

The mandi package

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Change History

v2.4.0

General: <code>\vpythonfile</code> now uses a uniform style.	99
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Added Lorentz force, with and without magnetic monopoles.	98
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Now coexists with the <code>commath</code> package.	7
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v2.5.0

General: <code>\absof</code> now shows a placeholder for a blank argument.	75
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v2.5.1

General: Fixed errors in build for uploading to CTAN.	7
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v2.6.0

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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 pdfL^AT_EX, which creates PDF files as output, to build the documentation. I have not tested the build with standard L^AT_EX, which creates DVI files.

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

3 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.75}. `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.

`\mandiversion`

Gives the current package version number and build date.

```
\mandiversion
```

2.6.0 dated 2016/06/29

4 Student Quick Guide

Use `\vect`^{→P.48} to put an arrow over a symbol to make it the symbol for a vector. Typing `\vect{p}` gives \vec{p} .

Use `\vectsub`^{→P.54} if the symbol needs a subscript. Typing `\vectsub{p}{ball}` gives \vec{p}_{ball} .

Use `\magvect`^{→P.48} or `\magvectsub`^{→P.54} to get the symbol for a vector's magnitude. Typing `\magvect{p}` or `\magvectsub{p}{ball}` gives $\|\vec{p}\|$ or $\|\vec{p}_{\text{ball}}\|$.

Use `\dirvect`^{→P.48} or `\dirvectsub`^{→P.54} to get the symbol for a vector's direction. Typing `\dirvect{p}` or `\dirvectsub{p}{ball}` gives \hat{p} or \hat{p}_{ball} .

Use `\compvect`^{→P.50} 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.21} by typing `\velocity{2.5}` gives 2.5 m/s. Use `\newphysicsquantity`^{→P.14} 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.49} 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.20} 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.49} 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.76} or `\xtento`^{→P.76} to get scientific notation. Typing either `2.54\timestento{-4}` or `2.54\xtento{-4}` gives 2.54×10^{-4} .

Use `\inparens`^{→P.75} to surround quantities with nicely formatted parentheses. Typing `\inparens{x^2 + 4}` gives $(x^2 + 4)$.

Use `\define`^{→P.12} to create a variable that can be used in an intermediate step in a solution. This is discussed later in this section.

Encapsulate an entire problem solution in a `problem`^{→P.112} environment by putting it between `\begin{problem}` and `\end{problem}`.

Show the steps in a calculation in a `mysolution`^{→P.110} 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](http://glowscript.org). You can link to a specific [GlowScript program](#) for this course. Links are active.

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`

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

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 L^AT_EX 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 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.

`\genericinteractionplaces{<thing>{<dist>{<direction>}}`

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

`\genericfieldofparticleplaces{<const>{<thing>}{<dist>}{<direction>}}`

Command for generic expression for an inverse square field. The 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.

`\genericfieldofparticleplaces{<const>{<thing>}{<dist>}{<direction>}}`

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

`\genericpotentialenergyplaces{<const>{<thing1>}{<thing2>}{<dist>}}`

Command for generic expression for an inverse square energy. The 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.

`\genericpotentialenergyplaces{<const>{<thing1>}{<thing2>}{<dist>}}`

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

`\gravitationalinteractionplaces{<mass1>}{<mass2>}{<distance>}{<direction>}}`

Command for gravitational interaction.

`\gravitationalinteractionplaces{<mass1>}{<mass2>}{<distance>}{<direction>}}`

$$(6.6738 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2) \frac{(_)(_)}{(_)^2} \langle _, _, _ \rangle$$

`\gfieldofparticleplaces{<mass>}{<distance>}{<direction>}}`

Command for gravitational field of a particle.

`\gfieldofparticleplaces{<mass>}{<distance>}{<direction>}}`

$$(6.6738 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2) \frac{(_)}{(_)^2} \langle _, _, _ \rangle$$

`\gravitationalpotentialenergyplaces{<mass1>}{<mass2>}{<distance>}}`

Command for gravitational potential energy.

`\gravitationalpotentialenergyplaces{<mass1>}{<mass2>}{<distance>}}`

$$-(6.6738 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2) \frac{(_)(_)}{(_)^2}$$

`\springinteractionplaces{<stiffness>}{<stretch>}{<direction>}}`

Command for a spring interaction.

`\springinteractionplaces{<stiffness>}{<stretch>}{<direction>}}`

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

`\springpotentialenergyplaces{<stiffness>}{<stretch>}}`

Command for spring potential energy.

`\springpotentialenergyplaces{<stiffness>}{<stretch>}}`

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

`\genericelectricdipoleonaxisplaces` $\{\langle const \rangle\}\{\langle charge \rangle\}\{\langle separation \rangle\}\{\langle dist \rangle\}\{\langle direction \rangle\}$

Command for generic expression for dipole field on the dipole's axis. The 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` $\{\langle const \rangle\}\{\langle charge \rangle\}\{\langle separation \rangle\}\{\langle dist \rangle\}\{\langle direction \rangle\}$

Command for generic expression for dipole field. The 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` $\{\langle charge1 \rangle\}\{\langle charge2 \rangle\}\{\langle distance \rangle\}\{\langle direction \rangle\}$

Command for electric interaction.

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

$$(8.9876 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2) \frac{(_)(_)}{(_)^2} \langle _, _, _ \rangle$$

`\Efieldofparticleplaces` $\{\langle charge \rangle\}\{\langle distance \rangle\}\{\langle direction \rangle\}$

Command for electric field of a particle.

`\Efieldofparticleplaces{}{}{}`

$$(8.9876 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2) \frac{(_)}{(_)^2} \langle _, _, _ \rangle$$

`\Bfieldofparticleplaces` $\{\langle charge \rangle\}\{\langle magvel \rangle\}\{\langle magr \rangle\}\{\langle vhat \rangle\}\{\langle rhat \rangle\}$

Command for magnetic field of a particle.

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

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

`\electricpotentialenergyplaces` $\{\langle charge1 \rangle\}\{\langle charge2 \rangle\}\{\langle distance \rangle\}$

Command for electric potential energy.

`\electricpotentialenergyplaces{}{}{}`

$$(8.9876 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2) \frac{(_)(_)}{(_)}$$

`\electricdipoleonaxisplaces` $\{\langle charge \rangle\}\{\langle separation \rangle\}\{\langle dist \rangle\}\{\langle direction \rangle\}$

Command for dipole electric field on the dipole's axis. The 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{}{}{}{}`

$$(8.9876 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2) \frac{2(_)(_)}{(_)^3} \langle _, _, _ \rangle$$

`\electricdipoleonbisectorplaces` $\{\langle charge \rangle\}\{\langle separation \rangle\}\{\langle dist \rangle\}\{\langle direction \rangle\}$

Command for dipole electric field. The 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{}{}{}{}`

$$(8.9876 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2) \frac{(1-1)(-)}{(-)^3} \langle -, -, - \rangle$$

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` $\{\langle variablename \rangle\}\{\langle quantity \rangle\}$

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 L^AT_EX.**

`\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.16} 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 L^AT_EX 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}
```

$$(6.6738 \times 10^{-11} \text{N} \cdot \text{m}^2/\text{kg}^2) \frac{(5 \text{ kg})(12 \text{ kg})}{(5 \text{ m})^2} \langle 0, -1, 0 \rangle = \langle 0, -1.60 \times 10^{-10}, 0 \rangle \text{N}$$

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 L^AT_EX 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**.

5 Features and Commands

5.1 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.

5.2 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

5.3 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 *drvunits* 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 `\newnameonlydrvunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in *drvunits* 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:

<code>\momentum{3}</code>	$3 \text{ kg} \cdot \text{m/s}$	unit set by global options
<code>\momentumbaseunit{3}</code>	$3 \text{ m} \cdot \text{kg} \cdot \text{s}^{-1}$	quantity with base unit
<code>\momentumdrvunit{3}</code>	$3 \text{ N} \cdot \text{s}$	quantity with derived unit
<code>\momentumtradunit{3}</code>	$3 \text{ kg} \cdot \text{m/s}$	quantity with traditional unit
<code>\momentumvalue{3}</code>	3	selects only numerical value
<code>\momentumonlybaseunit</code>	$\text{m} \cdot \text{kg} \cdot \text{s}^{-1}$	selects only base unit
<code>\momentumonlydrvunit</code>	$\text{N} \cdot \text{s}$	selects only derived unit
<code>\momentumonlytradunit</code>	$\text{kg} \cdot \text{m/s}$	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 `\speedP.21` command is just an alias for `\velocityP.21` 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.

5.3.1 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 `\mivectorP.49` 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 \text{ kg} \cdot \text{ m/s}  
\langle 3, 2, -1 \rangle \text{ kg} \cdot \text{ m/s}
```

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

5.3.2 First Semester Physics

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

\displacement{*\langle magnitude or vector \rangle*}

Command for displacement.

\vectordisplacement{*\langle commadelimitedlistofcomps \rangle*}

Command for vector displacement.

<code>\displacement{5}</code>	<code>\\</code>	5 m
<code>\displacement{\mivector{3,2,-1}}</code>	<code>\\</code>	$\langle 3, 2, -1 \rangle$ m
<code>\vectordisplacement{1,2,3}</code>		$\langle 1, 2, 3 \rangle$ m

\mass{*\langle magnitude \rangle*}

Command for mass.

<code>\mass{5}</code>	5 kg
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\duration{*\langle magnitude \rangle*}

Command for duration.

<code>\duration{5}</code>	5 s
---------------------------	-----

\current{*\langle magnitude \rangle*}

Command for current.

<code>\current{5}</code>	5 A
--------------------------	-----

\temperature{*\langle magnitude \rangle*}

Command for temperature.

