usk\reciprocal\A}%
  [\T]%
  [\N\per\C\usk(\m\per\s)] % also \Wb\per\m\squared
\newphysicsquantity{magneticflux}%
  {\m\squared\usk\kg\usk\s\reciprocalsquared\usk\reciprocal\A}%
  [\volt\usk\s]%
  [\T\usk\m\squared] % also \Wb and \J\per\A
\newphysicsquantity{cmagneticfield}%
```

```
  {\m\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}%
  [\V\per\m]%
  [\N\per\C]
\newphysicsquantity{linearchargedensity}%
  {\reciprocal\m\usk\s\usk\A}%
  [\C\per\m]%
  [\C\per\m]
\newphysicsquantity{areachargedensity}%
  {\reciprocalsquare\m\usk\s\usk\A}%
  [\C\per\square\m]%
  [\C\per\square\m]
\newphysicsquantity{volumechargedensity}%
  {\reciprocalcubic\m\usk\s\usk\A}%
  [\C\per\cubic\m]%
  [\C\per\cubic\m]
\newphysicsquantity{mobility}%
 {\m\squared\usk\kg\usk\s\reciprocalquarted\usk\reciprocal\A}%
 [\m\squared\per\volt\usk\s]%
 [(\m\per\s)\per(\N\per\C)]
\newphysicsquantity{numberdensity}%
  {\reciprocalcubic\m}%
  [\per\cubic\m]%
  [\per\cubic\m]
\newphysicsquantity{polarizability}%
  {\reciprocal\kg\usk\s\quarted\usk\square\A}%
  [\C\usk\square\m\per\V]%
  [\C\usk\m\per(\N\per\C)]
\newphysicsquantity{electricpotential}%
  {\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocal\A}%
  [\J\per\C]%
  [\V]
\newphysicsquantity{emf}%
  {\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocal\A}%
  [\J\per\C]%
  [\V]
\newphysicsquantity{dielectricconstant}%
  {}%
  []%
  []
\newphysicsquantity{indexofrefraction}%
  {}%
  []%
  []
\newphysicsquantity{relativepermittivity}%
  {}%
  []%
  []
\newphysicsquantity{relativepermeability}
  {}%
  []%
```

```
  []
\newphysicsquantity{energydensity}%
  {\m\reciprocaled\usk\kg\usk\reciprocalsquare\s}%
  [\J\per\cubic\m]%
  [\J\per\cubic\m]
\newphysicsquantity{energyflux}%
  {\kg\usk\s\reciprocalcubed}%
  [\W\per\m\squared]%
  [\W\per\m\squared]
\newphysicsquantity{momentumflux}%
  {\reciprocal\m\usk\kg\usk\s\reciprocalsquared}%
  [\N\per\m\squared]%
  [\N\per\m\squared]
\newphysicsquantity{electroncurrent}%
  {\reciprocal\s}%
  [\ensuremath{\mathrm{e}}\per\s]%
  [\ensuremath{\mathrm{e}}\per\s]
\newphysicsquantity{conventionalcurrent}%
  {\A}%
  [\C\per\s]%
  [\A]
\newphysicsquantity{magneticdipolemoment}%
  {\square\m\usk\A}%
  [\J\per\T]%
  [\A\usk\square\m]
\newphysicsquantity{currentdensity}%
  {\reciprocalsquare\m\usk\A}%
  [\C\usk\s\per\square\m]%
  [\A\per\square\m]
\newphysicsquantity{capacitance}%
  {\reciprocalsquare\m\usk\reciprocal\kg\usk\quartic\s\usk\square\A}%
  [\F]%
  [\C\per\V] % also \C\squared\per\N\usk\m, \s\per\ohm
\newphysicsquantity{inductance}%
  {\square\m\usk\kg\usk\reciprocalsquare\s\usk\reciprocalsquare\A}%
  [\henry]%
  [\volt\usk\s\per\A] % also \square\m\usk\kg\per\C\squared, \Wb\per\A
\newphysicsquantity{conductivity}%
  {\reciprocalcubic\m\usk\reciprocal\kg\usk\cubic\s\usk\square\A}%
  [\siemens\per\m]%
  [(\A\per\square\m)\per(\V\per\m)]
\newphysicsquantity{resistivity}%
  {\cubic\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocalsquare\A}%
  [\ohm\usk\m]%
  [(\V\per\m)\per(\A\per\square\m)]
\newphysicsquantity{resistance}%
  {\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocalsquare\A}%
  [\V\per\A]%
  [\ohm]
\newphysicsquantity{conductance}%
```

```
  {\reciprocalsquare\m\usk\reciprocal\kg\usk\cubic\s\usk\square\A}%
  [\A\per\V]%
  [\siemens]
\newphysicsquantity{magneticcharge}%
  {\m\usk\A}%
  [\m\usk\A]%
  [\m\usk\A]
\newcommand*{\vectordisplacement}[1]{\ensuremath{\displacement{\mivector{#1}}}}
\newcommand*{\vectorvelocity}[1]{\ensuremath{\velocity{\mivector{#1}}}}
\newcommand*{\vectorvelocityc}[1]{\ensuremath{\velocityc{\mivector{#1}}}}
\newcommand*{\vectoracceleration}[1]{\ensuremath{\acceleration{\mivector{#1}}}}
\newcommand*{\vectormomentum}[1]{\ensuremath{\momentum{\mivector{#1}}}}
\newcommand*{\vectorforce}[1]{\ensuremath{\force{\mivector{#1}}}}
\newcommand*{\vectorgravitationalfield}[1]
  {\ensuremath{\gravitationalfield{\mivector{#1}}}}
\newcommand*{\vectorimpulse}[1]{\ensuremath{\impulse{\mivector{#1}}}}
\newcommand*{\vectorangularvelocity}[1]{\ensuremath{\angularvelocity{\mivector{#1}}}}
\newcommand*{\vectorangularacceleration}[1]
  {\ensuremath{\angularacceleration{\mivector{#1}}}}
\newcommand*{\vectorangularmomentum}[1]{\ensuremath{\angularmomentum{\mivector{#1}}}}
\newcommand*{\vectorangularimpulse}[1]{\ensuremath{\angularimpulse{\mivector{#1}}}}
\newcommand*{\vectortorque}[1]{\ensuremath{\torque{\mivector{#1}}}}
\newcommand*{\vectorwavenumber}[1]{\ensuremath{\wavenumber{\mivector{#1}}}}
\newcommand*{\vectorelectricfield}[1]{\ensuremath{\electricfield{\mivector{#1}}}}
\newcommand*{\vectorelectricdipolemoment}[1]
  {\ensuremath{\electricdipolemoment{\mivector{#1}}}}
\newcommand*{\vectormagneticfield}[1]{\ensuremath{\magneticfield{\mivector{#1}}}}
\newcommand*{\vectorcmagneticfield}[1]{\ensuremath{\cmagneticfield{\mivector{#1}}}}
\newcommand*{\vectormagneticdipolemoment}[1]
  {\ensuremath{\magneticdipolemoment{\mivector{#1}}}}
\newcommand*{\vectorcurrentdensity}[1]{\ensuremath{\currentdensity{\mivector{#1}}}}
  \newcommand*{\lv}{\ensuremath{\left\langle}}
\newcommand*{\vectorenergyflux}[1]{\ensuremath{\energyflux{\mivector{#1}}}}
\newcommand*{\vectormomentumflux}[1]{\ensuremath{\momentumflux{\mivector{#1}}}}
\newcommand*{\poyntingvector}{\vectorenergyflux}
\newcommand*{\rv}{\ensuremath{\right\rangle}}
\ExplSyntaxOn % Written in LaTeX3
\NewDocumentCommand{\magvectncomps}{ m O{} }
  {%
    \sum_of_squares:nn { #1 }{ #2 }
  }%
\cs_new:Npn \sum_of_squares:nn #1 #2
  {%
    \tl_if_empty:nTF { #2 }
      {%
        \clist_set:Nn \l_tmpa_clist { #1 }
        \ensuremath{%
          \sqrt{\left(\clist_use:Nnnn \l_tmpa_clist { \right)^2+\left( } { \right)^2+
          \left( } { \right)^2+\left( } \right)^2 }
        }%
```

```
      }%
      {%
        \clist_set:Nn \l_tmpa_clist { #1 }
        \ensuremath{%
          \sqrt{\left(\clist_use:Nnnn \l_tmpa_clist {\;{ #2 }\right)^2+\left(} {\;
          { #2 }\right)^2+\left(} {\;{ #2 }\right)^2+\left(} \;{ #2 }\right)^2}
        }%
      }%
  }%
\ExplSyntaxOff
%
\newcommand*{\zerovect}{\vect{0}}
\ifthenelse{\boolean{@optboldvectors}}
  {\newcommand*{\vect}[1]{\ensuremath{\boldsymbol{#1}}}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\newcommand*{\vect}[1]{\ensuremath{\vv{\mathrm{#1}}}}}
   {\newcommand*{\vect}[1]{\ensuremath{\vv{#1}}}}}
\ifthenelse{\boolean{@optsinglemagbars}}
  {\newcommand*{\magvect}[1]{\ensuremath{\absof{\vect{#1}}}}}
  {\newcommand*{\magvect}[1]{\ensuremath{\magof{\vect{#1}}}}}
\newcommand*{\magsquaredvect}[1]{\ensuremath{\magvect{#1}\squared}}
\newcommand*{\magnvect}[2]{\ensuremath{\magvect{#1}^{#2}}}
\newcommand*{\dmagvect}[1]{\ensuremath{\dx{\magvect{#1}}}}
\newcommand*{\Dmagvect}[1]{\ensuremath{\Delta\!\magvect{#1}}}
\ifthenelse{\boolean{@optboldvectors}}
  {\newcommand*{\dirvect}[1]{\ensuremath{\widehat{\boldsymbol{#1}}}}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\newcommand*{\dirvect}[1]{\ensuremath{\widehat{\mathrm{#1}}}}}
   {\newcommand*{\dirvect}[1]{\ensuremath{\widehat{#1}}}}}
\newcommand*{\direction}[1]{\ensuremath{\mivector{#1}}}
\newcommand*{\vectordirection}{\direction}
\newcommand*{\factorvect}[1]{\magvect{#1}\dirvect{#1}}
\newcommand*{\componentalong}[2]{\ensuremath{\mathrm{comp}_{#1}{#2}}}
\newcommand*{\expcomponentalong}[2]{\ensuremath{\frac{\vectdotvect{#2}{#1}}
{\magof{#1}}}}
\newcommand*{\ucomponentalong}[2]{\ensuremath{\vectdotvect{#2}{#1}}}
\newcommand*{\projectiononto}[2]{\ensuremath{\mathrm{proj}_{#1}{#2}}}
\newcommand*{\expprojectiononto}[2]{\ensuremath{%
  \inparens{\frac{\vectdotvect{#2}{#1}}{\magof{#1}}}\frac{#1}{\magof{#1}}}}
\newcommand*{\uprojectiononto}[2]{\ensuremath{%
  \inparens{\vectdotvect{#2}{#1}}#1}}
\ifthenelse{\boolean{@optromanvectors}}
  {\newcommand*{\compvect}[2]{\ensuremath{\ssub{\mathrm{#1}}{\(#2\)}}}}
  {\newcommand*{\compvect}[2]{\ensuremath{\ssub{#1}{\(#2\)}}}}
\newcommand*{\scompsvect}[1]{\ensuremath{\lv%
  \compvect{#1}{x},%
  \compvect{#1}{y},%
  \compvect{#1}{z}\rv}}
\newcommand*{\scompsdirvect}[1]{\ensuremath{\lv%
  \compvect{\widehat{#1}}{x},%
```

```
  \compvect{\widehat{#1}}{y},%
  \compvect{\widehat{#1}}{z}\rv}}
\ifthenelse{\boolean{@optromanvectors}}
  {\newcommand*{\compdirvect}[2]{\ensuremath{%
    \ssub{\widehat{\mathrm{#1}}}{\(#2\)}}}}
  {\newcommand*{\compdirvect}[2]{\ensuremath{%
    \ssub{\widehat{#1}}{\(#2\)}}}}
\newcommand*{\magvectscomps}[1]{\ensuremath{\sqrt{%
  \compvect{#1}{x}\squared +%
  \compvect{#1}{y}\squared +%
  \compvect{#1}{z}\squared}}}
\newcommand*{\dvect}[1]{\ensuremath{\mathrm{d}\vect{#1}}}
\newcommand*{\Dvect}[1]{\ensuremath{\Delta\vect{#1}}}
\newcommand*{\dirdvect}[1]{\ensuremath{\widehat{\dvect{#1}}}}
\newcommand*{\dirDvect}[1]{\ensuremath{\widehat{\Dvect{#1}}}}
\newcommand*{\ddirvect}[1]{\ensuremath{\mathrm{d}\dirvect{#1}}}
\newcommand*{\ddirection}{\ddirvect}
\newcommand*{\Ddirvect}[1]{\ensuremath{\Delta\dirvect{#1}}}
\newcommand*{\Ddirection}{\Ddirvect}
\ifthenelse{\boolean{@optsinglemagbars}}
  {\newcommand*{\magdvect}[1]{\ensuremath{\absof{\dvect{#1}}}}
   \newcommand*{\magDvect}[1]{\ensuremath{\absof{\Dvect{#1}}}}}
  {\newcommand*{\magdvect}[1]{\ensuremath{\magof{\dvect{#1}}}}
   \newcommand*{\magDvect}[1]{\ensuremath{\magof{\Dvect{#1}}}}}
\newcommand*{\compdvect}[2]{\ensuremath{\mathrm{d}\compvect{#1}{#2}}}
\newcommand*{\compDvect}[2]{\ensuremath{\Delta\compvect{#1}{#2}}}
\newcommand*{\scompsdvect}[1]{\ensuremath{\lv%
  \compdvect{#1}{x},%
  \compdvect{#1}{y},%
  \compdvect{#1}{z}\rv}}
\newcommand*{\scompsDvect}[1]{\ensuremath{\lv%
  \compDvect{#1}{x},%
  \compDvect{#1}{y},%
  \compDvect{#1}{z}\rv}}
\newcommand*{\dervect}[2]{\ensuremath{\frac{\dvect{#1}}{\mathrm{d}{#2}}}}
\newcommand*{\Dervect}[2]{\ensuremath{\frac{\Dvect{#1}}{\Delta{#2}}}}
\newcommand*{\compdervect}[3]{\ensuremath{\dbyd{\compvect{#1}{#2}}{#3}}}
\newcommand*{\compDervect}[3]{\ensuremath{\DbyD{\compvect{#1}{#2}}{#3}}}
\newcommand*{\scompsdervect}[2]{\ensuremath{\lv%
  \compdervect{#1}{x}{#2},%
  \compdervect{#1}{y}{#2},%
  \compdervect{#1}{z}{#2}\rv}}
\newcommand*{\scompsDervect}[2]{\ensuremath{\lv%
  \compDervect{#1}{x}{#2},%
  \compDervect{#1}{y}{#2},%
  \compDervect{#1}{z}{#2}\rv}}
\ifthenelse{\boolean{@optsinglemagbars}}
  {\newcommand*{\magdervect}[2]{\ensuremath{\absof{\dervect{#1}{#2}}}}
   \newcommand*{\magDervect}[2]{\ensuremath{\absof{\Dervect{#1}{#2}}}}}
  {\newcommand*{\magdervect}[2]{\ensuremath{\magof{\dervect{#1}{#2}}}}
```