<code>\temperature{5}</code>	5 K
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\amount{*\langle magnitude \rangle*}

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 and astrophysics.

`\planeangle{<magnitude>}`

Command for plane angle in radians.

`\planeangle{5}`

5 m · m⁻¹

`\solidangle{<magnitude>}`

Command for solidangle.

`\solidangle{5}`

5 m² · m⁻²

`\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 ″

`\inFahrenheit{<magnitude>}`

Command for temperature in degrees Farenheit.

`\inFahrenheit{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 eV/c^2

`\ineVoc{<magnitude>}`

Command for momentum in eV/c .

`\ineVoc{3.6}`

3.6 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 MeV/c^2

`\inMeVoc{<magnitude>}`

Command for momentum in MeV/c .

`\inMeVoc{3.6}`

3.6 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}`

$4.3 \text{ c} \cdot \text{year}$

`\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.76} or `\xtento`^{P.76} to get scientific notation, with the mantissa immediately preceding the command and the power as the required argument. `\timestento`^{P.76} 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`.

<code>\direction{a,b,c}</code>	<code>\\</code>
<code>\direction{\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}}</code>	<code>\\</code>
<code>\vectordirection{a,b,c}</code>	<code>\\</code>
<code>\vectordirection{\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}}</code>	

$$\langle a, b, c \rangle$$

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

$$\langle a, b, c \rangle$$

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

`\velocity{<magnitude or vector>}`

Command for velocity as a fraction of c .

`\vectorvelocity{<commadelimitedlistofcomps>}`

Command for vector velocity as a fraction of c .

<code>\velocity{0.9987}</code>	<code>\\</code>	$0.9987c$
<code>\velocity{\mivector{0,0.9987,0}}</code>	<code>\\</code>	$\langle 0, 0.9987, 0 \rangle c$
<code>\mivector{\velocity{\frac{1}{\sqrt{3}}}}</code>	<code>\\</code>	$\frac{1}{\sqrt{3}}c$
<code>\velocity{\frac{1}{\sqrt{3}}}</code>	<code>\\</code>	$\frac{1}{\sqrt{3}}c$
<code>\velocity{\frac{1}{\sqrt{3}}}</code>	<code>\\</code>	$\frac{1}{\sqrt{3}}c$
<code>\vectorvelocity{0,0.9987,0}</code>		$\langle 0, 0.9987, 0 \rangle c$

`\velocity{<magnitude or vector>}`

Command for velocity.

`\vectorvelocity{<commadelimitedlistofcomps>}`

Command for vector velocity.

<code>\velocity{2.34}</code>	<code>\\</code>	2.34 m/s
<code>\velocity{\mivector{3,2,-1}}</code>	<code>\\</code>	$\langle 3, 2, -1 \rangle \text{ m/s}$
<code>\vectorvelocity{3,2,-1}</code>		$\langle 3, 2, -1 \rangle \text{ m/s}$

`\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.

<code>\velocity{8.25}</code>	8.25 m/s
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`\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.

<code>\lorentz{2.34}</code>	2.34
-----------------------------	--------

`\momentum{<magnitude or vector>}`

Command for momentum.

`\vectormomentum{<commadelimitedlistofcomps>}`

Command for vector momentum.

<code>\momentum{2.34}</code>	<code>\\</code>	2.34 kg · m/s
<code>\momentum{\mivector{3,2,-1}}</code>	<code>\\</code>	$\langle 3, 2, -1 \rangle$ kg · m/s
<code>\vectormomentum{3,2,-1}</code>		$\langle 3, 2, -1 \rangle$ kg · m/s

`\acceleration{<magnitude or vector>}`

Command for acceleration.

`\vectoracceleration{<commadelimitedlistofcomps>}`

Command for vector acceleration.

<code>\acceleration{2.34}</code>	<code>\\</code>	2.34 m/s ²
<code>\acceleration{\mivector{3,2,-1}}</code>	<code>\\</code>	$\langle 3, 2, -1 \rangle$ m/s ²
<code>\vectoracceleration{3,2,-1}</code>		$\langle 3, 2, -1 \rangle$ m/s ²

`\gravitationalfield{<commadelimitedlistofcomps>}`

Command for gravitational field.

`\vectorgravitationalfield{<magnitude or vector>}`

Command for vector gravitational field.

<code>\gravitationalfield{2.34}</code>	<code>\\</code>	2.34 N/kg
<code>\gravitationalfield{\mivector{3,2,-1}}</code>	<code>\\</code>	$\langle 3, 2, -1 \rangle$ N/kg
<code>\vectorgravitationalfield{3,2,-1}</code>		$\langle 3, 2, -1 \rangle$ N/kg

`\gravitationalpotential{<magnitude>}`

Command for gravitational potential.

<code>\gravitationalpotential{2.34}</code>	2.34 J/kg
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`\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.

<code>\impulse{2.34}</code>	<code>\\</code>	2.34 N · s
<code>\impulse{\mivector{3,2,-1}}</code>	<code>\\</code>	$\langle 3, 2, -1 \rangle$ N · s
<code>\vectorimpulse{3,2,-1}</code>		$\langle 3, 2, -1 \rangle$ N · s

`\force{<magnitude or vector>}`

Command for force.

`\vectorforce{⟨commadelimitedlistofcomps⟩}`

Command for vector force.

<code>\force{2.34}</code>	<code>\\</code>	2.34 N
<code>\force{\mivector{3,2,-1}}</code>	<code>\\</code>	$\langle 3, 2, -1 \rangle$ N
<code>\vectorforce{3,2,-1}</code>		$\langle 3, 2, -1 \rangle$ N

`\springstiffness{⟨magnitude⟩}`

Command for spring stiffness.

<code>\springstiffness{2.34}</code>	2.34 N/m
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`\springstretch{⟨magnitude⟩}`

Command for spring stretch.

<code>\springstretch{2.34}</code>	2.34 m
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`\area{⟨magnitude⟩}`

Command for area.

<code>\area{2.34}</code>	2.34 m ²
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`\volume{⟨magnitude⟩}`

Command for volume.

<code>\volume{2.34}</code>	2.34 m ³
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`\linearmassdensity{⟨magnitude⟩}`

Command for linear mass density.

<code>\linearmassdensity{2.34}</code>	2.34 kg/m
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`\areamassdensity{⟨magnitude⟩}`

Command for area mass density.

<code>\areamassdensity{2.34}</code>	2.34 kg/m ²
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`\volumemassdensity{⟨magnitude⟩}`

Command for volume mass density.

<code>\volumemassdensity{2.34}</code>	2.34 kg/m ³
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`\youngsmodulus{⟨magnitude⟩}`

Command for Young's modulus.

<code>\youngsmodulus{2.34\timestento{9}}</code>	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.

<code>\work{2.34}</code>	2.34 J
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`\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.

<code>\energy{2.34}</code>	2.34 J
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`\power{<magnitude>}`

Command for power.

<code>\power{2.34}</code>	2.34 W
---------------------------	--------

`\specificeatcapacity{<magnitude>}`

Command for specific heat capacity.

<code>\specificeatcapacity{4.18\xtento{3}}</code>	$4.18 \times 10^3 \text{ J/K} \cdot \text{kg}$
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`\angularvelocity{<magnitude or vector>}`

Command for angular velocity.

`\vectorangularvelocity{<commadelimitedlistofcomps>}`

Command for vector angular velocity.

<code>\angularvelocity{2.34}</code>	<code>\</code>	2.34 rad/s
<code>\angularvelocity{\mivector{3,2,-1}}</code>	<code>\</code>	$\langle 3, 2, -1 \rangle \text{ rad/s}$
<code>\vectorangularvelocity{3,2,-1}</code>		$\langle 3, 2, -1 \rangle \text{ rad/s}$

`\angularacceleration{<magnitude or vector>}`

Command for angular acceleration.

`\vectorangularacceleration{<commadelimitedlistofcomps>}`

Command for vector angular acceleration.

<code>\angularacceleration{2.34}</code>	<code>\</code>	2.34 rad/s^2
<code>\angularacceleration{\mivector{3,2,-1}}</code>	<code>\</code>	$\langle 3, 2, -1 \rangle \text{ rad/s}^2$
<code>\vectorangularacceleration{3,2,-1}</code>		$\langle 3, 2, -1 \rangle \text{ rad/s}^2$

`\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.

<code>\angularmomentum{2.34}</code>	<code>\</code>	$2.34 \text{ m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$
<code>\angularmomentum{\mivector{3,2,-1}}</code>	<code>\</code>	$\langle 3, 2, -1 \rangle \text{ m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$
<code>\vectorangularmomentum{3,2,-1}</code>		$\langle 3, 2, -1 \rangle \text{ m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$

\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.

<code>\angularimpulse{2.34}</code>	<code>\</code>	$2.34 \text{ J} \cdot \text{s}$
<code>\angularimpulse{\mivector{3,2,-1}}</code>	<code>\</code>	$\langle 3, 2, -1 \rangle \text{ J} \cdot \text{s}$
<code>\vectorangularimpulse{3,2,-1}</code>		$\langle 3, 2, -1 \rangle \text{ J} \cdot \text{s}$

\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.

<code>\torque{2.34}</code>	<code>\</code>	2.34 J
<code>\torque{\mivector{3,2,-1}}</code>	<code>\</code>	$\langle 3, 2, -1 \rangle \text{ J}$
<code>\vectortorque{3,2,-1}</code>		$\langle 3, 2, -1 \rangle \text{ J}$

\momentofinertia{*<magnitude>*}

Command for moment of inertia.

<code>\momentofinertia{2.34}</code>	$2.34 \text{ J} \cdot \text{s}^2$
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\entropy{*<magnitude>*}

Command for entropy.

<code>\entropy{2.34}</code>	2.34 J/K
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\wavelength{*<magnitude>*}

Command for wavelength.

<code>\wavelength{4.00\timestento{-7}}</code>	$4.00 \times 10^{-7} \text{ m}$
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\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 \times 10^6/\text{m}  
\langle 3, 2, -1 \rangle / \text{m}  
\langle 3, 2, -1 \rangle / \text{m}
```

\frequency{<magnitude>}

Command for frequency.

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

```
7.50 \times 10^{14}\text{Hz}
```

\angularfrequency{<magnitude>}

Command for angularfrequency.

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

```
4.70 \times 10^{15}\text{rad/s}
```

5.3.3 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 \times 10^{-9}\text{C}
```

\permittivity{<magnitude>}

Command for permittivity.

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

```
9 \times 10^{-12}\text{C}^2/\text{N} \cdot \text{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 \times 10^5\text{N/C}  
\langle 3, 2, -1 \rangle \text{N/C}  
\langle 3, 2, -1 \rangle \text{N/C}
```

\electricdipolemoment{<magnitude or vector>}

Command for electric dipole moment.

\vectorelectricdipolemoment{<commadelimitedlistofcomps>}

Command for vector electric dipole moment.

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

$2 \times 10^5 \text{C} \cdot \text{m}$
 $\langle 3, 2, -1 \rangle \text{C} \cdot \text{m}$
 $\langle 3, 2, -1 \rangle \text{C} \cdot \text{m}$

`\permeability`{ *\langle magnitude \rangle* }

Command for permeability.

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

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

`\magneticfield`{ *\langle magnitude or vector \rangle* }

Command for magnetic field (also called magnetic induction).

`\vectormagneticfield`{ *\langle commadelimitedlistofcomps \rangle* }

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

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

$1.25 \text{N/C} \cdot (\text{m/s})$
 $\langle 3, 2, -1 \rangle \text{N/C} \cdot (\text{m/s})$
 $\langle 3, 2, -1 \rangle \text{N/C} \cdot (\text{m/s})$

`\cmagneticfield`{ *\langle magnitude or vector \rangle* }

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

`\vectorcmagneticfield`{ *\langle commadelimitedlistofcomps \rangle* }

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

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

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

`\linearchargedensity`{ *\langle magnitude \rangle* }

Command for linear charge density.

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

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

`\areachargedensity`{ *\langle magnitude \rangle* }

Command for area charge density.

`\areachargedensity{1.25}`

1.25C/m^2

`\volumechargedensity`{ *\langle magnitude \rangle* }

Command for volume charge density.

`\volumechargedensity{1.25}`

1.25C/m^3

`\mobility`{ *\langle magnitude \rangle* }

Command for electron mobility.

<code>\areachargedensity{4.5\timestento{-3}}</code>	$4.5 \times 10^{-3} \text{C/m}^2$
<code>\numberdensity{⟨magnitude⟩}</code> Command for electron number density.	
<code>\numberdensity{2\timestento{18}}</code>	$2 \times 10^{18} / \text{m}^3$
<code>\polarizability{⟨magnitude⟩}</code> Command for polarizability.	
<code>\polarizability{1.96\timestento{-40}}</code>	$1.96 \times 10^{-40} \text{C} \cdot \text{m} / (\text{N/C})$
<code>\electricpotential{⟨magnitude⟩}</code> Command for electric potential.	
<code>\electricpotential{1.5}</code>	1.5 V
<code>\emf{⟨magnitude⟩}</code> Command for emf.	
<code>\emf{1.5}</code>	1.5 V
<code>\dielectricconstant{⟨magnitude⟩}</code> Command for dielectric constant.	
<code>\dielectricconstant{1.5}</code>	1.5
<code>\indexofrefraction{⟨magnitude⟩}</code> Command for index of refraction.	
<code>\indexofrefraction{1.5}</code>	1.5
<code>\relativepermittivity{⟨magnitude⟩}</code> Command for relative permittivity.	
<code>\relativepermittivity{0.9}</code>	0.9
<code>\relativepermeability{⟨magnitude⟩}</code> Command for relative permeability.	
<code>\relativepermeability{0.9}</code>	0.9
<code>\poyntingvector{⟨commadelimitedlistofcomps⟩}</code> Command for Poynting vector. This is an alias for <code>\vectorenergyflux</code> ^{→P. 29} .	

<code>\poyntingvector{3,2,-1}</code>	$\langle 3, 2, -1 \rangle \text{ W/m}^2$
<code>\energydensity{<magnitude>}</code> Command for energy density.	
<code>\energydensity{1.25}</code>	1.25 J/m^3
<code>\energyflux{<magnitude or vector>}</code> Command for energy flux.	
<code>\vectorenergyflux{<commadelimitedlistofcomps>}</code> Command for vector energy flux.	
<code>\energyflux{4\timestento{26}} \\\</code> <code>\energyflux{\mivector{3,2,-1}} \\\</code> <code>\vectorenergyflux{3,2,-1}</code>	$4 \times 10^{26} \text{ W/m}^2$ $\langle 3, 2, -1 \rangle \text{ W/m}^2$ $\langle 3, 2, -1 \rangle \text{ W/m}^2$
<code>\momentumflux{<magnitude or vector>}</code> Command for momentum flux.	
<code>\vectormomentumflux{<commadelimitedlistofcomps>}</code> Command for vector momentum flux.	
<code>\momentumflux{4\timestento{26}} \\\</code> <code>\momentumflux{\mivector{3,2,-1}} \\\</code> <code>\vectormomentumflux{3,2,-1}</code>	$4 \times 10^{26} \text{ N/m}^2$ $\langle 3, 2, -1 \rangle \text{ N/m}^2$ $\langle 3, 2, -1 \rangle \text{ N/m}^2$
<code>\electroncurrent{<magnitude>}</code> Command for electron current.	
<code>\electroncurrent{2\timestento{18}}</code>	$2 \times 10^{18} \text{ e/s}$
<code>\conventionalcurrent{<magnitude>}</code> Command for conventional current.	
<code>\conventionalcurrent{0.003}</code>	0.003 A
<code>\magneticdipolemoment{<magnitude or vector>}</code> Command for magnetic dipole moment.	
<code>\vectormagneticdipolemoment{<commadelimitedlistofcomps>}</code> Command for vector magnetic dipole moment.	
<code>\magneticdipolemoment{1.25} \\\</code> <code>\magneticdipolemoment{\mivector{3,2,-1}} \\\</code> <code>\vectormagneticdipolemoment{3,2,-1}</code>	$1.25 \text{ A} \cdot \text{m}^2$ $\langle 3, 2, -1 \rangle \text{ A} \cdot \text{m}^2$ $\langle 3, 2, -1 \rangle \text{ A} \cdot \text{m}^2$

`\currentdensity`{*<magnitude or vector>*}

Command for current density.

`\vectorcurrentdensity`{*<commadelimitedlistofcomps>*}

Command for vector current density.

<code>\currentdensity{1.25}</code>	<code>\\</code>	1.25 A/m^2
<code>\currentdensity{\mivector{3,2,-1}}</code>	<code>\\</code>	$\langle 3, 2, -1 \rangle \text{ A/m}^2$
<code>\vectorcurrentdensity{3,2,-1}</code>		$\langle 3, 2, -1 \rangle \text{ A/m}^2$

`\electricflux`{*<magnitude>*}

Command for electric flux.

<code>\electricflux{1.25}</code>	$1.25 \text{ N} \cdot \text{m}^2/\text{C}$
----------------------------------	--

`\magneticflux`{*<magnitude>*}

Command for magnetic flux.

<code>\magneticflux{1.25}</code>	$1.25 \text{ T} \cdot \text{m}^2$
----------------------------------	-----------------------------------

`\capacitance`{*<magnitude>*}

Command for capacitance.

<code>\capacitance{1.00}</code>	1.00 C/V
---------------------------------	--------------------

`\inductance`{*<magnitude>*}

Command for inductance.

<code>\inductance{1.00}</code>	$1.00 \text{ V} \cdot \text{s/A}$
--------------------------------	-----------------------------------

`\conductivity`{*<magnitude>*}

Command for conductivity.

<code>\conductivity{1.25}</code>	$1.25 \text{ (A/m}^2\text{)/(V/m)}$
----------------------------------	-------------------------------------

`\resistivity`{*<magnitude>*}

Command for resistivity.

<code>\resistivity{1.25}</code>	$1.25 \text{ (V/m)/(A/m}^2\text{)}$
---------------------------------	-------------------------------------

`\resistance`{*<magnitude>*}

Command for resistance.

<code>\resistance{1\timestento{6}}</code>	$1 \times 10^6 \Omega$
---	------------------------

`\conductance`{*<magnitude>*}

Command for conductance.

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

$1 \times 10^6 \text{S}$

```
\magneticcharge{<magnitude>}
```

Command for magnetic charge, in case it actually exists.

```
\magneticcharge{1.25}
```

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

5.3.4 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}}
```

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

```
\hereusedrvdunit{<magnitude>}
```

Command for using derived units in place.

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

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

```
\hereusetradunit{<magnitude>}
```

Command for using traditional units in place.

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

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

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}
```

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

```
\begin{usedrvdunit}  
  <environment content>  
\end{usedrvdunit}
```

Environment for using derived units.

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

3 N · s

```
\begin{usetradunit}
<environment content>
\end{usetradunit}
```

Environment for using traditional units.

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

3 kg · 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.