```
   \newcommand*{\magDervect}[2]{\ensuremath{\magof{\Dervect{#1}{#2}}}}}
\newcommand*{\dermagvect}[2]{\ensuremath{\dbyd{\magvect{#1}}{#2}}}
\newcommand*{\Dermagvect}[2]{\ensuremath{\DbyD{\magvect{#1}}{#2}}}
\newcommand*{\derdirvect}[2]{\ensuremath{\dbyd{\dirvect{#1}}{#2}}}
\newcommand*{\derdirection}{\derdirvect}
\newcommand*{\Derdirvect}[2]{\ensuremath{\DbyD{\dirvect{#1}}{#2}}}
\newcommand*{\Derdirection}{\Derdirvect}
\ifthenelse{\boolean{@optboldvectors}}
  {\newcommand*{\vectsub}[2]{\ensuremath{\boldsymbol{#1}_{\text{\tiny{}#2}}}}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\newcommand*{\vectsub}[2]{\ensuremath{\vv{\mathrm{#1}}_{\text{\tiny{#2}}}}}}
   {\newcommand*{\vectsub}[2]{\ensuremath{\vv{#1}_{\text{\tiny{#2}}}}}}}
\ifthenelse{\boolean{@optromanvectors}}
  {\newcommand*{\compvectsub}[3]{\ensuremath{\ssub{\mathrm{#1}}{#2,\(#3\)}}}}
  {\newcommand*{\compvectsub}[3]{\ensuremath{\ssub{#1}{#2,\(#3\)}}}}
\newcommand*{\scompsvectsub}[2]{\ensuremath{\lv%
  \compvectsub{#1}{#2}{x},%
  \compvectsub{#1}{#2}{y},%
  \compvectsub{#1}{#2}{z}\rv}}
\ifthenelse{\boolean{@optsinglemagbars}}
  {\newcommand*{\magvectsub}[2]{\ensuremath{\absof{\vectsub{#1}{#2}}}}}
  {\newcommand*{\magvectsub}[2]{\ensuremath{\magof{\vectsub{#1}{#2}}}}}
\newcommand*{\magsquaredvectsub}[2]{\ensuremath{\magvectsub{#1}{#2}\squared}}
\newcommand*{\magnvectsub}[3]{\ensuremath{\magvectsub{#1}{#2}^{#3}}}
\newcommand*{\magvectsubscomps}[2]{\ensuremath{\sqrt{%
    \compvectsub{#1}{#2}{x}\squared +%
    \compvectsub{#1}{#2}{y}\squared +%
    \compvectsub{#1}{#2}{z}\squared}}}
\ifthenelse{\boolean{@optromanvectors}}
  {\newcommand*{\dirvectsub}[2]{\ensuremath{\ssub{\widehat{\mathrm{#1}}}{#2}}}}
  {\newcommand*{\dirvectsub}[2]{\ensuremath{\ssub{\widehat{#1}}{#2}}}}
\newcommand*{\dvectsub}[2]{\ensuremath{\mathrm{d}\vectsub{#1}{#2}}}
\newcommand*{\Dvectsub}[2]{\ensuremath{\Delta\vectsub{#1}{#2}}}
\newcommand*{\compdvectsub}[3]{\ensuremath{\mathrm{d}\compvectsub{#1}{#2}{#3}}}
\newcommand*{\compDvectsub}[3]{\ensuremath{\Delta\compvectsub{#1}{#2}{#3}}}
\newcommand*{\scompsdvectsub}[2]{\ensuremath{\lv%
  \compdvectsub{#1}{#2}{x},%
  \compdvectsub{#1}{#2}{y},%
  \compdvectsub{#1}{#2}{z}\rv}}
\newcommand*{\scompsDvectsub}[2]{\ensuremath{\lv%
  \compDvectsub{#1}{#2}{x},%
  \compDvectsub{#1}{#2}{y},%
  \compDvectsub{#1}{#2}{z}\rv}}
\newcommand*{\dermagvectsub}[3]{\ensuremath{\dbyd{\magvectsub{#1}{#2}}{#3}}}
\newcommand*{\Dermagvectsub}[3]{\ensuremath{\DbyD{\magvectsub{#1}{#2}}{#3}}}
\newcommand*{\dervectsub}[3]{\ensuremath{\dbyd{\vectsub{#1}{#2}}{#3}}}
\newcommand*{\Dervectsub}[3]{\ensuremath{\DbyD{\vectsub{#1}{#2}}{#3}}}
\ifthenelse{\boolean{@optsinglemagbars}}
  {\newcommand*{\magdervectsub}[3]{\ensuremath{\absof{\dervectsub{#1}{#2}{#3}}}}}
   \newcommand*{\magDervectsub}[3]{\ensuremath{\absof{\Dervectsub{#1}{#2}{#3}}}}}
```

```
  {\newcommand*{\magdervectsub}[3]{\ensuremath{\magof{\dervectsub{#1}{#2}{#3}}}}
   \newcommand*{\magDervectsub}[3]{\ensuremath{\magof{\Dervectsub{#1}{#2}{#3}}}}}
\newcommand*{\compdervectsub}[4]{\ensuremath{\dbyd{\compvectsub{#1}{#2}{#3}}{#4}}}
\newcommand*{\compDervectsub}[4]{\ensuremath{\DbyD{\compvectsub{#1}{#2}{#3}}{#4}}}
\newcommand*{\scompsdervectsub}[3]{\ensuremath{\lv%
  \compdervectsub{#1}{#2}{x}{#3},%
  \compdervectsub{#1}{#2}{y}{#3},%
  \compdervectsub{#1}{#2}{z}{#3}\rv}}
\newcommand*{\scompsDervectsub}[3]{\ensuremath{\lv%
  \compDervectsub{#1}{#2}{x}{#3},%
  \compDervectsub{#1}{#2}{y}{#3},%
  \compDervectsub{#1}{#2}{z}{#3}\rv}}
\newcommand*{\vectdotvect}[2]{\ensuremath{{#1}\cdot{#2}}}
\newcommand*{\vectDotvect}[2]{\ensuremath{{#1}\bullet{#2}}}
\newcommand*{\vectdotsvect}[2]{\ensuremath{\scompsvect{#1}\cdot\scompsvect{#2}}}
\newcommand*{\vectDotsvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsvect{#2}}}
\newcommand*{\vectdotevect}[2]{\ensuremath{%
  \compvect{#1}{x}\compvect{#2}{x}+%
  \compvect{#1}{y}\compvect{#2}{y}+%
  \compvect{#1}{z}\compvect{#2}{z}}}
\newcommand*{\vectdotsdvect}[2]{\ensuremath{\scompsvect{#1}\cdot\scompsdvect{#2}}}
\newcommand*{\vectDotsdvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsdvect{#2}}}
\newcommand*{\vectdotsDvect}[2]{\ensuremath{\scompsvect{#1}\cdot\scompsDvect{#2}}}
\newcommand*{\vectDotsDvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsDvect{#2}}}
\newcommand*{\vectdotedvect}[2]{\ensuremath{%
  \compvect{#1}{x}\compdvect{#2}{x}+%
  \compvect{#1}{y}\compdvect{#2}{y}+%
  \compvect{#1}{z}\compdvect{#2}{z}}}
\newcommand*{\vectdoteDvect}[2]{\ensuremath{%
  \compvect{#1}{x}\compDvect{#2}{x}+%
  \compvect{#1}{y}\compDvect{#2}{y}+%
  \compvect{#1}{z}\compDvect{#2}{z}}}
\newcommand*{\vectsubdotsvectsub}[4]{\ensuremath{%
  \scompsvectsub{#1}{#2}\cdot\scompsvectsub{#3}{#4}}}
\newcommand*{\vectsubDotsvectsub}[4]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsvectsub{#3}{#4}}}
\newcommand*{\vectsubdotevectsub}[4]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compvectsub{#3}{#4}{x}+%
  \compvectsub{#1}{#2}{y}\compvectsub{#3}{#4}{y}+%
  \compvectsub{#1}{#2}{z}\compvectsub{#3}{#4}{z}}}
\newcommand*{\vectsubdotsdvectsub}[4]{\ensuremath{%
  \scompsvectsub{#1}{#2}\cdot\scompsdvectsub{#3}{#4}}}
\newcommand*{\vectsubDotsdvectsub}[4]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsdvectsub{#3}{#4}}}
\newcommand*{\vectsubdotsDvectsub}[4]{\ensuremath{%
  \scompsvectsub{#1}{#2}\cdot\scompsDvectsub{#3}{#4}}}
\newcommand*{\vectsubDotsDvectsub}[4]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsDvectsub{#3}{#4}}}
\newcommand*{\vectsubdotedvectsub}[4]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compdvectsub{#3}{#4}{x}+%
```

```
  \compvectsub{#1}{#2}{y}\compdvectsub{#3}{#4}{y}+%
  \compvectsub{#1}{#2}{z}\compdvectsub{#3}{#4}{z}}}
\newcommand*{\vectsubdoteDvectsub}[4]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compDvectsub{#3}{#4}{x}+%
  \compvectsub{#1}{#2}{y}\compDvectsub{#3}{#4}{y}+%
  \compvectsub{#1}{#2}{z}\compDvectsub{#3}{#4}{z}}}
\newcommand*{\vectsubdotsdvect}[3]{\ensuremath{%
  \scompsvectsub{#1}{#2}\cdot\scompsdvect{#3}}}
\newcommand*{\vectsubDotsdvect}[3]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsdvect{#3}}}
\newcommand*{\vectsubdotsDvect}[3]{\ensuremath{%
  \scompsvectsub{#1}{#2}\cdot\scompsDvect{#3}}}
\newcommand*{\vectsubDotsDvect}[3]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsDvect{#3}}}
\newcommand*{\vectsubdotedvect}[3]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compdvect{#3}{x}+%
  \compvectsub{#1}{#2}{y}\compdvect{#3}{y}+%
  \compvectsub{#1}{#2}{z}\compdvect{#3}{z}}}
\newcommand*{\vectsubdoteDvect}[3]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compDvect{#3}{x}+%
  \compvectsub{#1}{#2}{y}\compDvect{#3}{y}+%
  \compvectsub{#1}{#2}{z}\compDvect{#3}{z}}}
\newcommand*{\dervectdotsvect}[3]{\ensuremath{%
  \scompsdervect{#1}{#2}\cdot\scompsvect{#3}}}
\newcommand*{\dervectDotsvect}[3]{\ensuremath{%
  \scompsdervect{#1}{#2}\bullet\scompsvect{#3}}}
\newcommand*{\Dervectdotsvect}[3]{\ensuremath{%
  \scompsDervect{#1}{#2}\cdot\scompsvect{#3}}}
\newcommand*{\DervectDotsvect}[3]{\ensuremath{%
  \scompsDervect{#1}{#2}\bullet\scompsvect{#3}}}
\newcommand*{\dervectdotevect}[3]{\ensuremath{%
  \compdervect{#1}{x}{#2}\compvect{#3}{x}+%
  \compdervect{#1}{y}{#2}\compvect{#3}{y}+%
  \compdervect{#1}{z}{#2}\compvect{#3}{z}}}
\newcommand*{\Dervectdotevect}[3]{\ensuremath{%
  \compDervect{#1}{x}{#2}\compvect{#3}{x}+%
  \compDervect{#1}{y}{#2}\compvect{#3}{y}+%
  \compDervect{#1}{z}{#2}\compvect{#3}{z}}}
\newcommand*{\vectdotsdervect}[3]{\ensuremath{%
  \scompsvect{#1}\cdot\scompsdervect{#2}{#3}}}
\newcommand*{\vectDotsdervect}[3]{\ensuremath{%
  \scompsvect{#1}\bullet\scompsdervect{#2}{#3}}}
\newcommand*{\vectdotsDervect}[3]{\ensuremath{%
  \scompsvect{#1}\cdot\scompsDervect{#2}{#3}}}
\newcommand*{\vectDotsDervect}[3]{\ensuremath{%
  \scompsvect{#1}\bullet\scompsDervect{#2}{#3}}}
\newcommand*{\vectdotedervect}[3]{\ensuremath{%
  \compvect{#1}{x}\compdervect{#2}{x}{#3}+%
  \compvect{#1}{y}\compdervect{#2}{y}{#3}+%
  \compvect{#1}{z}\compdervect{#2}{z}{#3}}}
```