5.3.5 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 \luminous	baseunit cd	drvdunit cd	tradunit cd
name \planeangle	baseunit $\text{m} \cdot \text{m}^{-1}$	drvdunit rad	tradunit $\text{m} \cdot \text{m}^{-1}$
name \solidangle	baseunit $\text{m}^2 \cdot \text{m}^{-2}$	drvdunit sr	tradunit $\text{m}^2 \cdot \text{m}^{-2}$
name \velocity	baseunit $\text{m} \cdot \text{s}^{-1}$	drvdunit $\text{m} \cdot \text{s}^{-1}$	tradunit m/s
name \acceleration	baseunit $\text{m} \cdot \text{s}^{-2}$	drvdunit N/kg	tradunit m/s^2
name \gravitationalfield	baseunit $\text{m} \cdot \text{s}^{-2}$	drvdunit N/kg	tradunit N/kg
name \gravitationalpotential	baseunit $\text{m}^2 \cdot \text{s}^{-2}$	drvdunit J/kg	tradunit J/kg
name \momentum	baseunit $\text{m} \cdot \text{kg} \cdot \text{s}^{-1}$	drvdunit $\text{N} \cdot \text{s}$	tradunit $\text{kg} \cdot \text{m}/\text{s}$
name \impulse	baseunit $\text{m} \cdot \text{kg} \cdot \text{s}^{-1}$	drvdunit $\text{N} \cdot \text{s}$	tradunit $\text{N} \cdot \text{s}$
name \force	baseunit $\text{m} \cdot \text{kg} \cdot \text{s}^{-2}$	drvdunit N	tradunit N
name \springstiffness	baseunit $\text{kg} \cdot \text{s}^{-2}$	drvdunit N/m	tradunit N/m
name \springstretch	baseunit m	drvdunit m	tradunit m
name \area	baseunit m^2	drvdunit m^2	tradunit m^2
name \volume	baseunit m^3	drvdunit m^3	tradunit m^3
name \linearmassdensity	baseunit $\text{m}^{-1} \cdot \text{kg}$	drvdunit kg/m	tradunit kg/m
name \areamassdensity	baseunit $\text{m}^{-2} \cdot \text{kg}$	drvdunit kg/m^2	tradunit kg/m^2
name \volumemassdensity	baseunit $\text{m}^{-3} \cdot \text{kg}$	drvdunit kg/m^3	tradunit kg/m^3
name \youngsmodulus	baseunit $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$	drvdunit N/m^2	tradunit Pa

name \stress	baseunit $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$	drvdunit N/m^2	tradunit Pa
name \pressure	baseunit $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$	drvdunit N/m^2	tradunit Pa
name \strain	baseunit	drvdunit	tradunit
name \work	baseunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2}$	drvdunit $\text{N} \cdot \text{m}$	tradunit J
name \energy	baseunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2}$	drvdunit $\text{N} \cdot \text{m}$	tradunit J
name \power	baseunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3}$	drvdunit J/s	tradunit W
name \specificheatcapacity	baseunit J/K · kg	drvdunit J/K · kg	tradunit J/K · kg
name \angularvelocity	baseunit $\text{rad} \cdot \text{s}^{-1}$	drvdunit rad/s	tradunit rad/s
name \angularacceleration	baseunit $\text{rad} \cdot \text{s}^{-2}$	drvdunit rad/s^2	tradunit rad/s^2
name \momentofinertia	baseunit $\text{m}^2 \cdot \text{kg}$	drvdunit $\text{m} \cdot \text{kg}^2$	tradunit $\text{J} \cdot \text{s}^2$
name \angularmomentum	baseunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$	drvdunit $\text{N} \cdot \text{m} \cdot \text{s}$	tradunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$
name \angularimpulse	baseunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$	drvdunit $\text{N} \cdot \text{m} \cdot \text{s}$	tradunit J · s
name \torque	baseunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2}$	drvdunit $\text{N} \cdot \text{m}$	tradunit J
name \entropy	baseunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{K}^{-1}$	drvdunit J/K	tradunit J/K
name \wavelength	baseunit m	drvdunit m	tradunit m
name \wavenumber	baseunit m^{-1}	drvdunit /m	tradunit /m
name \frequency	baseunit s^{-1}	drvdunit Hz	tradunit Hz
name \angularfrequency	baseunit $\text{rad} \cdot \text{s}^{-1}$	drvdunit rad/s	tradunit rad/s

name \charge	baseunit $A \cdot s$	drvdunit C	tradunit C
name \permittivity	baseunit $m^{-3} \cdot kg^{-1} \cdot s^{-4} \cdot A^2$	drvdunit F/m	tradunit $C^2/N \cdot m^2$
name \permeability	baseunit $m \cdot kg \cdot s^{-2} \cdot A^{-2}$	drvdunit H/m	tradunit $T \cdot m/A$
name \linearchargedensity	baseunit $m^{-1} \cdot s \cdot A$	drvdunit C/m	tradunit C/m
name \areachargedensity	baseunit $m^{-2} \cdot s \cdot A$	drvdunit C/m^2	tradunit C/m^2
name \volumechargedensity	baseunit $m^{-3} \cdot s \cdot A$	drvdunit C/m^3	tradunit C/m^3
name \electricfield	baseunit $m \cdot kg \cdot s^{-3} \cdot A^{-1}$	drvdunit V/m	tradunit N/C
name \electricdipolemoment	baseunit $m \cdot s \cdot A$	drvdunit $C \cdot m$	tradunit $C \cdot m$
name \electricflux	baseunit $m^3 \cdot kg \cdot s^{-3} \cdot A^{-1}$	drvdunit $V \cdot m$	tradunit $N \cdot m^2/C$
name \magneticfield	baseunit $kg \cdot s^{-2} \cdot A^{-1}$	drvdunit T	tradunit $N/C \cdot (m/s)$
name \magneticflux	baseunit $m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$	drvdunit $V \cdot s$	tradunit $T \cdot m^2$
name \cmagneticfield	baseunit $m \cdot kg \cdot s^{-3} \cdot A^{-1}$	drvdunit V/m	tradunit N/C
name \mobility	baseunit $m^2 \cdot kg \cdot s^{-4} \cdot A^{-1}$	drvdunit $m^2/V \cdot s$	tradunit $(m/s)/(N/C)$
name \numberdensity	baseunit m^{-3}	drvdunit $/m^3$	tradunit $/m^3$
name \polarizability	baseunit $kg^{-1} \cdot s^4 \cdot A^2$	drvdunit $C \cdot m^2/V$	tradunit $C \cdot m/(N/C)$
name \electricpotential	baseunit $m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$	drvdunit J/C	tradunit V
name \emf	baseunit $m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$	drvdunit J/C	tradunit V
name \dielectricconstant	baseunit	drvdunit	tradunit

name <code>\indexofrefraction</code>	baseunit	drvdunit	tradunit
name <code>\relativepermittivity</code>	baseunit	drvdunit	tradunit
name <code>\relativepermeability</code>	baseunit	drvdunit	tradunit
name <code>\energydensity</code>	baseunit $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$	drvdunit J/m^3	tradunit J/m^3
name <code>\momentumflux</code>	baseunit $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$	drvdunit N/m^2	tradunit N/m^2
name <code>\energyflux</code>	baseunit $\text{kg} \cdot \text{s}^{-3}$	drvdunit W/m^2	tradunit W/m^2
name <code>\electroncurrent</code>	baseunit s^{-1}	drvdunit e/s	tradunit e/s
name <code>\conventionalcurrent</code>	baseunit A	drvdunit C/s	tradunit A
name <code>\magneticdipolemoment</code>	baseunit $\text{m}^2 \cdot \text{A}$	drvdunit J/T	tradunit $\text{A} \cdot \text{m}^2$
name <code>\currentdensity</code>	baseunit $\text{m}^{-2} \cdot \text{A}$	drvdunit $\text{C} \cdot \text{s}/\text{m}^2$	tradunit A/m^2
name <code>\capacitance</code>	baseunit $\text{m}^{-2} \cdot \text{kg}^{-1} \cdot \text{s}^4 \cdot \text{A}^2$	drvdunit F	tradunit C/V
name <code>\inductance</code>	baseunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{A}^{-2}$	drvdunit H	tradunit $\text{V} \cdot \text{s}/\text{A}$
name <code>\conductivity</code>	baseunit $\text{m}^{-3} \cdot \text{kg}^{-1} \cdot \text{s}^3 \cdot \text{A}^2$	drvdunit S/m	tradunit $(\text{A}/\text{m}^2)/(\text{V}/\text{m})$
name <code>\resistivity</code>	baseunit $\text{m}^3 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-2}$	drvdunit $\Omega \cdot \text{m}$	tradunit $(\text{V}/\text{m})/(\text{A}/\text{m}^2)$
name <code>\resistance</code>	baseunit $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-2}$	drvdunit V/A	tradunit Ω
name <code>\conductance</code>	baseunit $\text{m}^{-2} \cdot \text{kg}^{-1} \cdot \text{s}^3 \cdot \text{A}^2$	drvdunit A/V	tradunit S
name <code>\magneticcharge</code>	baseunit $\text{m} \cdot \text{A}$	drvdunit $\text{m} \cdot \text{A}$	tradunit $\text{m} \cdot \text{A}$

5.4 Physical Constants

5.4.1 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}{6.6261}\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 `\nameonlydrvunit` 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.

5.4.2 Predefined Physical Constants

In this section, precise values of constants are used. Approximate values are available as an option when the package is loaded.

`\oofpez`

Coulomb constant.

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

$$\frac{1}{4\pi\epsilon_0} \approx 8.9876 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2$$

`\oofpezcs`

Alternate form of Coulomb constant.