```
\newcommand*{\vectdoteDervect}[3]{\ensuremath{%
  \compvect{#1}{x}\compDervect{#2}{x}{#3}+%
  \compvect{#1}{y}\compDervect{#2}{y}{#3}+%
  \compvect{#1}{z}\compDervect{#2}{z}{#3}}}
\newcommand*{\dervectdotsdvect}[3]{\ensuremath{%
  \scompsdervect{#1}{#2}\cdot\scompsdvect{#3}}}
\newcommand*{\dervectDotsdvect}[3]{\ensuremath{%
  \scompsdervect{#1}{#2}\bullet\scompsdvect{#3}}}
\newcommand*{\DervectdotsDvect}[3]{\ensuremath{%
  \scompsDervect{#1}{#2}\cdot\scompsDvect{#3}}}
\newcommand*{\DervectDotsDvect}[3]{\ensuremath{%
  \scompsDervect{#1}{#2}\bullet\scompsDvect{#3}}}
\newcommand*{\dervectdotedvect}[3]{\ensuremath{%
  \compdervect{#1}{x}{#2}\compdvect{#3}{x}+%
  \compdervect{#1}{y}{#2}\compdvect{#3}{y}+%
  \compdervect{#1}{z}{#2}\compdvect{#3}{z}}}
\newcommand*{\DervectdoteDvect}[3]{\ensuremath{%
  \compDervect{#1}{x}{#2}\compDvect{#3}{x}+%
  \compDervect{#1}{y}{#2}\compDvect{#3}{y}+%
  \compDervect{#1}{z}{#2}\compDvect{#3}{z}}}
\newcommand*{\vectcrossvect}[2]{\ensuremath{%
  {#1}\boldsymbol{\times}{#2}}}
\newcommand*{\ltriplecross}[3]{\ensuremath{%
  \inparens{{#1}\boldsymbol{\times}{#2}}\boldsymbol{\times}{#3}}}
\newcommand*{\rtriplecross}[3]{\ensuremath{{#1}\boldsymbol{\times}%
  \inparens{{#2}\boldsymbol{\times}{#3}}}}
\newcommand*{\ltriplescalar}[3]{\ensuremath{%
  {#1}\boldsymbol{\times}{#2}\cdot{#3}}}
\newcommand*{\ltripleScalar}[3]{\ensuremath{%
  {#1}\boldsymbol{\times}{#2}\bullet{#3}}}
\newcommand*{\rtriplescalar}[3]{\ensuremath{%
  {#1}\cdot{#2}\boldsymbol{\times}{#3}}}
\newcommand*{\rtripleScalar}[3]{\ensuremath{%
  {#1}\bullet{#2}\boldsymbol{\times}{#3}}}
\newcommand*{\ezero}{\ensuremath{\boldsymbol{e}_0}}
\newcommand*{\eone}{\ensuremath{\boldsymbol{e}_1}}
\newcommand*{\etwo}{\ensuremath{\boldsymbol{e}_2}}
\newcommand*{\ethree}{\ensuremath{\boldsymbol{e}_3}}
\newcommand*{\efour}{\ensuremath{\boldsymbol{e}_4}}
\newcommand*{\ek}[1]{\ensuremath{\boldsymbol{e}_{#1}}}
\newcommand*{\e}{\ek}
\newcommand*{\uezero}{\ensuremath{\widehat{\boldsymbol{e}}_0}}
\newcommand*{\ueone}{\ensuremath{\widehat{\boldsymbol{e}}_1}}
\newcommand*{\uetwo}{\ensuremath{\widehat{\boldsymbol{e}}_2}}
\newcommand*{\uethree}{\ensuremath{\widehat{\boldsymbol{e}}_3}}
\newcommand*{\uefour}{\ensuremath{\widehat{\boldsymbol{e}}_4}}
\newcommand*{\uek}[1]{\ensuremath{\widehat{\boldsymbol{e}}_{#1}}}
\newcommand*{\ue}{\uek}
\newcommand*{\ezerozero}{\ek{00}}
\newcommand*{\ezeroone}{\ek{01}}
```

```
\newcommand*{\ezerotwo}{\ek{02}}
\newcommand*{\ezerothree}{\ek{03}}
\newcommand*{\ezerofour}{\ek{04}}
\newcommand*{\eoneone}{\ek{11}}
\newcommand*{\eonetwo}{\ek{12}}
\newcommand*{\eonethree}{\ek{13}}
\newcommand*{\eonefour}{\ek{14}}
\newcommand*{\etwoone}{\ek{21}}
\newcommand*{\etwotwo}{\ek{22}}
\newcommand*{\etwothree}{\ek{23}}
\newcommand*{\etwofour}{\ek{24}}
\newcommand*{\ethreeone}{\ek{31}}
\newcommand*{\ethreetwo}{\ek{32}}
\newcommand*{\ethreethree}{\ek{33}}
\newcommand*{\ethreefour}{\ek{34}}
\newcommand*{\efourone}{\ek{41}}
\newcommand*{\efourtwo}{\ek{42}}
\newcommand*{\efourthree}{\ek{43}}
\newcommand*{\efourfour}{\ek{44}}
\newcommand*{\euzero}{\ensuremath{\boldsymbol{e}^0}}
\newcommand*{\euone}{\ensuremath{\boldsymbol{e}^1}}
\newcommand*{\eutwo}{\ensuremath{\boldsymbol{e}^2}}
\newcommand*{\euthree}{\ensuremath{\boldsymbol{e}^3}}
\newcommand*{\eufour}{\ensuremath{\boldsymbol{e}^4}}
\newcommand*{\euk}[1]{\ensuremath{\boldsymbol{e}^{#1}}}
\newcommand*{\eu}{\euk}
\newcommand*{\ueuzero}{\ensuremath{\widehat{\boldsymbol{e}}^0}}
\newcommand*{\ueuone}{\ensuremath{\widehat{\boldsymbol{e}}^1}}
\newcommand*{\ueutwo}{\ensuremath{\widehat{\boldsymbol{e}}^2}}
\newcommand*{\ueuthree}{\ensuremath{\widehat{\boldsymbol{e}}^3}}
\newcommand*{\ueufour}{\ensuremath{\widehat{\boldsymbol{e}}^4}}
\newcommand*{\ueuk}[1]{\ensuremath{\widehat{\boldsymbol{e}}^{#1}}}
\newcommand*{\ueu}{\ueuk}
\newcommand*{\euzerozero}{\euk{00}}
\newcommand*{\euzeroone}{\euk{01}}
\newcommand*{\euzerotwo}{\euk{02}}
\newcommand*{\euzerothree}{\euk{03}}
\newcommand*{\euzerofour}{\euk{04}}
\newcommand*{\euoneone}{\euk{11}}
\newcommand*{\euonetwo}{\euk{12}}
\newcommand*{\euonethree}{\euk{13}}
\newcommand*{\euonefour}{\euk{14}}
\newcommand*{\eutwoone}{\euk{21}}
\newcommand*{\eutwotwo}{\euk{22}}
\newcommand*{\eutwothree}{\euk{23}}
\newcommand*{\eutwofour}{\euk{24}}
\newcommand*{\euthreeone}{\euk{31}}
\newcommand*{\euthreetwo}{\euk{32}}
\newcommand*{\euthreethree}{\euk{33}}
\newcommand*{\euthreefour}{\euk{34}}
```

```
\newcommand*{\eufourone}{\euk{41}}
\newcommand*{\eufourtwo}{\euk{42}}
\newcommand*{\eufourthree}{\euk{43}}
\newcommand*{\eufourfour}{\euk{44}}
\newcommand*{\gzero}{\ensuremath{\boldsymbol{\gamma}_0}}
\newcommand*{\gone}{\ensuremath{\boldsymbol{\gamma}_1}}
\newcommand*{\gtwo}{\ensuremath{\boldsymbol{\gamma}_2}}
\newcommand*{\gthree}{\ensuremath{\boldsymbol{\gamma}_3}}
\newcommand*{\gfour}{\ensuremath{\boldsymbol{\gamma}_4}}
\newcommand*{\gk}[1]{\ensuremath{\boldsymbol{\gamma}_{#1}}}
\newcommand*{\g}{\gk}
\newcommand*{\gzerozero}{\gk{00}}
\newcommand*{\gzeroone}{\gk{01}}
\newcommand*{\gzerotwo}{\gk{02}}
\newcommand*{\gzerothree}{\gk{03}}
\newcommand*{\gzerofour}{\gk{04}}
\newcommand*{\goneone}{\gk{11}}
\newcommand*{\gonetwo}{\gk{12}}
\newcommand*{\gonethree}{\gk{13}}
\newcommand*{\gonefour}{\gk{14}}
\newcommand*{\gtwoone}{\gk{21}}
\newcommand*{\gtwotwo}{\gk{22}}
\newcommand*{\gtwothree}{\gk{23}}
\newcommand*{\gtwofour}{\gk{24}}
\newcommand*{\gthreeone}{\gk{31}}
\newcommand*{\gthreetwo}{\gk{32}}
\newcommand*{\gthreethree}{\gk{33}}
\newcommand*{\gthreefour}{\gk{34}}
\newcommand*{\gfourone}{\gk{41}}
\newcommand*{\gfourtwo}{\gk{42}}
\newcommand*{\gfourthree}{\gk{43}}
\newcommand*{\gfourfour}{\gk{44}}
\newcommand*{\guzero}{\ensuremath{\boldsymbol{\gamma}^0}}
\newcommand*{\guone}{\ensuremath{\boldsymbol{\gamma}^1}}
\newcommand*{\gutwo}{\ensuremath{\boldsymbol{\gamma}^2}}
\newcommand*{\guthree}{\ensuremath{\boldsymbol{\gamma}^3}}
\newcommand*{\gufour}{\ensuremath{\boldsymbol{\gamma}^4}}
\newcommand*{\guk}[1]{\ensuremath{\boldsymbol{\gamma}^{#1}}}
\newcommand*{\gu}{\guk}
\newcommand*{\guzerozero}{\guk{00}}
\newcommand*{\guzeroone}{\guk{01}}
\newcommand*{\guzerotwo}{\guk{02}}
\newcommand*{\guzerothree}{\guk{03}}
\newcommand*{\guzerofour}{\guk{04}}
\newcommand*{\guoneone}{\guk{11}}
\newcommand*{\guonetwo}{\guk{12}}
\newcommand*{\guonethree}{\guk{13}}
\newcommand*{\guonefour}{\guk{14}}
\newcommand*{\gutwoone}{\guk{21}}
\newcommand*{\gutwotwo}{\guk{22}}
```

```
\newcommand*{\gutwothree}{\guk{23}}
\newcommand*{\gutwofour}{\guk{24}}
\newcommand*{\guthreeone}{\guk{31}}
\newcommand*{\guthreetwo}{\guk{32}}
\newcommand*{\guthreethree}{\guk{33}}
\newcommand*{\guthreefour}{\guk{34}}
\newcommand*{\gufourone}{\guk{41}}
\newcommand*{\gufourtwo}{\guk{42}}
\newcommand*{\gufourthree}{\guk{43}}
\newcommand*{\gufourfour}{\guk{44}}
\ExplSyntaxOn % Vectors formated as in M\&I, written in LaTeX3
\NewDocumentCommand{\mivector}{ O{,} m o }%
 {%
   \mi_vector:nn { #1 } { #2 }
   \IfValueT{#3}{\;{#3}}
 }%
\seq_new:N \l__mi_list_seq
\cs_new_protected:Npn \mi_vector:nn #1 #2
{%
  \ensuremath{%
    \seq_set_split:Nnn \l__mi_list_seq { , } { #2 }
    \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \left\langle }
    \seq_use:Nnnn \l__mi_list_seq { #1 } { #1 } { #1 }
    \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \right\rangle }
  }%
}%
\ExplSyntaxOff
\ExplSyntaxOn % Column and row vectors, written in LaTeX3
\seq_new:N \l__vector_arg_seq
\cs_new_protected:Npn \vector_main:nnnn #1 #2 #3 #4
 {%
  \seq_set_split:Nnn \l__vector_arg_seq { #3 } { #4 }
  \begin{#1matrix}
    \seq_use:Nnnn \l__vector_arg_seq { #2 } { #2 } { #2 }
  \end{#1matrix}
 }%
\NewDocumentCommand{\rowvector}{ O{,} m }
 {%
  \ensuremath{
  \vector_main:nnnn { p } { \,\, } { #1 } { #2 }
  }%
 }%
\NewDocumentCommand{\colvector}{ O{,} m }
 {%
  \ensuremath{
  \vector_main:nnnn { p } { \\ } { #1 } { #2 }
  }%
 }%
\ExplSyntaxOff
\newcommandx{\scompscvect}[2][1,usedefault]{%
```

```
  \ifthenelse{\equal{#1}{}}%
  {%
    \colvector{\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
  }%
  {%
    \colvector{\msub{#2}{0},\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
  }%
}%
\newcommandx{\scompsCvect}[2][1,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
  {%
    \colvector{\msup{#2}{1},\msup{#2}{2},\msup{#2}{3}}%
  }%
  {%
    \colvector{\msup{#2}{0},\msup{#2}{1},\msup{#2}{2},\msup{#2}{3}}%
  }%
}%
\newcommandx{\scompsrvect}[2][1,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
  {%
    \rowvector[,]{\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
  }%
  {%
    \rowvector[,]{\msub{#2}{0},\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
  }%
}%
\newcommandx{\scompsRvect}[2][1,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
  {%
    \rowvector[,]{\msup{#2}{1},\msup{#2}{2},\msup{#2}{3}}%
  }%
  {%
    \rowvector[,]{\msup{#2}{0},\msup{#2}{1},\msup{#2}{2},\msup{#2}{3}}%
  }%
}%
\newcommand*{\bra}[1]{\ensuremath{\left\langle{#1}\right\lvert}}
\newcommand*{\ket}[1]{\ensuremath{\left\lvert{#1}\right\rangle}}
\newcommand*{\bracket}[2]{\ensuremath{\left\langle{#1}\!\!\right.%
  \left\lvert{#2}\right\rangle}}
\newphysicsconstant{oofpez}%
  {\ensuremath{\frac{1}{\phantom{_o}4\pi\epsilon_0}}}%
  {\mi@p{9}{8.9875517873681764}\timestento{9}}%
  {\m\cubed\usk\kg\usk\reciprocalquartic\s\usk\A\reciprocalsquared}%
  [\m\per\farad]%
  [\newton\usk\m\squared\per\coulomb\squared]
\newphysicsconstant{oofpezcs}%
  {\ensuremath{\frac{1}{\phantom{_o}4\pi\epsilon_0 c^2\phantom{_o}}}}%
  {\tento{-7}}%
  {\m\usk\kg\usk\s\reciprocalsquared\usk\A\reciprocalsquared}%
  [\T\usk\m\squared]%
```

```
  [\N\usk\s\squared\per\C\squared]
\newphysicsconstant{vacuumpermittivity}%
  {\ensuremath{\epsilon_0}}%
  {\mi@p{9.0}{8.854187817}\timestento{-12}}%
  {\m\reciprocalcubed\usk\reciprocal\kg\usk\s\quarted\usk\A\squared}%
  [\F\per\m]%
  [\C\squared\per\N\usk\m\squared]
\newphysicsconstant{mzofp}%
  {\ensuremath{\frac{\phantom{_oo}\mu_0\phantom{_o}}{4\pi}}}%
  {\tento{-7}}%
  {\m\usk\kg\usk\s\reciprocalsquared\usk\A\reciprocalsquared}%
  [\henry\per\m]%
  [\tesla\usk\m\per\A]
\newphysicsconstant{vacuumpermeability}%
  {\ensuremath{\mu_0}}%
  {4\pi\timestento{-7}}%
  {\m\usk\kg\usk\s\reciprocalsquared\usk\A\reciprocalsquared}%
  [\henry\per\m]%
  [\T\usk\m\per\A]
\newphysicsconstant{boltzmann}%
  {\ensuremath{k_B}}%
  {\mi@p{1.4}{1.38064852}\timestento{-23}}%
  {\m\squared\usk\kg\usk\reciprocalsquare\s\usk\reciprocal\K}%
  [\joule\per\K]%
  [\J\per\K]
\newphysicsconstant{boltzmannineV}%
  {\ensuremath{k_B}}%
  {\mi@p{8.6}{8.6173303}\timestento{-5}}%
  {\eV\usk\reciprocal\K}%
  [\eV\per\K]%
  [\eV\per\K]
\newphysicsconstant{stefanboltzmann}%
  {\ensuremath{\sigma}}%
  {\mi@p{5.7}{5.670367}\timestento{-8}}%
  {\kg\usk\s\reciprocalcubed\usk\K\reciprocalquarted}%
  [\W\per\m\squared\usk\K^4]%
  [\W\per\m\squared\usk\K\quarted]
\newphysicsconstant{planck}%
  {\ensuremath{h}}%
  {\mi@p{6.6}{6.626070040}\timestento{-34}}%
  {\m\squared\usk\kg\usk\reciprocal\s}%
  [\J\usk\s]%
  [\J\usk\s]
\newphysicsconstant{planckineV}%
  {\ensuremath{h}}%
  {\mi@p{4.1}{4.135667662}\timestento{-15}}%
  {\eV\usk\s}%
  [\eV\usk\s]%
  [\eV\usk\s]
\newphysicsconstant{planckbar}%
```

```
  {\ensuremath{\hslash}}%
  {\mi@p{1.1}{1.054571800}\timestento{-34}}%
  {\m\squared\usk\kg\usk\reciprocal\s}%
  [\J\usk\s]%
  [\J\usk\s]
\newphysicsconstant{planckbarineV}%
  {\ensuremath{\hslash}}%
  {\mi@p{6.6}{6.582119514}\timestento{-16}}%
  {\eV\usk\s}%
  [\eV\usk\s]%
  [\eV\usk\s]
\newphysicsconstant{planckc}%
  {\ensuremath{hc}}%
  {\mi@p{2.0}{1.98644568}\timestento{-25}}%
  {\m\cubed\usk\kg\usk\reciprocalsquare\s}%
  [\J\usk\m]%
  [\J\usk\m]
\newphysicsconstant{planckcineV}%
  {\ensuremath{hc}}%
  {\mi@p{1240}{1.23984193}\timestento{3}}%
  {\eV\usk\text{n}\m}%
  [\eV\usk\text{n}\m]%
  [\eV\usk\text{n}\m]
\newphysicsconstant{rydberg}%
  {\ensuremath{\msub{R}{\infty}}}%
  {\mi@p{1.1}{1.0973731568508}\timestento{7}}%
  {\reciprocal\m}%
  [\reciprocal\m]%
  [\reciprocal\m]
\newphysicsconstant{bohrradius}%
  {\ensuremath{a_0}}%
  {\mi@p{5.3}{5.2917721067}\timestento{-11}}%
  {\m}%
  [\m]%
  [\m]
\newphysicsconstant{finestructure}%
  {\ensuremath{\alpha}}%
  {\mi@p{\frac{1}{137}}{7.2973525664\timestento{-3}}}%
  {}%
  []%
  []
\newphysicsconstant{avogadro}%
  {\ensuremath{N_A}}%
  {\mi@p{6.0}{6.022140857}\timestento{23}}%
  {\reciprocal\mol}%
  [\reciprocal\mol]%
  [\reciprocal\mol]
\newphysicsconstant{universalgrav}%
  {\ensuremath{G}}%
  {\mi@p{6.7}{6.67408}\timestento{-11}}%
```

```
  {\m\cubed\usk\reciprocal\kg\usk\s\reciprocalsquared}%
  [\J\usk\m\per\kg\squared]%
  [\N\usk\m\squared\per\kg\squared]
\newphysicsconstant{surfacegravfield}%
  {\ensuremath{g}}%
  {\mi@p{9.8}{9.807}}%
  {\m\usk\s\reciprocalsquared}%
  [\N\per\kg]%
  [\N\per\kg]
\newphysicsconstant{clight}%
  {\ensuremath{c}}%
  {\mi@p{3}{2.99792458}\timestento{8}}%
  {\m\usk\reciprocal\s}%
  [\m\per\s]%
  [\m\per\s]
\newphysicsconstant{clightinfeet}%
  {\ensuremath{c}}%
  {\mi@p{1}{0.983571}}%
  {\text{ft}\usk\reciprocal{\text{n}\s}}%
  [\text{ft}\per\text{n}\s]%
  [\text{ft}\per\mathrm{n}\s]
\newphysicsconstant{Ratom}%
  {\ensuremath{r_{\text{atom}}}}%
  {\tento{-10}}%
  {\m}%
  [\m]%
  [\m]
\newphysicsconstant{Mproton}%
  {\ensuremath{m_p}}%
  {\mi@p{1.7}{1.672621898}\timestento{-27}}%
  {\kg}%
  [\kg]%
  [\kg]
\newphysicsconstant{Mneutron}%
  {\ensuremath{m_n}}%
  {\mi@p{1.7}{1.674927471}\timestento{-27}}%
  {\kg}%
  [\kg]%
  [\kg]
\newphysicsconstant{Mhydrogen}%
  {\ensuremath{m_H}}%
  {\mi@p{1.7}{1.6737236}\timestento{-27}}%
  {\kg}%
  [\kg]%
  [\kg]
\newphysicsconstant{Melectron}%
  {\ensuremath{m_e}}%
  {\mi@p{9.1}{9.10938356}\timestento{-31}}%
  {\kg}%
  [\kg]%
```

```
  [\kg]
\newphysicsconstant{echarge}%
  {\ensuremath{e}}%
  {\mi@p{1.6}{1.6021766208}\timestento{-19}}%
  {\A\usk\s}%
  [\C]%
  [\C]
\newphysicsconstant{Qelectron}%
  {\ensuremath{Q_e}}%
  {-\echargevalue}%
  {\A\usk\s}%
  [\C]%
  [\C]
\newphysicsconstant{qelectron}%
  {\ensuremath{q_e}}%
  {-\echargevalue}%
  {\A\usk\s}%
  [\C]%
  [\C]
\newphysicsconstant{Qproton}%
  {\ensuremath{Q_p}}%
  {+\echargevalue}%
  {\A\usk\s}%
  [\C]%
  [\C]
\newphysicsconstant{qproton}%
  {\ensuremath{q_p}}%
  {+\echargevalue}%
  {\A\usk\s}%
  [\C]%
  [\C]
\newphysicsconstant{MEarth}%
  {\ensuremath{M_{\text{Earth}}}}%
  {\mi@p{6.0}{5.97237}\timestento{24}}%
  {\kg}%
  [\kg]%
  [\kg]
\newphysicsconstant{MMoon}%
  {\ensuremath{M_{\text{Moon}}}}%
  {\mi@p{7.3}{7.342}\timestento{22}}%
  {\kg}%
  [\kg]%
  [\kg]
\newphysicsconstant{MSun}%
  {\ensuremath{M_{\text{Sun}}}}%
  {\mi@p{2.0}{1.98855}\timestento{30}}%
  {\kg}%
  [\kg]%
  [\kg]
\newphysicsconstant{REarth}%
```

```
  {\ensuremath{R_{\text{Earth}}}}%
  {\mi@p{6.4}{6.371}\timestento{6}}%
  {\m}%
  [\m]%
  [\m]
\newphysicsconstant{RMoon}%
  {\ensuremath{R_{\text{Moon}}}}%
  {\mi@p{1.7}{1.7371}\timestento{6}}%
  {\m}%
  [\m]%
  [\m]
\newphysicsconstant{RSun}%
  {\ensuremath{R_{\text{Sun}}}}%
  {\mi@p{7.0}{6.957}\timestento{8}}%
  {\m}%
  [\m]%
  [\m]
\newphysicsconstant{ESdist}%
  {\magvectsub{r}{ES}}%
  {\mi@p{1.5}{1.496}\timestento{11}}%
  {\m}%
  [\m]%
  [\m]
\newphysicsconstant{SEdist}%
  {\magvectsub{r}{SE}}%
  {\mi@p{1.5}{1.496}\timestento{11}}%
  {\m}%
  [\m]%
  [\m]
\newphysicsconstant{EMdist}%
  {\magvectsub{r}{EM}}%
  {\mi@p{3.8}{3.81550}\timestento{8}}%
  {\m}%
  [\m]%
  [\m]
\newphysicsconstant{MEdist}%
  {\magvectsub{r}{ME}}%
  {\mi@p{3.8}{3.81550}\timestento{8}}%
  {\m}%
  [\m]%
  [\m]
\newphysicsconstant{LSun}%
  {\ensuremath{L_{\text{Sun}}}}%
  {\mi@p{3.8}{3.8460}\timestento{26}}%
  {\m\squared\usk\kg\usk\s\reciprocalcubed}%
  [\W]
  [\J\per\s]
\newphysicsconstant{TSun}%
  {\ensuremath{T_{\text{Sun}}}}%
  {\mi@p{5800}{5778}}%
```

```
  {\K}%
  [\K]%
  [\K]
\newphysicsconstant{MagSun}%
  {\ensuremath{M_{\text{Sun}}}}%
  {+4.83}%
  {}%
  []%
  []
\newphysicsconstant{magSun}%
  {\ensuremath{m_{\text{Sun}}}}%
  {-26.74}%
  {}%
  []%
  []
\newcommand*{\coulombconstant}{\oofpez}
\newcommand*{\altcoulombconstant}{\oofpezcs}
\newcommand*{\biotsavartconstant}{\mzofp}
\newcommand*{\boltzmannconstant}{\boltzmann}
\newcommand*{\stefanboltzmannconstant}{\stefanboltzmann}
\newcommand*{\planckconstant}{\planck}
\newcommand*{\reducedplanckconstant}{\planckbar}
\newcommand*{\planckconstanttimesc}{\planckc}
\newcommand*{\rydbergconstant}{\rydberg}
\newcommand*{\finestructureconstant}{\finestructure}
\newcommand*{\avogadroconstant}{\avogadro}
\newcommand*{\universalgravitationalconstant}{\universalgrav}
\newcommand*{\earthssurfacegravitationalfield}{\surfacegravfield}
\newcommand*{\photonconstant}{\clight}
\newcommand*{\elementarycharge}{\echarge}
\newcommand*{\EarthSundistance}{\ESdist}
\newcommand*{\SunEarthdistance}{\SEdist}
\newcommand*{\EarthMoondistance}{\ESdist}
\newcommand*{\MoonEarthdistance}{\SEdist}
\newcommand*{\Lstar}[1][\(\star\)]{\ensuremath{L_{\text{#1}}}\xspace}
\newcommand*{\Lsolar}{\ensuremath{\Lstar[\(\odot\)]}\xspace}
\newcommand*{\Tstar}[1][\(\star\)]{\ensuremath{T_{\text{#1}}}\xspace}
\newcommand*{\Tsolar}{\ensuremath{\Tstar[\(\odot\)]}\xspace}
\newcommand*{\Rstar}[1][\(\star\)]{\ensuremath{R_{\text{#1}}}\xspace}
\newcommand*{\Rsolar}{\ensuremath{\Rstar[\(\odot\)]}\xspace}
\newcommand*{\Mstar}[1][\(\star\)]{\ensuremath{M_{\text{#1}}}\xspace}
\newcommand*{\Msolar}{\ensuremath{\Mstar[\(\odot\)]}\xspace}
\newcommand*{\Fstar}[1][\(\star\)]{\ensuremath{F_{\text{#1}}}\xspace}
\newcommand*{\fstar}[1][\(\star\)]{\ensuremath{f_{\text{#1}}}\xspace}
\newcommand*{\Fsolar}{\ensuremath{\Fstar[\(\odot\)]}\xspace}
\newcommand*{\fsolar}{\ensuremath{\fstar[\(\odot\)]}\xspace}
\newcommand*{\Magstar}[1][\(\star\)]{\ensuremath{M_{\text{#1}}}\xspace}
\newcommand*{\magstar}[1][\(\star\)]{\ensuremath{m_{\text{#1}}}\xspace}
\newcommand*{\Magsolar}{\ensuremath{\Magstar[\(\odot\)]}\xspace}
\newcommand*{\magsolar}{\ensuremath{\magstar[\(\odot\)]}\xspace}
```