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

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

`\vacuumpermittivity`

Vacuum permittivity.

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

$$\epsilon_0 \approx 8.8542 \times 10^{-12} \text{C}^2/\text{N} \cdot \text{m}^2$$

`\mzofp`

Biot-Savart constant.

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

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

`\vacuumpermeability`

Vacuum permeability.

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

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

`\boltzmann`

Boltzmann constant.

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

$$k_B \approx 1.3806 \times 10^{-23} \text{J}/\text{K}$$

`\boltzmannineV`

Alternate form of Boltzmann constant.

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

$$k_B \approx 8.6173 \times 10^{-5} \text{eV}/\text{K}$$

`\stefan`

Stefan-Boltzmann constant.

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

$$\sigma \approx 5.6704 \times 10^{-8} \text{W/m}^2 \cdot \text{K}^4$$

`\planck`

Planck constant.

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

$$h \approx 6.6261 \times 10^{-34} \text{J} \cdot \text{s}$$

`\planckineV`

Alternate form of Planck constant.

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

$$h \approx 4.1357 \times 10^{-15} \text{eV} \cdot \text{s}$$

`\planckbar`

Reduced Planck constant (Dirac constant).

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

$$\hbar \approx 1.0546 \times 10^{-34} \text{J} \cdot \text{s}$$

`\planckbarineV`

Alternate form of reduced Planck constant (Dirac constant).

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

$$\hbar \approx 6.5821 \times 10^{-16} \text{eV} \cdot \text{s}$$

`\planckc`

Planck constant times light speed.

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

$$hc \approx 1.9864 \times 10^{-25} \text{J} \cdot \text{m}$$

`\planckcineV`

Alternate form of Planck constant times light speed.

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

$$hc \approx 1.9864 \times 10^{-25} \text{eV} \cdot \text{nm}$$

`\rydberg`

Rydberg constant.

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

$$R_{\infty} \approx 1.0974 \times 10^7 \text{m}^{-1}$$

`\bohrradius`

Bohr radius.

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

$$a_0 \approx 5.2918 \times 10^{-11} \text{m}$$

\finestructure

Fine structure constant.

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

$$\alpha \approx 7.2974 \times 10^{-3}$$

\avogadro

Avogadro constant.

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

$$N_A \approx 6.0221 \times 10^{23} \text{mol}^{-1}$$

\universalgrav

Universal gravitational constant.

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

$$G \approx 6.6738 \times 10^{-11} \text{N} \cdot \text{m}^2/\text{kg}^2$$

\surfacegravfield

Earth's surface gravitational field strength.

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

$$g \approx 9.80 \text{N/kg}$$

\clight

Magnitude of light's velocity (photon constant).

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

$$c \approx 2.9979 \times 10^8 \text{m/s}$$

\clightinfeet

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

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

$$c \approx 0.9836 \text{ft/ns}$$

\Ratom

Approximate atomic radius.

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

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

\Mproton

Proton mass.

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

$$m_p \approx 1.6726 \times 10^{-27} \text{kg}$$

\Mneutron

Neutron mass.

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

$$m_n \approx 1.6749 \times 10^{-27} \text{kg}$$

\Mhydrogen

Hydrogen atom mass.

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

$$m_H \approx 1.6737 \times 10^{-27} \text{kg}$$

\Melectron

Electron mass.

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

$$m_e \approx 9.1094 \times 10^{-31} \text{kg}$$

\echarge

Elementary charge quantum.

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

$$e \approx 1.6022 \times 10^{-19} \text{C}$$

\Qelectron

Electron charge.

\qelectron

Alias for `\Qelectron`.

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

$$Q_e \approx -1.6022 \times 10^{-19} \text{C}$$

\Qproton

Proton charge.

\qproton

Alias for `\Qproton`.

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

$$Q_p \approx +1.6022 \times 10^{-19} \text{C}$$

\MEarth

Earth's mass.

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

$$M_{\text{Earth}} \approx 5.9736 \times 10^{24} \text{kg}$$

\MMoon

Moon's mass.

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

$$M_{\text{Moon}} \approx 7.3459 \times 10^{22} \text{kg}$$

\MSun

Sun's mass.

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

$$M_{\text{Sun}} \approx 1.9891 \times 10^{30} \text{kg}$$

`\REarth`

Earth's radius.

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

$$R_{\text{Earth}} \approx 6.3675 \times 10^6 \text{m}$$

`\RMoon`

Moon's radius.

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

$$R_{\text{Moon}} \approx 1.7375 \times 10^6 \text{m}$$

`\RSun`

Sun's radius.

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

$$R_{\text{Sun}} \approx 6.9634 \times 10^8 \text{m}$$

`\ESdist`

Earth-Sun distance.

`\SEdist`

Alias for `\ESdist`.

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

$$\|\vec{r}_{\text{ES}}\| \approx 1.4960 \times 10^{11} \text{m}$$

`\EMdist`

Earth-Moon distance.

`\MEDist`

Alias for `\EMdist`.

`\(\EMdistmathsymbol \approx \MEDist\)`

$$\|\vec{r}_{\text{EM}}\| \approx 3.8440 \times 10^8 \text{m}$$

5.4.3 All Predefined Constants

`\chkconstant{\langle constantname \rangle}`

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	baseunit	drvdunit	tradunit
<code>\oofpez</code>	$\frac{1}{4\pi\epsilon_0}$	8.9876×10^9	$\text{m}^3 \cdot \text{kg} \cdot \text{s}^{-4} \cdot \text{A}^{-2}$	m/F	$\text{N} \cdot \text{m}^2/\text{C}^2$
name	symbol	value	baseunit	drvdunit	tradunit
<code>\oofpezcs</code>	$\frac{1}{4\pi\epsilon_0 c^2}$	10^{-7}	$\text{m} \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{A}^{-2}$	$\text{T} \cdot \text{m}^2$	$\text{N} \cdot \text{s}^2/\text{C}^2$

<code>\vacuumpermittivity</code>	name symbol	value	baseunit	drvdunit	tradunit
	ϵ_0	8.8542×10^{-12}	$\text{m}^{-3} \cdot \text{kg}^{-1} \cdot \text{s}^4 \cdot \text{A}^2$	F/m	$\text{C}^2/\text{N} \cdot \text{m}^2$
<code>\mzofp</code>	name symbol	value	baseunit	drvdunit	tradunit
	$\frac{\mu_0}{4\pi}$	10^{-7}	$\text{m} \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{A}^{-2}$	H/m	$\text{T} \cdot \text{m}/\text{A}$
<code>\vacuumpermeability</code>	name symbol	value	baseunit	drvdunit	tradunit
	μ_0	$4\pi \times 10^{-7}$	$\text{m} \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{A}^{-2}$	H/m	$\text{T} \cdot \text{m}/\text{A}$
<code>\boltzmann</code>	name symbol	value	baseunit	drvdunit	tradunit
	k_B	1.3806×10^{-23}	$\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{K}^{-1}$	J/K	J/K
<code>\boltzmannineV</code>	name symbol	value	baseunit	drvdunit	tradunit
	k_B	8.6173×10^{-5}	$\text{eV} \cdot \text{K}^{-1}$	eV/K	eV/K
<code>\stefanboltzmann</code>	name symbol	value	baseunit	drvdunit	tradunit
	σ	5.6704×10^{-8}	$\text{kg} \cdot \text{s}^{-3} \cdot \text{K}^{-4}$	$\text{W}/\text{m}^2 \cdot \text{K}^4$	$\text{W}/\text{m}^2 \cdot \text{K}^4$
<code>\planck</code>	name symbol	value	baseunit	drvdunit	tradunit
	h	6.6261×10^{-34}	$\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$	J · s	J · s
<code>\planckineV</code>	name symbol	value	baseunit	drvdunit	tradunit
	h	4.1357×10^{-15}	$\text{eV} \cdot \text{s}$	eV · s	eV · s
<code>\planckbar</code>	name symbol	value	baseunit	drvdunit	tradunit
	\hbar	1.0546×10^{-34}	$\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$	J · s	J · s
<code>\planckbarineV</code>	name symbol	value	baseunit	drvdunit	tradunit
	\hbar	6.5821×10^{-16}	$\text{eV} \cdot \text{s}$	eV · s	eV · s
<code>\planckc</code>	name symbol	value	baseunit	drvdunit	tradunit
	hc	1.9864×10^{-25}	$\text{m}^3 \cdot \text{kg} \cdot \text{s}^{-2}$	J · m	J · m
<code>\planckcineV</code>	name symbol	value	baseunit	drvdunit	tradunit
	hc	1.9864×10^{-25}	$\text{eV} \cdot \text{nm}$	eV · nm	eV · nm
<code>\rydberg</code>	name symbol	value	baseunit	drvdunit	tradunit
	R_∞	1.0974×10^7	m^{-1}	m^{-1}	m^{-1}
<code>\bohrradius</code>	name symbol	value	baseunit	drvdunit	tradunit
	a_0	5.2918×10^{-11}	m	m	m
<code>\finestructure</code>	name symbol	value	baseunit	drvdunit	tradunit
	α	7.2974×10^{-3}			
<code>\avogadro</code>	name symbol	value	baseunit	drvdunit	tradunit
	N_A	6.0221×10^{23}	mol^{-1}	mol^{-1}	mol^{-1}