```
\newcommand*{\Dstar}[1][\(\star\)]{\ensuremath{D_{\text{#1}}}\xspace}
\newcommand*{\dstar}[1][\(\star\)]{\ensuremath{d_{\text{#1}}}\xspace}
\newcommand*{\Dsolar}{\ensuremath{\Dstar[\(\odot\)]}\xspace}
\newcommand*{\dsolar}{\ensuremath{\dstar[\(\odot\)]}\xspace}
\newcommand*{\onehalf}{\ensuremath{\frac{1}{2}}\xspace}
\newcommand*{\onethird}{\ensuremath{\frac{1}{3}}\xspace}
\newcommand*{\onefourth}{\ensuremath{\frac{1}{4}}\xspace}
\newcommand*{\onefifth}{\ensuremath{\frac{1}{5}}\xspace}
\newcommand*{\onesixth}{\ensuremath{\frac{1}{6}}\xspace}
\newcommand*{\oneseventh}{\ensuremath{\frac{1}{7}}\xspace}
\newcommand*{\oneeighth}{\ensuremath{\frac{1}{8}}\xspace}
\newcommand*{\oneninth}{\ensuremath{\frac{1}{9}}\xspace}
\newcommand*{\onetenth}{\ensuremath{\frac{1}{10}}\xspace}
\newcommand*{\twooneths}{\ensuremath{\frac{2}{1}}\xspace}
\newcommand*{\twohalves}{\ensuremath{\frac{2}{2}}\xspace}
\newcommand*{\twothirds}{\ensuremath{\frac{2}{3}}\xspace}
\newcommand*{\twofourths}{\ensuremath{\frac{2}{4}}\xspace}
\newcommand*{\twofifths}{\ensuremath{\frac{2}{5}}\xspace}
\newcommand*{\twosixths}{\ensuremath{\frac{2}{6}}\xspace}
\newcommand*{\twosevenths}{\ensuremath{\frac{2}{7}}\xspace}
\newcommand*{\twoeighths}{\ensuremath{\frac{2}{8}}\xspace}
\newcommand*{\twoninths}{\ensuremath{\frac{2}{9}}\xspace}
\newcommand*{\twotenths}{\ensuremath{\frac{2}{10}}\xspace}
\newcommand*{\threeoneths}{\ensuremath{\frac{3}{1}}\xspace}
\newcommand*{\threehalves}{\ensuremath{\frac{3}{2}}\xspace}
\newcommand*{\threethirds}{\ensuremath{\frac{3}{3}}\xspace}
\newcommand*{\threefourths}{\ensuremath{\frac{3}{4}}\xspace}
\newcommand*{\threefifths}{\ensuremath{\frac{3}{5}}\xspace}
\newcommand*{\threesixths}{\ensuremath{\frac{3}{6}}\xspace}
\newcommand*{\threesevenths}{\ensuremath{\frac{3}{7}}\xspace}
\newcommand*{\threeeighths}{\ensuremath{\frac{3}{8}}\xspace}
\newcommand*{\threeninths}{\ensuremath{\frac{3}{9}}\xspace}
\newcommand*{\threetenths}{\ensuremath{\frac{3}{10}}\xspace}
\newcommand*{\fouroneths}{\ensuremath{\frac{4}{1}}\xspace}
\newcommand*{\fourhalves}{\ensuremath{\frac{4}{2}}\xspace}
\newcommand*{\fourthirds}{\ensuremath{\frac{4}{3}}\xspace}
\newcommand*{\fourfourths}{\ensuremath{\frac{4}{4}}\xspace}
\newcommand*{\fourfifths}{\ensuremath{\frac{4}{5}}\xspace}
\newcommand*{\foursixths}{\ensuremath{\frac{4}{6}}\xspace}
\newcommand*{\foursevenths}{\ensuremath{\frac{4}{7}}\xspace}
\newcommand*{\foureighths}{\ensuremath{\frac{4}{8}}\xspace}
\newcommand*{\fourninths}{\ensuremath{\frac{4}{9}}\xspace}
\newcommand*{\fourtenths}{\ensuremath{\frac{4}{10}}\xspace}
\newcommand*{\sumoverall}[1]{\ensuremath{\displaystyle
  \sum_{\substack{\text{\tiny{all }}\text{\tiny{{#1}}}}}}}
\newcommand*{\dx}[1]{\ensuremath{\,\mathrm{d}{#1}}}
\newcommand*{\dslashx}[1]{\ensuremath{\,\mathchar'26\mkern-12mu \mathrm{d}{#1}}}
\newcommandx{\evaluatedfromto}[2][2,usedefault]{\ensuremath{%
  \Bigg.\Bigg\rvert_{#1}^{#2}}}
\newcommand*{\evaluatedat}{\evaluatedfromto}
```

```
\newcommandx{\integral}[4][1,2,usedefault]{\ensuremath{%
  \int_{\ifthenelse{\equal{#1}{}}{}{#4=#1}}^{\ifthenelse{%
    \equal{#2}{}}{}{#4=#2}}}{#3}\dx{#4}}
\newcommand*{\opensurfaceintegral}[2]{\ensuremath{%
  \iint\nolimits_{#1}\vectdotvect{#2}{\dirvect{n}}\dx{A}}}
\newcommand*{\closedsurfaceintegral}[2]{\ensuremath{%
  \varoiint\nolimits_{#1}\vectdotvect{#2}{\dirvect{n}}\dx{A}}}
\newcommand*{\openlineintegral}[2]{\ensuremath{%
  \int\nolimits_{#1}\vectdotvect{#2}{\dirvect{t}}\dx{\ell}}}
\newcommand*{\closedlineintegral}[2]{\ensuremath{%
  \oint\nolimits_{#1}\vectdotvect{#2}{\dirvect{t}}\dx{\ell}}}
\newcommand*{\volumeintegral}[2]{\ensuremath{%
  \iiint\nolimits_{#1}{#2}\dx{V}}}
\newcommandx{\dbydt}[1][1]{\ensuremath{%
  \frac{\mathrm{d}{#1}}{\mathrm{d}t}}}
\newcommandx{\DbyDt}[1][1]{\ensuremath{%
  \frac{\Delta{#1}}{\Delta t}}}
\newcommandx{\ddbydt}[1][1]{\ensuremath{%
  \frac{\mathrm{d}^{2}{#1}}{\mathrm{d}t^{2}}}}
\newcommandx{\DDbyDt}[1][1]{\ensuremath{%
  \frac{\Delta^{2}{#1}}{\Delta t^{2}}}}
\newcommandx{\pbypt}[1][1]{\ensuremath{%
  \frac{\partial{#1}}{\partial t}}}
\newcommandx{\ppbypt}[1][1]{\ensuremath{%
  \frac{\partial^{2}{#1}}{\partial t^{2}}}}
\newcommand*{\dbyd}[2]{\ensuremath{\frac{%
  \mathrm{d}{#1}}{\mathrm{d}{#2}}}}
\newcommand*{\DbyD}[2]{\ensuremath{\frac{%
  \Delta{#1}}{\Delta{#2}}}}
\newcommand*{\ddbyd}[2]{\ensuremath{%
  \frac{\mathrm{d}^{2}{#1}}{\mathrm{d}{#2}^{2}}}}
\newcommand*{\DDbyD}[2]{\ensuremath{%
  \frac{\Delta^{2}{#1}}{\Delta{#2}^{2}}}}
\newcommand*{\pbyp}[2]{\ensuremath{%
  \frac{\partial{#1}}{\partial{#2}}}}
\newcommand*{\ppbyp}[2]{\ensuremath{%
  \frac{\partial^{2}{#1}}{\partial{#2}^{2}}}}
\newcommand*{\seriesfofx}{\ensuremath{%
  f(x) \approx f(a) + \frac{f^\prime (a)}{1!}(x-a) + \frac{f^{\prime\prime}(a)}{2!}
  (x-a)^2 + \frac{f^{\prime\prime\prime}(a)}{3!}(x-a)^3 + \ldots}\xspace}
\newcommand*{\seriesexpx}{\ensuremath{%
  e^x \approx 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots}\xspace}
\newcommand*{\seriessinx}{\ensuremath{%
  \sin x \approx x - \frac{x^3}{3!} + \frac{x^5}{5!} - \ldots}\xspace}
\newcommand*{\seriescosx}{\ensuremath{%
  \cos x \approx 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \ldots}\xspace}
\newcommand*{\seriestanx}{\ensuremath{%
  \tan x \approx x + \frac{x^3}{3} + \frac{2x^5}{15} + \ldots}\xspace}
\newcommand*{\seriesatox}{\ensuremath{%
  a^x \approx 1 + x \ln{a} + \frac{(x \ln a)^2}{2!} + \frac{(x \ln a)^3}{3!} + %
```

```
  \ldots}\xspace}
\newcommand*{\serieslnoneplusx}{\ensuremath{%
  \ln(1 \pm x) \approx \pm\; x - \frac{x^2}{2} \pm \frac{x^3}{3} - %
    \frac{x^4}{4} \pm \ldots}\xspace}
\newcommand*{\binomialseries}{\ensuremath{%
  (1 + x)^n \approx 1 + nx + \frac{n(n-1)}{2!}x^2 + \ldots}\xspace}
\newcommand*{\gradient}{\ensuremath{\boldsymbol{\nabla}}}
\newcommand*{\divergence}{\ensuremath{\boldsymbol{\nabla}\bullet}}
\newcommand*{\curl}{\ensuremath{\boldsymbol{\nabla\times}}}
\newcommand{\taigrad}{\ensuremath{\nabla}}%
\newcommand{\taisvec}{\ensuremath{%
  \stackinset{c}{0.07ex}{c}{0.1ex}{\tiny$-$}{$\nabla$}}
}%
\newcommand{\taidivg}{\ensuremath{%
  \stackinset{c}{0.07ex}{c}{0.1ex}{$\cdot$}{$\nabla$}}
}%
\newcommand{\taicurl}{\ensuremath{%
  \stackinset{c}{0.04ex}{c}{0.32ex}{\tiny$\times$}{$\nabla$}}
}%
\newcommand*{\laplacian}{\ensuremath{\boldsymbol{\nabla}^2}}
\newcommand*{\dalembertian}{\ensuremath{\boldsymbol{\Box}}}
\newcommand*{\diracdelta}[1]{\ensuremath{\delta}(#1)}
\newcommand*{\orderof}[1]{\ensuremath{\mathcal{O}(#1)}}
\DeclareMathOperator{\asin}{\sin^{-1}}
\DeclareMathOperator{\acos}{\cos^{-1}}
\DeclareMathOperator{\atan}{\tan^{-1}}
\DeclareMathOperator{\asec}{\sec^{-1}}
\DeclareMathOperator{\acsc}{\csc^{-1}}
\DeclareMathOperator{\acot}{\cot^{-1}}
\DeclareMathOperator{\sech}{sech}
\DeclareMathOperator{\csch}{csch}
\DeclareMathOperator{\asinh}{\sinh^{-1}}
\DeclareMathOperator{\acosh}{\cosh^{-1}}
\DeclareMathOperator{\atanh}{\tanh^{-1}}
\DeclareMathOperator{\asech}{\sech^{-1}}
\DeclareMathOperator{\acsch}{\csch^{-1}}
\DeclareMathOperator{\acoth}{\coth^{-1}}
\DeclareMathOperator{\sgn}{sgn}
\DeclareMathOperator{\dex}{dex}
\newcommand*{\logb}[1][\relax]{\ensuremath{\log_{#1}}}
\ifthenelse{\boolean{@optboldvectors}}
  {\newcommand*{\cB}{\ensuremath{\boldsymbol{c\mskip -3.00mu B}}}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\newcommand*{\cB}{\ensuremath{\textsf{c}\mskip -3.00mu\mathrm{B}}}}
   {\newcommand*{\cB}{\ensuremath{c\mskip -3.00mu B}}}}
\newcommand*{\newpi}{\ensuremath{\pi\mskip -7.8mu\pi}}
\newcommand*{\scripty}[1]{\ensuremath{\mathcalligra{#1}}}
\newcommand*{\Lagr}{\ensuremath{\mathcal{L}}}
\newcommandx{\flux}[1][1]{\ensuremath{\ssub{\Phi}{#1}}}
\newcommandx{\circulation}[1][1]{\ensuremath{\ssub{\Gamma}{#1}}}
```

```
\newcommand*{\absof}[1]{\ensuremath{%
  \left\lvert{\ifblank{#1}{\:\_\:}{#1}}\right\rvert}}
\newcommand*{\inparens}[1]{\ensuremath{%
  \left({\ifblank{#1}{\:\_\:}{#1}}\right)}}
\newcommand*{\magof}[1]{\ensuremath{%
  \left\lVert{\ifblank{#1}{\:\_\:}{#1}}\right\rVert}}
\newcommand*{\dimsof}[1]{\ensuremath{%
  \left[{\ifblank{#1}{\:\_\:}{#1}}\right]}}
\newcommand*{\unitsof}[1]{\ensuremath{%
  \left[{\ifblank{#1}{\:\_\:}{#1}}\right]_u}}
\newcommand*{\changein}[1]{\ensuremath{\delta{#1}}}
\newcommand*{\Changein}[1]{\ensuremath{\Delta{#1}}}
\newcommandx{\timestento}[2][2=\!\!,usedefault]{\ensuremath{%
  \ifthenelse{\equal{#2}{}}
    {\unit{\;\times\;10^{#1}}{}}
    {\unit{\;\times\;10^{#1}}{#2}}}}
\newcommand*{\xtento}{\timestento}
\newcommandx{\tento}[2][2=\!\!,usedefault]{\ensuremath{%
  \ifthenelse{\equal{#2}{}}
    {\unit{10^{#1}}{}}
    {\unit{10^{#1}}{#2}}}}
\newcommand*{\ee}[2]{\texttt{{#1}e{#2}}}
\newcommand*{\EE}[2]{\texttt{{#1}E{#2}}}
\newcommand*{\dms}[3]{\ensuremath{%
  \indegrees{#1}\inarcminutes{#2}\inarcseconds{#3}}}
\newcommand*{\hms}[3]{\ensuremath{%
  {#1}^{\hour}{#2}^{\mathrm{m}}{#3}^{\s}}}
\newcommand*{\clockreading}{\hms}
\newcommand*{\latitude}[1]{\unit{#1}{\mkern-\thickmuskip\degree}}
\newcommand*{\latitudeN}[1]{\unit{#1}{\mkern-\thickmuskip\degree\;\mathrm{N}}}
\newcommand*{\latitudeS}[1]{\unit{#1}{\mkern-\thickmuskip\degree\;\mathrm{S}}}
\newcommand*{\longitude}[1]{\unit{#1}{\mkern-\thickmuskip\degree}}
\newcommand*{\longitudeE}[1]{\unit{#1}{\mkern-\thickmuskip\degree\;\mathrm{E}}}
\newcommand*{\longitudeW}[1]{\unit{#1}{\mkern-\thickmuskip\degree\;\mathrm{W}}}
\newcommand*{\ssub}[2]{\ensuremath{#1_{\text{#2}}}}
\newcommand*{\ssup}[2]{\ensuremath{#1^{\text{#2}}}}
\newcommand*{\ssud}[3]{\ensuremath{#1^{\text{#2}}_{\text{#3}}}}
\newcommand*{\msub}[2]{\ensuremath{#1_{#2}}}
\newcommand*{\msup}[2]{\ensuremath{#1^{#2}}}
\newcommand*{\msud}[3]{\ensuremath{#1^{#2}_{#3}}}
\newcommand*{\levicivita}[1]{\ensuremath{%
  \varepsilon_{\scriptscriptstyle{#1}}}}
\newcommand*{\kronecker}[1]{\ensuremath{%
  \delta_{\scriptscriptstyle{#1}}}}
\newcommand*{\xaxis}{\ensuremath{x\text{-axis}}\xspace}
\newcommand*{\yaxis}{\ensuremath{y\text{-axis}}\xspace}
\newcommand*{\zaxis}{\ensuremath{z\text{-axis}}\xspace}
\newcommand*{\naxis}[1]{\ensuremath{{#1}\text{-axis}}\xspace}
\newcommand*{\axis}{\ensuremath{\text{-axis}}\xspace}
\newcommand*{\xyplane}{\ensuremath{xy\text{-plane}}\xspace}
```

```
\newcommand*{\yzplane}{\ensuremath{yz\text{-plane}}\xspace}
\newcommand*{\zxplane}{\ensuremath{zx\text{-plane}}\xspace}
\newcommand*{\yxplane}{\ensuremath{yx\text{-plane}}\xspace}
\newcommand*{\zyplane}{\ensuremath{zy\text{-plane}}\xspace}
\newcommand*{\xzplane}{\ensuremath{xz\text{-plane}}\xspace}
\newcommand*{\plane}{\ensuremath{\text{-plane}}\xspace}
% Frequently used roots. Prepend |f| for fractional exponents.
\newcommand*{\cuberoot}[1]{\ensuremath{\sqrt[3]{#1}}}
\newcommand*{\fourthroot}[1]{\ensuremath{\sqrt[4]{#1}}}
\newcommand*{\fifthroot}[1]{\ensuremath{\sqrt[5]{#1}}}
\newcommand*{\fsqrt}[1]{\ensuremath{{#1}^\onehalf}}
\newcommand*{\fcuberoot}[1]{\ensuremath{{#1}^\onethird}}
\newcommand*{\ffourthroot}[1]{\ensuremath{{#1}^\onefourth}}
\newcommand*{\ffifthroot}[1]{\ensuremath{{#1}^\onefifth}}
\newcommand*{\relgamma}[1]{\ensuremath{%
  \frac{1}{\sqrt{1-\inparens{\frac{#1}{c}}\squared}}}}
\newcommand*{\frelgamma}[1]{\ensuremath{%
  \inparens{1-\frac{{#1}\squared}{c\squared}}^{-\onehalf}}}
\newcommand*{\oosqrtomxs}[1]{\ensuremath{\frac{1}{\sqrt{1-{#1}\squared}}}}
\newcommand*{\oosqrtomx}[1]{\ensuremath{\frac{1}{\sqrt{1-{#1}}}}}
\newcommand*{\ooomx}[1]{\ensuremath{\frac{1}{1-{#1}}}}
\newcommand*{\ooopx}[1]{\ensuremath{\frac{1}{1+{#1}}}}
\newcommand*{\isequals}{\wordoperator{?}{=}\xspace}
\newcommand*{\wordoperator}[2]{\ensuremath{%
  \mathrel{\vcenter{\offinterlineskip
  \halign{\hfil\tiny\upshape##\hfil\cr\noalign{\vskip-.5ex}
    {#1}\cr\noalign{\vskip.5ex}{#2}\cr}}}}}
\newcommand*{\definedas}{\wordoperator{defined}{as}\xspace}
\newcommand*{\associated}{\wordoperator{associated}{with}\xspace}
\newcommand*{\adjustedby}{\wordoperator{adjusted}{by}\xspace}
\newcommand*{\earlierthan}{\wordoperator{earlier}{than}\xspace}
\newcommand*{\laterthan}{\wordoperator{later}{than}\xspace}
\newcommand*{\forevery}{\wordoperator{for}{every}\xspace}
\newcommand*{\pwordoperator}[2]{\ensuremath{\left(%
  \mathrel{\vcenter{\offinterlineskip%
  \halign{\hfil\tiny\upshape##\hfil\cr\noalign{\vskip-.5ex}%
    {#1}\cr\noalign{\vskip.5ex}{#2}\cr}}}\right)}}%
\newcommand*{\pdefinedas}{\pwordoperator{defined}{as}\xspace}
\newcommand*{\passociated}{\pwordoperator{associated}{with}\xspace}
\newcommand*{\padjustedby}{\pwordoperator{adjusted}{by}\xspace}
\newcommand*{\pearlierthan}{\pwordoperator{earlier}{than}\xspace}
\newcommand*{\platerthan}{\pwordoperator{later}{than}\xspace}
\newcommand*{\pforevery}{\pwordoperator{for}{every}\xspace}
\newcommand*{\defines}{\ensuremath{\stackrel{\text{\tiny{def}}}{=}}\xspace}
\newcommand*{\inframe}[1][\relax]{\ensuremath{%
  \xrightarrow[\text\tiny{\mathcal #1}]{}}\xspace}
\newcommand*{\associates}{\ensuremath{%
  \xrightarrow{\text{\tiny{assoc}}}}\xspace}
\newcommand*{\becomes}{\ensuremath{%
  \xrightarrow{\text{\tiny{becomes}}}}\xspace}
```

```
\newcommand*{\rrelatedto}[1]{\ensuremath{%
  \xLongrightarrow{\text{\tiny{#1}}}}}
\newcommand*{\lrelatedto}[1]{\ensuremath{%
  \xLongleftarrow[\text{\tiny{#1}}]{}}}
\newcommand*{\brelatedto}[2]{\ensuremath{%
  \xLongleftrightarrow[\text{\tiny{#1}}]{\text{\tiny{#2}}}}}
\newcommand*{\genericinteractionplaces}[5]{\ensuremath{\inparens{#1}
  \frac{\inparens{#2}\inparens{#3}}{\inparens{#4}^2}{{\ifblank{#5}{%
  \mivector{\_ , \_ , \_}}{#5}}}}}
\newcommand*{\genericfieldofparticleplaces}[4]{\ensuremath{\inparens{#1}
  \frac{\inparens{#2}}{\inparens{#3}^2}{{\ifblank{#4}{\mivector{\_ , \_ , \_}}{#4}}}}}
\newcommand*{\genericpotentialenergyplaces}[4]{\ensuremath{%
  \inparens{#1}\frac{\inparens{#2}\inparens{#3}}{\inparens{#4}}}}
\newcommand*{\genericelectricdipoleplaces}[5]{%
  \ensuremath{\inparens{#1}\frac{\inparens{#2}\inparens{#3}}{\inparens{#4}^3}%
  {{\ifblank{#5}{\mivector{\_ , \_ , \_}}{#5}}}}}
\newcommand*{\genericelectricdipoleonaxisplaces}[5]{%
  \ensuremath{\inparens{#1}\frac{2\inparens{#2}\inparens{#3}}{\inparens{#4}^3}%
  {{\ifblank{#5}{\mivector{\_ , \_ , \_}}{#5}}}}}
\newcommand*{\gfieldofparticle}{\ensuremath{\universalgravmathsymbol\frac{M}%
  {\magsquaredvect{r}}\inparens{-\dirvect{r}}}}
\newcommand*{\gravitationalinteractionplaces}[4]{%
  \genericinteractionplaces{\universalgrav}{#1}{#2}{#3}{#4}}
\newcommand*{\gfieldofparticleplaces}[3]{%
  \genericfieldofparticleplaces{\universalgrav}{#1}{#2}{#3}}
\newcommand*{\electricinteractionplaces}[4]{%
  \genericinteractionplaces{\oofpez}{#1}{#2}{#3}{#4}}
\newcommand*{\Efieldofparticleplaces}[3]{%
  \genericfieldofparticleplaces{\oofpez}{#1}{#2}{#3}}
\newcommand*{\Bfieldofparticleplaces}[5]{\ensuremath{\inparens{\mzofp}%
  \frac{\inparens{#1}\inparens{#2}}{\inparens{#3}^2}{{\ifblank{#4}{%
  \mivector{\_ , \_ , \_}}{#4}}}\times{{\ifblank{#5}{\mivector{\_ , \_ , \_}}{#5}}}}}
\newcommand*{\springinteractionplaces}[3]{\ensuremath{\inparens{#1}
  \inparens{#2}{{\ifblank{#3}{\mivector{\_ , \_ , \_}}{#3}}}}}
\newcommand*{\gravitationalpotentialenergyplaces}[3]{\ensuremath{%
  -\genericpotentialenergyplaces{\universalgrav}{#1}{#2}{#3}}}
\newcommand*{\electricpotentialenergyplaces}[3]{%
  \genericpotentialenergyplaces{\oofpez}{#1}{#2}{#3}}
\newcommand*{\springpotentialenergyplaces}[2]{\ensuremath{%
  \onehalf\inparens{#1}\inparens{#2}^2}}
\newcommand*{\electricdipoleonaxisplaces}[4]{%
  \genericelectricdipoleonaxisplaces{\oofpez}{\absof{#1}}{#2}{#3}{{\ifblank{#4}{%
  \mivector{\_ , \_ , \_}}{#4}}}}
\newcommand*{\electricdipoleonbisectorplaces}[4]{%
  \genericelectricdipoleplaces{\oofpez}{\absof{#1}}{#2}{#3}{{\ifblank{#4}{%
  \mivector{\_ , \_ , \_}}{#4}}}}
\newcommand{\define}[2]{\newcommand{#1}{#2}}
\newcommand*{\momentumprinciple}{\ensuremath{%
  \vectsub{p}{sys,final}=\vectsub{p}{sys,initial}+\Fnetsys\Delta t}}
\newcommand*{\LHSmomentumprinciple}{\ensuremath{\vectsub{p}{sys,final}}}
```

```
\newcommand*{\RHSmomentumprinciple}{\ensuremath{%
  \vectsub{p}{sys,initial}+\Fnetsys\Delta t}}
\newcommand*{\momentumprinciplediff}{\ensuremath{%
  \Dvectsub{p}{sys}=\Fnetsys\Delta t}}
\newcommand*{\energyprinciple}{\ensuremath{%
  \ssub{E}{sys,final}=\ssub{E}{sys,initial}+W+Q}}
\newcommand*{\LHSenergyprinciple}{\ensuremath{\ssub{E}{sys,final}}}
\newcommand*{\RHSenergyprinciple}{\ensuremath{\ssub{E}{sys,initial}+W+Q}}
\newcommand*{\energyprinciplediff}{\ensuremath{\Delta\ssub{E}{sys}=W+Q}}
\newcommand*{\angularmomentumprinciple}{\ensuremath{%
  \vectsub{L}{\(A\),sys,final}=\vectsub{L}{\(A\),sys,initial}+\Tsub{net}\Delta t}}
\newcommand*{\LHSangularmomentumprinciple}{\ensuremath{%
  \vectsub{L}{\(A\),sys,final}}}
\newcommand*{\RHSangularmomentumprinciple}{\ensuremath{%
  \vectsub{L}{\(A\),sys,initial}+\Tsub{net}\Delta t}}
\newcommand*{\angularmomentumprinciplediff}{\ensuremath{%
  \Dvectsub{L}{\(A\),sys}=\Tsub{net}\Delta t}}
\newcommand*{\gravitationalinteraction}{\ensuremath{%
  \universalgravmathsymbol\frac{\msub{M}{1}\msub{M}{2}}{%
  \magvectsub{r}{12}\squared}(-\dirvectsub{r}{12})}}
\newcommand*{\electricinteraction}{\ensuremath{%
  \oofpezmathsymbol\frac{\msub{Q}{1}\msub{Q}{2}}{\magvectsub{r}{12}\squared}
  \dirvectsub{r}{12}}}
\newcommand*{\springinteraction}{\ensuremath{\ks\magvect{s}(-\dirvect{s})}}
\newcommand*{\Bfieldofparticle}{\ensuremath{%
  \mzofpmathsymbol\frac{Q\magvect{v}}{\magsquaredvect{r}}\dirvect{v}\times
  \dirvect{r}}}
\newcommand*{\Efieldofparticle}{\ensuremath{%
  \oofpezmathsymbol\frac{Q}{\magsquaredvect{r}}\dirvect{r}}}
\newcommandx{\Esys}[1][1]{\ifthenelse{%
  \equal{#1}{}}{\ssub{E}{sys}}{\ssub{E}{sys,#1}}}
\newcommandx{\Us}[1][1]{\ifthenelse{%
  \equal{#1}{}}{\ssub{U}{\(s\)}}{\ssub{U}{\(s\),#1}}}
\newcommandx{\Ug}[1][1]{\ifthenelse{%
  \equal{#1}{}}{\ssub{U}{\(g\)}}{\ssub{U}{\(g\),#1}}}
\newcommandx{\Ue}[1][1]{\ifthenelse{%
  \equal{#1}{}}{\ssub{U}{\(e\)}}{\ssub{U}{\(e\),#1}}}
\newcommandx{\Ktrans}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{K}{trans}}
  {\ssub{K}{trans,#1}}}
\newcommandx{\Krot}[1][1]{\ifthenelse{%
  \equal{#1}{}}{\ssub{K}{rot}}{\ssub{K}{rot,#1}}}
\newcommandx{\Kvib}[1][1]{\ifthenelse{%
  \equal{#1}{}}{\ssub{K}{vib}}{\ssub{K}{vib,#1}}}
\newcommandx{\Eparticle}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{particle}}
  {\ssub{E}{particle,#1}}}
\newcommandx{\Einternal}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{internal}}
  {\ssub{E}{internal,#1}}}
\newcommandx{\Erest}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{rest}}{\ssub{E}
  {rest,#1}}}
\newcommandx{\Echem}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{chem}}{\ssub{E}
```