name \universalgrav	symbol G	value 6.6738×10^{-11}	baseunit $\text{m}^3 \cdot \text{kg}^{-1} \cdot \text{s}^{-2}$	drvdunit $\text{J} \cdot \text{m}/\text{kg}^2$	tradunit $\text{N} \cdot \text{m}^2/\text{kg}^2$
name \surfacegravfield	symbol g	value 9.80	baseunit $\text{m} \cdot \text{s}^{-2}$	drvdunit N/kg	tradunit N/kg
name \clight	symbol c	value 2.9979×10^8	baseunit $\text{m} \cdot \text{s}^{-1}$	drvdunit m/s	tradunit m/s
name \clightinfeet	symbol c	value 0.9836	baseunit $\text{ft} \cdot \text{ns}^{-1}$	drvdunit ft/ns	tradunit ft/ns
name \Ratom	symbol r_{atom}	value 10^{-10}	baseunit m	drvdunit m	tradunit m
name \Mproton	symbol m_p	value 1.6726×10^{-27}	baseunit kg	drvdunit kg	tradunit kg
name \Mneutron	symbol m_n	value 1.6749×10^{-27}	baseunit kg	drvdunit kg	tradunit kg
name \Mhydrogen	symbol m_H	value 1.6737×10^{-27}	baseunit kg	drvdunit kg	tradunit kg
name \Melectron	symbol m_e	value 9.1094×10^{-31}	baseunit kg	drvdunit kg	tradunit kg
name \echarge	symbol e	value 1.6022×10^{-19}	baseunit $\text{A} \cdot \text{s}$	drvdunit C	tradunit C
name \Qelectron	symbol Q_e	value -1.6022×10^{-19}	baseunit $\text{A} \cdot \text{s}$	drvdunit C	tradunit C
name \qelectron	symbol q_e	value -1.6022×10^{-19}	baseunit $\text{A} \cdot \text{s}$	drvdunit C	tradunit C
name \Qproton	symbol Q_p	value $+1.6022 \times 10^{-19}$	baseunit $\text{A} \cdot \text{s}$	drvdunit C	tradunit C
name \qproton	symbol q_p	value $+1.6022 \times 10^{-19}$	baseunit $\text{A} \cdot \text{s}$	drvdunit C	tradunit C
name \MEarth	symbol M_{Earth}	value 5.9736×10^{24}	baseunit kg	drvdunit kg	tradunit kg
name \MMoon	symbol M_{Moon}	value 7.3459×10^{22}	baseunit kg	drvdunit kg	tradunit kg

name	symbol	value	baseunit	drvdunit	tradunit
<code>\MSun</code>	M_{Sun}	1.9891×10^{30}	kg	kg	kg
name	symbol	value	baseunit	drvdunit	tradunit
<code>\REarth</code>	R_{Earth}	6.3675×10^6	m	m	m
name	symbol	value	baseunit	drvdunit	tradunit
<code>\RMoon</code>	R_{Moon}	1.7375×10^6	m	m	m
name	symbol	value	baseunit	drvdunit	tradunit
<code>\RSun</code>	R_{Sun}	6.9634×10^8	m	m	m
name	symbol	value	baseunit	drvdunit	tradunit
<code>\ESdist</code>	$\ \vec{r}_{\text{ES}}\ $	1.4960×10^{11}	m	m	m
name	symbol	value	baseunit	drvdunit	tradunit
<code>\EMdist</code>	$\ \vec{r}_{\text{EM}}\ $	3.8440×10^8	m	m	m
name	symbol	value	baseunit	drvdunit	tradunit
<code>\LSun</code>	L_{Sun}	3.8460×10^{26}	$\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3}$	W	J/s
name	symbol	value	baseunit	drvdunit	tradunit
<code>\TSun</code>	T_{Sun}	5778	K	K	K
name	symbol	value	baseunit	drvdunit	tradunit
<code>\MagSun</code>	M_{Sun}	+4.83			
name	symbol	value	baseunit	drvdunit	tradunit
<code>\magSun</code>	m_{Sun}	-26.74			

5.5 Astronomical Constants and Quantities

`\LSun`

Sun's luminosity.

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

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

`\TSun`

Sun's effective temperature.

`\(\TSunmathsymbol \approx \TSun\)`

$$T_{\text{Sun}} \approx 5778 \text{ K}$$

`\MagSun`

Sun's absolute magnitude.

`\(\MagSunmathsymbol \approx \MagSun\)`

$$M_{\text{Sun}} \approx +4.83$$

`\magSun`

Sun's apparent magnitude.

`\(\magSunmathsymbol \approx \magSun\)`

$m_{\text{Sun}} \approx -26.74$

`\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`^{→P. 47}.

<code>\Fstar</code> or <code>\Fstar[Sirius]</code>	F_{\star} or F_{Sirius}
--	------------------------------------

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

`\fsolar`
Alias for `\fsolar`.

<code>\Fsolar</code>	F_{\odot}
----------------------	-------------

`\Magstar[⟨object⟩]`
Symbol for stellar absolute magnitude.

<code>\Magstar</code> or <code>\Magstar[Sirius]</code>	M_{\star} or M_{Sirius}
--	------------------------------------

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

<code>\Magsolar</code>	M_{\odot}
------------------------	-------------

`\magstar[⟨object⟩]`
Symbol for stellar apparent magnitude.

<code>\magstar</code> or <code>\magstar[Sirius]</code>	m_{\star} or m_{Sirius}
--	------------------------------------

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

<code>\magsolar</code>	m_{\odot}
------------------------	-------------

`\Dstar[⟨object⟩]`
Symbol for stellar distance.

`\dstar`
Alias for `\Dstar` that uses a lower case d.

<code>\Dstar</code> or <code>\Dstar[Sirius]</code>	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}

5.6 Symbolic Expressions with Vectors

5.6.1 Basic Vectors

`\vect{<kernel>}`

Symbol for a vector quantity.

`\vect{p}`

\vec{p}

`\magvect{<kernel>}`

Symbol for magnitude of a vector quantity.

`\magvect{p}`

$\|\vec{p}\|$

`\magsquaredvect{<kernel>}`

Symbol for squared magnitude of a vector quantity.

`\magsquaredvect{p}`

$\|\vec{p}\|^2$

`\magnvect{<kernel>}{<exponent>}`

Symbol for magnitude of a vector quantity to arbitrary power.

`\magnvect{r}{5}`

$\|\vec{r}\|^5$

`\dirvect{<kernel>}`

Symbol for direction of a vector quantity.

`\dirvect{p}` or `\direction{p}`

\hat{p} or p

`\componentalong{<alongvector>}{<ofvector>}`

Symbol for the component along a vector of another vector.

`\componentalong{\vect{v}}{\vect{u}}`

$\text{comp}_{\vec{v}} \vec{u}$

`\expcomponentalong{<alongvector>}{<ofvector>}`

Symbolic expression for the component along a vector of another vector.

`\expcomponentalong{\vect{v}}{\vect{u}}`

$\frac{\vec{u} \cdot \vec{v}}{\|\vec{v}\|}$

`\ucomponentalong` $\{\langle alongvector \rangle\}\{\langle ofvector \rangle\}$

Symbolic expression with unit vectors for the component along a vector of another vector.

`\ucomponentalong{\dirvect{v}}{\vect{u}}`

$$\vec{u} \bullet \hat{v}$$

`\projectiononto` $\{\langle ontovector \rangle\}\{\langle ofvector \rangle\}$

Symbol for the projection onto a vector of another vector.

`\projectiononto{\vect{v}}{\vect{u}}`

$$\text{proj}_{\vec{v}} \vec{u}$$

`\expprojectiononto` $\{\langle alongvector \rangle\}\{\langle ofvector \rangle\}$

Symbolic expression for the projection onto a vector of another vector.

`\expprojectiononto{\vect{v}}{\vect{u}}`

$$\left(\frac{\vec{u} \bullet \vec{v}}{\|\vec{v}\|} \right) \frac{\vec{v}}{\|\vec{v}\|}$$

`\uprojectiononto` $\{\langle alongvector \rangle\}\{\langle ofvector \rangle\}$

Symbolic expression with unit vectors for the projection onto a vector of another vector.

`\uprojectiononto{\dirvect{v}}{\vect{u}}`

$$(\vec{u} \bullet \hat{v}) \hat{v}$$

`\mivector` $[\langle printeddelimter \rangle]\{\langle commadelimitedlistofcomps \rangle\}[\langle unit \rangle]$

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

$$u_{\mu} = \langle e_0, e_1, e_2, e_3 \rangle$$

$$u_{\mu} = \langle e_0 \quad e_1 \quad e_2 \quad e_3 \rangle$$

$$\vec{v} = \langle 1, 3, 5 \rangle \text{ m/s}$$

$$\vec{E} = \left\langle \frac{1}{4\pi\epsilon_0} \frac{Q}{x^2}, 0, 0 \right\rangle$$

$$\vec{E} = \left\langle \frac{1}{4\pi\epsilon_0} \frac{Q}{x^2} \quad 0 \quad 0 \right\rangle$$

`\magvectncomps` $\{\langle listofcomps \rangle\}[\langle unit \rangle]$

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}}}
```

$$\sqrt{(3.12 \text{ m/s})^2 + (4.04 \text{ m/s})^2 + (6.73 \text{ m/s})^2}$$

$$\sqrt{(3.12 \text{ m/s})^2 + (4.04 \text{ m/s})^2 + (6.73 \text{ m/s})^2}$$

$$\sqrt{\left(\frac{1}{\sqrt{3}}\right)^2 + \left(\frac{1}{\sqrt{3}}\right)^2 + \left(\frac{1}{\sqrt{3}}\right)^2}$$

\scompsvect{*<kernel>*}

Expression for a vector's symbolic components.

<code>\scompsvect{E}</code>	$\langle E_x, E_y, E_z \rangle$
-----------------------------	---------------------------------

\compvect{*<kernel>*}{*<component>*}

Isolates one of a vector's symbolic components.

<code>\compvect{E}{y}</code>	E_y
------------------------------	-------

\scompsdirvect{*<kernel>*}

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

<code>\scompsdirvect{r}</code>	$\langle \hat{r}_x, \hat{r}_y, \hat{r}_z \rangle$
--------------------------------	---

\compdirvect{*<kernel>*}{*<component>*}

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

<code>\compdirvect{r}{z}</code>	\hat{r}_z
---------------------------------	-------------

\magvectscomps{*<kernel>*}

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

<code>\magvectscomps{B}</code>	$\sqrt{B_x^2 + B_y^2 + B_z^2}$
--------------------------------	--------------------------------

5.6.2 Differentials and Derivatives of Vectors

\dvect{*<kernel>*}

Symbol for the differential of a vector.

\Dvect{*<kernel>*}

Identical to `\dvect` but uses Δ .

a change <code>\dvect{E}</code> in electric field \\ a change <code>\Dvect{E}</code> in electric field	a change $d\vec{E}$ 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 \ll
the direction `\dirDvect{E}` of the change

the direction $\widehat{d\vec{E}}$ 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}` \ll
the change `\Ddirvect{E}` or `\Ddirection{E}` in the direction of `\vect{E}`

the change $d\hat{E}$ or $d\vec{E}$ in the direction of \vec{E}
the change $\Delta\hat{E}$ or $\Delta\vec{E}$ 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 \ll
the magnitude `\magDvect{E}` of the change

the magnitude $\|d\vec{E}\|$ of the change
the magnitude $\|\Delta\vec{E}\|$ 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 \ll
the change `\Dmagvect{E}` in the magnitude

the change $d\|\vec{E}\|$ in the magnitude
the change $\Delta\|\vec{E}\|$ 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 $\langle dE_x, dE_y, dE_z \rangle$
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 dE_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 $\frac{d\vec{E}}{dt}$
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 $\frac{d\|\vec{E}\|}{dt}$
the derivative $\frac{\Delta\|\vec{E}\|}{\Delta t}$

`\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 $\frac{d\hat{E}}{dt}$ or $\frac{d\hat{E}}{dt}$
the derivative $\frac{\Delta\hat{E}}{\Delta t}$ or $\frac{\Delta\hat{E}}{\Delta t}$

`\scompsdervect{<kernel>}{<indvar>}`

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

`\scompDervect{<kernel>}{<indvar>}`

Identical to `\scompsdervect` but uses Δ .

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

the derivative $\left\langle \frac{dE_x}{dt}, \frac{dE_y}{dt}, \frac{dE_z}{dt} \right\rangle$
the derivative $\left\langle \frac{dE_x}{dt}, \frac{dE_y}{dt}, \frac{dE_z}{dt} \right\rangle$

`\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 $\frac{dE_y}{dt}$
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 $\left\| \frac{d\vec{E}}{dt} \right\|$
the derivative $\left\| \frac{\Delta\vec{E}}{\Delta t} \right\|$

5.6.3 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.

5.6.4 Subscripted or Indexed Vectors

Now we have commands for vectors that carry subscripts or indices, usually to identify an object or something similar. Basically, $\backslash\text{vect}$ ^{P. 48} becomes $\backslash\text{vectsub}$ ^{P. 54}. Ideally, a subscript should not contain mathematical symbols. However, if you wish to do so, just wrap the symbol with $\backslash(\dots\backslash)$ 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. $\backslash\text{vectsub}\{\text{r}\}\{\text{ball},\text{f}\}$).

$\backslash\text{vectsub}\{\langle\text{kernel}\rangle\}\{\langle\text{sub}\rangle\}$

Symbol for a subscripted vector.

the vector $\backslash\text{vectsub}\{\text{p}\}\{\text{ball}\}$

the vector \vec{p}_{ball}

$\backslash\text{magvectsub}\{\langle\text{kernel}\rangle\}\{\langle\text{sub}\rangle\}$

Symbol for a subscripted vector's magnitude.

$\backslash\text{magvectsub}\{\text{p}\}\{\text{ball}\}$

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

$\backslash\text{magsquaredvectsub}\{\langle\text{kernel}\rangle\}\{\langle\text{sub}\rangle\}$

Symbol for a subscripted vector's squared magnitude.

$\backslash\text{magsquaredvectsub}\{\text{p}\}\{\text{ball}\}$

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

$\backslash\text{magnvectsub}\{\langle\text{kernel}\rangle\}\{\langle\text{sub}\rangle\}\{\langle\text{exponent}\rangle\}$

Symbol for a subscripted vector's magnitude to an arbitrary power.

$\backslash\text{magnvectsub}\{\text{r}\}\{\text{dipole}\}\{5\}$

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

$\backslash\text{dirvectsub}\{\langle\text{kernel}\rangle\}\{\langle\text{sub}\rangle\}$

Symbol for a subscripted vector's direction.

$\backslash\text{directionsub}\{\langle\text{kernel}\rangle\}\{\langle\text{sub}\rangle\}$

Alias for $\backslash\text{dirvectsub}$.

$\backslash\text{dirvectsub}\{\text{p}\}\{\text{ball}\}$ or $\backslash\text{directionsub}\{\text{p}\}\{\text{ball}\}$

\hat{p}_{ball} or \hat{p}_{ball}

$\backslash\text{scompsvectsub}\{\langle\text{kernel}\rangle\}\{\langle\text{sub}\rangle\}$

Symbolic components of a subscripted vector.

the vector $\backslash\text{scompsvectsub}\{\text{p}\}\{\text{ball}\}$

the vector $\langle p_{\text{ball},x}, p_{\text{ball},y}, p_{\text{ball},z} \rangle$

$\backslash\text{compvectsub}\{\langle\text{kernel}\rangle\}\{\langle\text{sub}\rangle\}\{\langle\text{component}\rangle\}$

Isolates one component of a subscripted vector.

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

the component $p_{\text{ball},z}$

`\magvectsubcomps{<kernel>}{<sub>}`

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

the magnitude `\magvectsubcomps{p}{ball}`

the magnitude $\sqrt{p_{\text{ball},x}^2 + p_{\text{ball},y}^2 + p_{\text{ball},z}^2}$

`\dvectsub{<kernel>}{<sub>}`

Differential of a subscripted vector.

`\Dvectsub{<kernel>}{<sub>}`

Identical to `\dvectsub` but uses Δ .

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

the change $d\vec{p}_{\text{ball}}$
the change $\Delta\vec{p}_{\text{ball}}$

`\scompsdvectsub{<kernel>}{<sub>}`

Symbolic components of a subscripted vector's differential.

`\scompsDvectsub{<kernel>}{<sub>}`

Identical to `\scompsdvectsub` but uses Δ .

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

the vector $\langle dp_{\text{ball},x}, dp_{\text{ball},y}, dp_{\text{ball},z} \rangle$
the vector $\langle \Delta p_{\text{ball},x}, \Delta p_{\text{ball},y}, \Delta p_{\text{ball},z} \rangle$

`\compdvectsub{<kernel>}{<sub>}{<component>}`

Isolates one component of a subscripted vector's differential.

`\compDvectsub{<kernel>}{<sub>}{<component>}`

Identical to `\compdvectsub` but uses Δ .

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

the component $dp_{\text{ball},y}$
the component $\Delta p_{\text{ball},y}$

`\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 .

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

the derivative $\frac{d\vec{p}_{\text{ball}}}{dt}$
the derivative $\frac{\Delta\vec{p}_{\text{ball}}}{\Delta t}$

`\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 .

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

the derivative $\frac{d\|\vec{E}_{\text{ball}}\|}{dt}$
the derivative $\frac{\Delta\|\vec{E}_{\text{ball}}\|}{\Delta t}$

`\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 .

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

the vector $\left\langle \frac{dp_{\text{ball},x}}{dt}, \frac{dp_{\text{ball},y}}{dt}, \frac{dp_{\text{ball},z}}{dt} \right\rangle$
the vector $\left\langle \frac{\Delta p_{\text{ball},x}}{\Delta t}, \frac{\Delta p_{\text{ball},y}}{\Delta t}, \frac{\Delta p_{\text{ball},z}}{\Delta t} \right\rangle$

`\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 .

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

the component $\frac{dp_{\text{ball},y}}{dt}$
the component $\frac{\Delta p_{\text{ball},y}}{\Delta t}$

`\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 .

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

the derivative $\left\| \frac{d\vec{p}_{\text{ball}}}{dt} \right\|$
the derivative $\left\| \frac{\Delta \vec{p}_{\text{ball}}}{\Delta t} \right\|$

5.6.5 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{\vect{F}}{\vect{v}}`

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

`\vectdotsvect{<kernel1>}{<kernel2>}`

Symbol for dot of two vectors with symbolic components.

`\vectdotsvect{F}{v}`

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

`\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} \ \backslash`
`\vectdotsDvect{F}{r}`

$$\langle F_x, F_y, F_z \rangle \bullet \langle dr_x, dr_y, dr_z \rangle$$

$$\langle F_x, F_y, F_z \rangle \bullet \langle \Delta r_x, \Delta r_y, \Delta r_z \rangle$$

`\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} \ \backslash`
`\vectdoteDvect{F}{r}`

$$F_x dr_x + F_y dr_y + F_z dr_z$$

$$F_x \Delta r_x + F_y \Delta r_y + F_z \Delta r_z$$

`\vectsubdotsvectsub{<kernel1>}{<sub1>}{<kernel2>}{<sub2>}`

Dot of two subscripted vectors with symbolic components.

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

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

`\vectsubdotevectsub{<kernel1>}{<sub1>}{<kernel2>}{<sub2>}`

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{<kernel1>}{<sub1>}{<kernel2>}{<sub2>}`

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

`\vectsubdotsDvectsub{<kernel1>}{<sub1>}{<kernel2>}{<sub2>}`

Identical to `\vectsubdotsdvectsub` but uses Δ .

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

$$\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z} \rangle \bullet \langle dB_{\text{car},x}, dB_{\text{car},y}, dB_{\text{car},z} \rangle$$

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

`\vectsubdotedvectsub{<kernel1>}{<sub1>}{<kernel2>}{<sub2>}`

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

`\vectsubdotedDvectsub{<kernel1>}{<sub1>}{<kernel2>}{<sub2>}`

Identical to `\vectsubdotedvectsub` but uses Δ .

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

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

`\vectsubdotsdvect{<kernel1>}{<sub1>}{<kernel2>}`

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

`\vectsubdotsDvect{<kernel1>}{<sub1>}{<kernel2>}`

Identical to `\vectsubdotsdvect` but uses Δ .

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

$\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z} \rangle \bullet \langle dB_x, dB_y, dB_z \rangle$
 $\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z} \rangle \bullet \langle \Delta B_x, \Delta B_y, \Delta B_z \rangle$

`\vectsubdotedvect{<kernel1>}{<sub1>}{<kernel2>}`

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

`\vectsubdotedDvect{<kernel1>}{<sub1>}{<kernel2>}`

Identical to `\vectsubdotedvect` but uses Δ .

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

$A_{\text{ball},x} dB_x + A_{\text{ball},y} dB_y + A_{\text{ball},z} dB_z$
 $A_{\text{ball},x} \Delta B_x + A_{\text{ball},y} \Delta B_y + A_{\text{ball},z} \Delta B_z$

`\dervectdotsvect{<kernel1>}{<indvar>}{<kernel2>}`

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}`

$\left\langle \frac{dA_x}{dt}, \frac{dA_y}{dt}, \frac{dA_z}{dt} \right\rangle \bullet \langle B_x, B_y, B_z \rangle$
 $\left\langle \frac{\Delta A_x}{\Delta t}, \frac{\Delta A_y}{\Delta t}, \frac{\Delta A_z}{\Delta t} \right\rangle \bullet \langle B_x, B_y, B_z \rangle$

`\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}`

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

`\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}

$$\langle A_x, A_y, A_z \rangle \bullet \left\langle \frac{dB_x}{dt}, \frac{dB_y}{dt}, \frac{dB_z}{dt} \right\rangle$$

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

\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}

$$A_x \frac{dB_x}{dt} + A_y \frac{dB_y}{dt} + A_z \frac{dB_z}{dt}$$

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

\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}

$$\left\langle \frac{dA_x}{dt}, \frac{dA_y}{dt}, \frac{dA_z}{dt} \right\rangle \bullet \langle dB_x, dB_y, dB_z \rangle$$

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

\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}

$$\frac{dA_x}{dt} dB_x + \frac{dA_y}{dt} dB_y + \frac{dA_z}{dt} dB_z$$

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

5.6.6 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}}`

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

`\rtriplecross{\langle kernel1 \rangle}{\langle kernel2 \rangle}{\langle kernel3 \rangle}`

Symbol for right associated triple cross product.

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

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

`\ltriplescalar{\langle kernel1 \rangle}{\langle kernel2 \rangle}{\langle kernel3 \rangle}`

Symbol for left associated triple scalar product.

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

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

`\rtriplescalar{\langle kernel1 \rangle}{\langle kernel2 \rangle}{\langle kernel3 \rangle}`

Symbol for right associated triple scalar product.

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

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

5.6.7 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`

$$e_0, e_1, e_2, e_3, e_4$$

`\uezero`

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

`\ueone`

`\uetwo`

`\uethree`

`\uefour`

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

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

`\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`

<code>\ezerozero, \ezeroone, \ezerotwo, \\</code>	<code>e00, e01, e02,</code>
<code>\ezerothree, \ezerofour, \eoneone, \\</code>	<code>e03, e04, e11,</code>
<code>\eonetwo, \eonethree, \eonefour, \\</code>	<code>e12, e13, e14,</code>
<code>\etwoone, \etwotwo, \etwothree, \\</code>	<code>e21, e22, e23,</code>
<code>\etwofour, \ethreeone, \ethreetwo, \\</code>	<code>e24, e31, e32,</code>
<code>\ethreethree, \ethreefour, \efourone, \\</code>	<code>e33, e34, e41,</code>
<code>\efourtwo, \efourthree, \efourfour</code>	<code>e42, e43, e44</code>

`\euzero`

Symbols for basis vectors with upper indices up to 4.

`\euone`

`\eutwo`

`\euthree`

`\eufour`

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

e^0, e^1, e^2, e^3, e^4

`\ueuzero`

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

`\ueuone`

`\ueutwo`

`\ueuthree`

`\ueufour`

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

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

`\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`

<code>\euzerozero, \euzeroone, \euzerotwo, \\</code>	$e^{00}, e^{01}, e^{02},$
<code>\euzerothree, \euzerofour, \euoneone, \\</code>	$e^{03}, e^{04}, e^{11},$
<code>\euonetwo, \euonethree, \euonefour, \\</code>	$e^{12}, e^{13}, e^{14},$
<code>\eutwoone, \eutwotwo, \eutwothree, \\</code>	$e^{21}, e^{22}, e^{23},$
<code>\eutwofour, \euthreeone, \euthreetwo, \\</code>	$e^{24}, e^{31}, e^{32},$
<code>\euthreethree, \euthreefour, \eufourone, \\</code>	$e^{33}, e^{34}, e^{41},$
<code>\eufourtwo, \eufourthree, \eufourfour</code>	e^{42}, e^{43}, e^{44}

`\gzero`

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

<code>\gzero, \gone, \gtwo, \gthree, \gfour</code>	$\gamma_0, \gamma_1, \gamma_2, \gamma_3, \gamma_4$
--	--

`\guzero`

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

<code>\guzero, \guone, \gutwo, \guthree, \gufour</code>	$\gamma^0, \gamma^1, \gamma^2, \gamma^3, \gamma^4$
---	--

`\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`

<code>\gzerozero, \gzeroone, \gzerotwo, \\</code>	<code>\gamma_{00}, \gamma_{01}, \gamma_{02},</code>
<code>\gzerothree, \gzerofour, \goneone, \\</code>	<code>\gamma_{03}, \gamma_{04}, \gamma_{11},</code>
<code>\gonetwo, \gonethree, \gonefour, \\</code>	<code>\gamma_{12}, \gamma_{13}, \gamma_{14},</code>
<code>\gtwoone, \gtwotwo, \gtwothree, \\</code>	<code>\gamma_{21}, \gamma_{22}, \gamma_{23},</code>
<code>\gtwofour, \gthreeone, \gthreetwo, \\</code>	<code>\gamma_{24}, \gamma_{31}, \gamma_{32},</code>
<code>\gthreethree, \gthreefour, \gfourone, \\</code>	<code>\gamma_{33}, \gamma_{34}, \gamma_{41},</code>
<code>\gfourtwo, \gfourthree, \gfourfour</code>	<code>\gamma_{42}, \gamma_{43}, \gamma_{44}</code>

`\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