```
  {chem,#1}}}
\newcommandx{\Etherm}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{therm}}
  {\ssub{E}{therm,#1}}}
\newcommandx{\Evib}[1][1]{\ifthenelse{%
  \equal{#1}{}}{\ssub{E}{vib}}{\ssub{E}{vib,#1}}}
\newcommandx{\Ephoton}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{photon}}
  {\ssub{E}{photon,#1}}}
\newcommand*{\DEsys}{\Changein\Esys}
\newcommand*{\DUs}{\Changein\Us}
\newcommand*{\DUg}{\Changein\Ug}
\newcommand*{\DUe}{\Changein\Ue}
\newcommand*{\DKtrans}{\Changein\Ktrans}
\newcommand*{\DKrot}{\Changein\Krot}
\newcommand*{\DKvib}{\Changein\Kvib}
\newcommand*{\DEparticle}{\Changein\Eparticle}
\newcommand*{\DEinternal}{\Changein\Einternal}
\newcommand*{\DErest}{\Changein\Erest}
\newcommand*{\DEchem}{\Changein\Echem}
\newcommand*{\DEtherm}{\Changein\Etherm}
\newcommand*{\DEvib}{\Changein\Evib}
\newcommand*{\DEphoton}{\Changein\Ephoton}
\newcommand*{\springpotentialenergy}{\onehalf\ks\magsquaredvect{s}}
\newcommand*{\finalspringpotentialenergy}
  {\ssub{\left(\springpotentialenergy\right)}{\!\!final}}
\newcommand*{\initialspringpotentialenergy}
  {\ssub{\left(\springpotentialenergy\right)}{\!\!initial}}
\newcommand*{\gravitationalpotentialenergy}{\ensuremath{%
  -G\frac{\msub{M}{1}\msub{M}{2}}{\magvectsub{r}{12}}}}
\newcommand*{\finalgravitationalpotentialenergy}
  {\ssub{\left(\gravitationalpotentialenergy\right)}{\!\!final}}
\newcommand*{\initialgravitationalpotentialenergy}
  {\ssub{\left(\gravitationalpotentialenergy\right)}{\!\!initial}}
\newcommand*{\electricpotentialenergy}{\ensuremath{%
  \oofpezmathsymbol\frac{\ssub{Q}{1}\ssub{Q}{2}}{\magvectsub{r}{12}}}}
\newcommand*{\finalelectricpotentialenergy}
  {\ssub{\left(\electricpotentialenergy\right)}{\!\!final}}
\newcommand*{\initialelectricpotentialenergy}
  {\ssub{\left(\electricpotentialenergy\right)}{\!\!initial}}
\newcommand*{\ks}{\msub{k}{s}}
\newcommand*{\Fnet}{\ensuremath{\vectsub{F}{net}}}
\newcommand*{\Fnetext}{\ensuremath{\vectsub{F}{net,ext}}}
\newcommand*{\Fnetsys}{\ensuremath{\vectsub{F}{net,sys}}}
\newcommand*{\Fsub}[1]{\ensuremath{\vectsub{F}{#1}}}
\newcommand*{\Ltotal}{\ensuremath{\vectsub{L}{\(A\),total}}}
\newcommand*{\Lsys}{\ensuremath{\vectsub{L}{\(A\),sys}}}
\newcommand*{\Lsub}[1]{\ensuremath{\vectsub{L}{\(A\),{#1}}}}
\newcommand*{\Tnet}{\ensuremath{\vectsub{\tau}{\(A\),net}}}
\newcommand*{\Tnetext}{\ensuremath{\vectsub{\tau}{\(A\),net,ext}}}
\newcommand*{\Tnetsys}{\ensuremath{\vectsub{\tau}{\(A\),net,sys}}}
\newcommand*{\Tsub}[1]{\ensuremath{\vectsub{\tau}{\(A\),#1}}}
```

```
\newcommand*{\LHSmaxwelliint}[1][\partial V]{\ensuremath{%
  \closedsurfaceintegral{#1}{\vect{E}}}}
\newcommand*{\RHSmaxwelliint}{\ensuremath{\frac{\ssub{Q}{\(e\),net}}%
  {\vacuumpermittivitymathsymbol}}}
\newcommand*{\RHSmaxwelliinta}[1][V]{\ensuremath{%
  \frac{1}{\vacuumpermittivitymathsymbol}\volumeintegral{#1}{\msub{\rho}{e}}}}
\newcommand*{\RHSmaxwelliintfree}{\ensuremath{0}}
\newcommand*{\maxwelliint}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliint[#1]=\RHSmaxwelliint}}
\newcommandx*{\maxwelliinta}[2][1={\partial V},2={V},usedefault]{\ensuremath{%
  \LHSmaxwelliint[#1]=\RHSmaxwelliinta[#2]}}
\newcommand*{\maxwelliintfree}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliint[#1]=\RHSmaxwelliintfree}}
\newcommand*{\LHSmaxwelliiint}[1][\partial V]{\ensuremath{%
  \closedsurfaceintegral{#1}{\vect{B}}}}
\newcommand*{\RHSmaxwelliiint}{\ensuremath{0}}
\newcommand*{\RHSmaxwelliiintm}{\ensuremath{%
  \vacuumpermeabilitymathsymbol\ssub{Q}{\(m\),net}}}
\newcommand*{\RHSmaxwelliiintma}[1][V]{\ensuremath{%
  \vacuumpermeabilitymathsymbol\volumeintegral{#1}{\msub{\rho}{m}}}}
\newcommand*{\RHSmaxwelliiintfree}{\ensuremath{0}}
\newcommand*{\maxwelliiint}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliiint[#1]=\RHSmaxwelliiint}}
\newcommand*{\maxwelliiintm}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliiint[#1]=\RHSmaxwelliiintm}}
\newcommandx*{\maxwelliiintma}[2][1={\partial V},2={V},usedefault]{\ensuremath{%
  \LHSmaxwelliiint[#1]=\RHSmaxwelliiintma[#2]}}
\newcommand*{\maxwelliiintfree}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliiint[#1]=\RHSmaxwelliiintfree}}
\newcommand*{\LHSmaxwelliiiint}[1][\partial\Omega]{\ensuremath{%
  \closedlineintegral{#1}{\vect{E}}}}
\newcommand*{\RHSmaxwelliiiint}[1][\Omega]{\ensuremath{%
  -\dbydt\opensurfaceintegral{#1}{\vect{B}}}}
\newcommand*{\RHSmaxwelliiiintm}[1][\Omega]{\ensuremath{%
  -\dbydt\opensurfaceintegral{#1}{\vect{B}}%
  -\vacuumpermeabilitymathsymbol\ssub{I}{\(m\),net}}}
\newcommand*{\RHSmaxwelliiiintma}[1][\Omega]{\ensuremath{%
  -\dbydt\opensurfaceintegral{#1}{\vect{B}}%
  -\vacuumpermeabilitymathsymbol\opensurfaceintegral{#1}{\vectsub{J}{\(m\)}}}}
\newcommand*{\RHSmaxwelliiiintfree}{\RHSmaxwelliiiint}
\newcommandx*{\maxwelliiiint}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwelliiiint[#1]=\RHSmaxwelliiiint[#2]}}
\newcommandx*{\maxwelliiiintm}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwelliiiint[#1]=\RHSmaxwelliiiintm[#2]}}
\newcommandx*{\maxwelliiiintma}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwelliiiint[#1]=\RHSmaxwelliiiintma[#2]}}
\newcommand*{\maxwelliiiintfree}{\maxwelliiiint}
\newcommand*{\LHSmaxwellivint}[1][\partial\Omega]{\ensuremath{%
  \closedlineintegral{#1}{\vect{B}}}}
\newcommand*{\RHSmaxwellivint}[1][\Omega]{\ensuremath{%
```

```
  \vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol%
  \dbydt\opensurfaceintegral{#1}{\vect{E}}+%
  \vacuumpermeabilitymathsymbol\ssub{I}{\(e\),net}}}
\newcommand*{\RHSmaxwellivinta}[1][\Omega]{\ensuremath{%
  \vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol%
  \dbydt\opensurfaceintegral{#1}{\vect{E}}+%
  \vacuumpermeabilitymathsymbol\opensurfaceintegral{#1}{\vectsub{J}{\(e\)}}}}
\newcommand*{\RHSmaxwellivintfree}[1][\Omega]{\ensuremath{%
  \vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol%
  \dbydt\opensurfaceintegral{#1}{\vect{E}}}}
\newcommandx*{\maxwellivint}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwellivint[#1]=\RHSmaxwellivint[#2]}}
\newcommandx*{\maxwellivinta}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwellivint[#1]=\RHSmaxwellivinta[#2]}}
\newcommandx*{\maxwellivintfree}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwellivint[#1]=\RHSmaxwellivintfree[#2]}}
\newcommand*{\LHSmaxwellidif}{\ensuremath{\divergence{\vect{E}}}}
\newcommand*{\RHSmaxwellidif}{\ensuremath{\frac{\msub{\rho}{e}}
  {\vacuumpermittivitymathsymbol}}}
\newcommand*{\RHSmaxwellidiffree}{\ensuremath{0}}
\newcommand*{\maxwellidif}{\ensuremath{\LHSmaxwellidif=\RHSmaxwellidif}}
\newcommand*{\maxwellidiffree}{\ensuremath{\LHSmaxwellidif=\RHSmaxwellidiffree}}
\newcommand*{\LHSmaxwelliidif}{\ensuremath{\divergence{\vect{B}}}}
\newcommand*{\RHSmaxwelliidif}{\ensuremath{0}}
\newcommand*{\RHSmaxwelliidifm}{\ensuremath{\vacuumpermeabilitymathsymbol%
  \msub{\rho}{m}}}
\newcommand*{\RHSmaxwelliidiffree}{\ensuremath{0}}
\newcommand*{\maxwelliidif}{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidif}}
\newcommand*{\maxwelliidifm}{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidifm}}
\newcommand*{\maxwelliidiffree}{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidiffree}}
\newcommand*{\LHSmaxwelliiidif}{\ensuremath{\curl{\vect{E}}}}
\newcommand*{\RHSmaxwelliiidif}{\ensuremath{-\pbypt[\vect{B}]}}
\newcommand*{\RHSmaxwelliiidifm}{\ensuremath{-\pbypt[\vect{B}]-%
  \vacuumpermeabilitymathsymbol\vectsub{J}{\(m\)}}}
\newcommand*{\RHSmaxwelliiidiffree}{\RHSmaxwelliiidif}
\newcommand*{\maxwelliiidif}{\ensuremath{\LHSmaxwelliiidif=\RHSmaxwelliiidif}}
\newcommand*{\maxwelliiidifm}{\ensuremath{\LHSmaxwelliiidif=\RHSmaxwelliiidifm}}
\newcommand*{\maxwelliiidiffree}{\ensuremath{\LHSmaxwelliiidif=\RHSmaxwelliiidif}}
\newcommand*{\LHSmaxwellivdif}{\ensuremath{\curl{\vect{B}}}}
\newcommand*{\RHSmaxwellivdif}{\ensuremath{\vacuumpermeabilitymathsymbol%
  \vacuumpermittivitymathsymbol\pbypt[\vect{E}]+%
  \vacuumpermeabilitymathsymbol\vectsub{J}{\(e\)}}}
\newcommand*{\RHSmaxwellivdiffree}{\ensuremath{\vacuumpermeabilitymathsymbol
  \vacuumpermittivitymathsymbol\pbypt[\vect{E}]}}
\newcommand*{\maxwellivdif}{\ensuremath{\LHSmaxwellivdif=\RHSmaxwellivdif}}
\newcommand*{\maxwellivdiffree}{\ensuremath{\LHSmaxwellivdif=\RHSmaxwellivdiffree}}
\newcommand*{\RHSlorentzforce}{\ensuremath{\msub{q}{e}\left(\vect{E}+%
  \vectcrossvect{\vect{v}}{\vect{B}}\right)}}
\newcommand*{\RHSlorentzforcem}{\ensuremath{\RHSlorentzforce+\msub{q}{m}\left(%
  \vect{B}-\vectcrossvect{\vect{v}}{\frac{\vect{E}}{c^2}}\right)}}
```

```
\newcommandx{\eulerlagrange}[1][1={q_i},usedefault]{\ensuremath{%
  \pbyp{\mathcal{L}}{#1}-\dbydt\inparens{\pbyp{\mathcal{L}}{\dot{#1}}} = 0}}
\newcommandx{\Eulerlagrange}[1][1={q_i},usedefault]{\ensuremath{%
  \DbyD{\mathcal{L}}{#1}-\DbyDt\inparens{\DbyD{\mathcal{L}}{\dot{#1}}} = 0}}
\newcommand*{\vpythonline}{\lstinline[style=vpython]}
\newcommand*{\glowscriptline}{\lstinline[style=vpython]}
\lstnewenvironment{vpythonblock}[1][]{\lstset{style=vpython,caption={#1}}}{}
\lstnewenvironment{glowscriptblock}[1][]{\lstset{style=vpython,caption={#1}}}{}
\newcommand*{\vpythonfile}[1][]{\newpage\lstinputlisting[style=vpython,caption={#1}]}
\newcommand*{\glowscriptfile}[1][]{%
  \newpage\lstinputlisting[style=vpython,caption={#1}]}
\newcommandx{\emptyanswer}[2][1=0.80,2=0.1,usedefault]
  {\begin{minipage}{#1\textwidth}\hfill\vspace{#2\textheight}\end{minipage}}
\newenvironmentx{activityanswer}[5][1=white,2=black,3=black,4=0.90,%
  5=0.10,usedefault]{%
  \def\skipper{#5}%
  \def\response@fbox{\fcolorbox{#2}{#1}}%
  \begin{center}%
    \begin{lrbox}{\@tempboxa}%
      \begin{minipage}[c][#5\textheight][c]{#4\textwidth}\color{#3}%
        \vspace{#5\textheight}}{%
        \vspace{\skipper\textheight}%
      \end{minipage}%
    \end{lrbox}%
    \response@fbox{\usebox{\@tempboxa}}%
  \end{center}%
}%
\newenvironmentx{adjactivityanswer}[5][1=white,2=black,3=black,4=0.90,5=0.00,%
  usedefault]{%
  \def\skipper{#5}%
  \def\response@fbox{\fcolorbox{#2}{#1}}%
  \begin{center}%
    \begin{lrbox}{\@tempboxa}%
      \begin{minipage}[c]{#4\textwidth}\color{#3}%
        \vspace{#5\textheight}}{%
        \vspace{\skipper\textheight}%
      \end{minipage}%
    \end{lrbox}%
    \response@fbox{\usebox{\@tempboxa}}%
  \end{center}%
}%
\newcommandx{\emptybox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=0.10,usedefault]%
  {\begin{center}%
     \fcolorbox{#3}{#2}{%
       \begin{minipage}[c][#6\textheight][c]{#5\textwidth}\color{#4}%
         {#1}%
       \end{minipage}}%
     \vspace{\baselineskip}%
   \end{center}%
```

```
}%
\newcommandx{\adjemptybox}[7][1=\hfill,2=white,3=black,4=black,5=0.90,6=,%
  7=0.0,usedefault]
  {\begin{center}%
     \fcolorbox{#3}{#2}{%
       \begin{minipage}[c]{#5\textwidth}\color{#4}%
         \vspace{#7\textheight}%
           {#1}%
         \vspace{#7\textheight}%
       \end{minipage}}%
     \vspace{\baselineskip}%
   \end{center}%
}%
\newcommandx{\answerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=0.1,usedefault]%
  {\ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\adjanswerbox}[7][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=0.1,7=0.0,usedefault]%
  {\ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\adjemptybox[#1][#2][#3][#4][#5][#6][#7]}%
}%
\newcommandx{\smallanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=0.10,usedefault]%
  {\ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\smallanswerform}[4][1=q1,2=Response,3=0.10,4=0.90,usedefault]{%
  \vspace{\baselineskip}%
    \begin{Form}
      \begin{center}%
       \TextField[value={#2},%
        name=#1,%
        width=#4\linewidth,%
```

```
        height=#3\textheight,%
        backgroundcolor=formcolor,%
        multiline=true,%
        charsize=10pt,%
        bordercolor=black]{}%
      \end{center}%
    \end{Form}%
  \vspace{\baselineskip}%
}%
\newcommandx{\mediumanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=0.20,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\mediumanswerform}[4][1=q1,2=Response,3=0.20,4=0.90,usedefault]{%
  \vspace{\baselineskip}%
    \begin{Form}
      \begin{center}%
        \TextField[value={#2},%
        name=#1,%
        width=#4\linewidth,%
        height=#3\textheight,%
        backgroundcolor=formcolor,%
        multiline=true,%
        charsize=10pt,%
        bordercolor=black]{}%
      \end{center}%
    \end{Form}%
  \vspace{\baselineskip}%
}%
\newcommandx{\largeanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=0.25,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\largeanswerform}[4][1=q1,2=Response,3=0.25,4=0.90,usedefault]{%
  \vspace{\baselineskip}%
    \begin{Form}
      \begin{center}%
        \TextField[value={#2},%
```

```
        name=#1,%
        width=#4\linewidth,%
        height=#3\textheight,%
        backgroundcolor=formcolor,%
        multiline=true,%
        charsize=10pt,%
        bordercolor=black]{}%
      \end{center}%
    \end{Form}%
  \vspace{\baselineskip}%
}%
\newcommandx{\largeranswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=0.33,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\largeranswerform}[4][1=q1,2=Response,3=0.33,4=0.90,%
  usedefault]{%
  \vspace{\baselineskip}%
    \begin{Form}
      \begin{center}%
        \TextField[value={#2},%
        name=#1,%
        width=#4\linewidth,%
        height=#3\textheight,%
        backgroundcolor=formcolor,%
        multiline=true,%
        charsize=10pt,%
        bordercolor=black]{}%
      \end{center}%
    \end{Form}%
  \vspace{\baselineskip}%
}%
\newcommandx{\hugeanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=0.50,usedefault]{%
  \ifthenelse{\equal{#1}{}}
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\hugeanswerform}[4][1=q1,2=Response,3=0.50,4=0.90,usedefault]{%
  \vspace{\baselineskip}%
```

```
    \begin{Form}
      \begin{center}%
        \TextField[value={#2},%
        name=#1,%
        width=#4\linewidth,%
        height=#3\textheight,%
        backgroundcolor=formcolor,%
        multiline=true,%
        charsize=10pt,%
        bordercolor=black]{}%
      \end{center}%
    \end{Form}%
  \vspace{\baselineskip}%
}%
\newcommandx{\hugeranswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=0.75,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\hugeranswerform}[4][1=q1,2=Response,3=0.75,4=0.90,usedefault]{%
  \vspace{\baselineskip}%
    \begin{Form}
      \begin{center}%
        \TextField[value={#2},%
        name=#1,%
        width=#4\linewidth,%
        height=#3\textheight,%
        backgroundcolor=formcolor,%
        multiline=true,%
        charsize=10pt,%
        bordercolor=black]{}%
      \end{center}%
    \end{Form}%
  \vspace{\baselineskip}%
}%
\newcommandx{\fullpageanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
  6=1.00,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
```

```
\newcommandx{\fullpageanswerform}[4][1=q1,2=Response,3=1.00,4=0.90,usedefault]{%
  \vspace{\baselineskip}%
    \begin{Form}
      \begin{center}%
        \TextField[value={#2},%
        name=#1,%
        width=#4\linewidth,%
        height=#3\textheight,%
        backgroundcolor=formcolor,%
        multiline=true,%
        charsize=10pt,%
        bordercolor=black]{}%
      \end{center}%
    \end{Form}%
  \vspace{\baselineskip}%
}%
\mdfdefinestyle{miinstructornotestyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    nobreak=true,
    frametitle={INSTRUCTOR NOTE},
    frametitlebackgroundcolor=cyan!60,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=cyan!25,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{miinstructornote}{%
  \begin{mdframed}[style=miinstructornotestyle]
    \begin{adjactivityanswer}[cyan!25][cyan!25][black]
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
\mdfdefinestyle{mistudentnotestyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    nobreak=true,
    frametitle={STUDENT NOTE},
    frametitlebackgroundcolor=cyan!60,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=cyan!25,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{mistudentnote}{%
  \begin{mdframed}[style=mistudentnotestyle]
    \begin{adjactivityanswer}[cyan!25][cyan!25][black]
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
\mdfdefinestyle{miderivationstyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=0pt,rightmargin=0pt,linewidth=1,roundcorner=10,
    nobreak=true,
```

```
    frametitle={DERIVATION},
    frametitlebackgroundcolor=orange!60,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=orange!25,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{miderivation}{%
  \begin{mdframed}[style=miderivationstyle]
  \setcounter{equation}{0}
    \begin{align}
      \BODY
    \end{align}
  \end{mdframed}
}%
\NewEnviron{miderivation*}{%
  \begin{mdframed}[style=miderivationstyle]
  \setcounter{equation}{0}
    \begin{align*}
      \BODY
    \end{align*}
  \end{mdframed}
}%
\mdfdefinestyle{mistandardstyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    nobreak=true,
    frametitle={STANDARD},
    frametitlebackgroundcolor=cyan!60,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=cyan!25,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{mistandard}{%
  \begin{mdframed}[style=mistandardstyle]
    \begin{adjactivityanswer}[cyan!25][cyan!25][black]
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
\mdfdefinestyle{bwinstructornotestyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    nobreak=true,
    frametitle={INSTRUCTOR NOTE},
    frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=gray!20,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{bwinstructornote}{%
  \begin{mdframed}[style=bwinstructornotestyle]
    \begin{adjactivityanswer}[gray!20][gray!20][black]
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
```

```
\mdfdefinestyle{bwstudentnotestyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    nobreak=true,
    frametitle={STUDENT NOTE},
    frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=gray!20,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{bwstudentnote}{%
  \begin{mdframed}[style=bwstudentnotestyle]
    \begin{adjactivityanswer}[gray!20][gray!20][black]
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
\mdfdefinestyle{bwderivationstyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=0pt,rightmargin=0pt,linewidth=1,roundcorner=10,
    nobreak=true,
    frametitle={DERIVATION},
    frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=gray!20,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{bwderivation}{%
  \begin{mdframed}[style=bwderivationstyle]
  \setcounter{equation}{0}
    \begin{align}
      \BODY
    \end{align}
  \end{mdframed}
}%
\NewEnviron{bwderivation*}{%
  \begin{mdframed}[style=bwderivationstyle]
  \setcounter{equation}{0}
    \begin{align*}
      \BODY
    \end{align*}
  \end{mdframed}
}%
\mdfdefinestyle{bwstandardstyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    nobreak=true,
    frametitle={STANDARD},
    frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=gray!20,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{bwstandard}{%
  \begin{mdframed}[style=bwstandardstyle]
    \begin{adjactivityanswer}[gray!20][gray!20][black]
```

```
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
\NewEnviron{mysolution}{%
  \setcounter{equation}{0}
  \begin{align}
    \BODY
  \end{align}
}%
\NewEnviron{mysolution*}{%
  \setcounter{equation}{0}
  \begin{align*}
    \BODY
  \end{align*}
}%
\newenvironment{problem}[1]{%
  \newpage%
  \section*{#1}%
  \newlist{parts}{enumerate}{2}%
  \setlist[parts]{label=(\alph*)}}{\newpage}
\newcommand{\problempart}{\item}%
\newcommand{\reason}[1]{\begin{minipage}{5cm}{#1}\end{minipage}}
\newcommand*{\checkpoint}{%
  \vspace{1cm}\begin{center}%
    \colorbox{yellow!80}{|--------- CHECKPOINT ---------|}%
  \end{center}}%
\newcommandx*{\image}[4][1={scale=1},usedefault]{%
  \begin{figure}[H]
    \begin{center}%
      \includegraphics[#1]{#2}%
    \end{center}%
    \caption{#3}%
    \label{#4}%
  \end{figure}}
\newcommand*{\sneakyone}[1]{\ensuremath{\cancelto{1}{#1}}}
\newcommand*{\parallelto}{\ensuremath{{{\mkern3mu\vphantom{\perp}\vrule depth 0pt
  \mkern2mu\vrule depth 0pt\mkern3mu}}}}
\newcommand*{\perpendicularto}{\ensuremath{\perp}}
\newcommand*{\qed}{\ensuremath{\text{ Q.E.D.}}}
\newcommand*{\chkquantity}[1]{%
  \begin{center}
    \begin{tabular}{C{4.5cm} C{4cm} C{4cm} C{4cm}}
      name    & baseunit & drvdunit & tradunit \tabularnewline
      \cs{#1} & \csname #1onlybaseunit\endcsname & \csname #1onlydrvdunit\endcsname &
        \csname #1onlytradunit\endcsname
    \end{tabular}
  \end{center}
}%
\newcommand*{\chkconstant}[1]{%
```

```
  \begin{center}
    \begin{tabular}{C{4cm} C{4cm} C{4cm}}
      name    & symbol & value \tabularnewline
      \cs{#1} & \csname #1mathsymbol\endcsname & \csname #1value\endcsname
      \tabularnewline
      baseunit & drvdunit & tradunit \tabularnewline
      \csname #1onlybaseunit\endcsname & \csname #1onlydrvdunit\endcsname &
      \csname #1onlytradunit\endcsname
    \end{tabular}
  \end{center}
}%
```

8 Acknowledgements

I thank Marcel Heldoorn, Joseph Wright, Scott Pakin, Thomas Sturm, Aaron Titus, David Zaslavsky, Ruth Chabay, and Bruce Sherwood. Special thanks to Martin Scharrer for his `sty2dtx.pl` utility, which saved me days of typing. Special thanks also to Herbert Schulz for his custom `dtx` engine for `TeXShop`. Very special thanks to Ulrich Diez for providing the mechanism that defines physics quantities and constants. Also very special thanks to students who helped test recent versions of this package.

9 Index

Page numbers refer to page where the corresponding entry is described. Not every command defined in the package is indexed. There may be commands similar to indexed commands described in relevant parts of the documentation.

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