```

```

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

```

5.6.8 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}

```

$$(x^0 \ x^1 \ x^2 \ x^3)$$

$$(x_0 \ x_1 \ x_2 \ x_3)$$

`\scompscvect[<any nonzero>]{<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[<any nonzero>]{<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[*<any nonzero>*]{*<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[*<any nonzero>*]{*<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^*}
```

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

\ket{*<ket>*}

Typesets a Dirac ket.

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

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

\bracket{*<bra>*}{*<ket>*}

Typesets a Dirac bracket.

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

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

5.7 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, \twonineths, \\
\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`

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

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

`\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\)
```

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

5.8 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).

$\backslash(\ \mathrm{d}x\{y\}\ \backslash)$
 $\mathrm{d}y$

$\backslash\mathrm{evaluatedfromto}\{\langle lower \rangle\}[\langle upper \rangle]$

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

 $\backslash(\ \mathrm{\frac{1}{3}y^3}\backslash\mathrm{evaluatedfromto}\{0\}[3]\ \backslash)\ \backslash\backslash$
 $\backslash(\ \mathrm{\frac{1}{3}y^3}\backslash\mathrm{evaluatedfromto}\{0\}\ \backslash)$

$$\left. \frac{1}{3}y^3 \right|_0^3$$

$\backslash\mathrm{evaluatedat}\{\langle evaluationpoint \rangle\}$

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

 $\backslash(\ \mathrm{\text{LMST}}\backslash\mathrm{evaluatedat}\{\mathrm{longitude}\{0\}\}\ \backslash)$

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

$\backslash\mathrm{integral}[\langle lower \rangle][\langle upper \rangle]\{\langle integrand \rangle\}\{\langle var \rangle\}$

Typesets indefinite and definite integrals.

 $\backslash[\ \mathrm{integral}\{y^2\}\{y\}\ \backslash]$
 $\backslash[\ \mathrm{integral}\{0\}[3]\{y^2\}\{y\}\ \backslash]$

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

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

$\backslash\mathrm{opensurfaceintegral}\{\langle surfacename \rangle\}\{\langle vectormame \rangle\}$

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

 $\backslash[\ \mathrm{opensurfaceintegral}\{S\}\{\mathrm{vect}\{E\}\}\ \backslash]$

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

$\backslash\mathrm{closedsurfaceintegral}\{\langle surfacename \rangle\}\{\langle vectormame \rangle\}$

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

 $\backslash[\ \mathrm{closedsurfaceintegral}\{S\}\{\mathrm{vect}\{E\}\}\ \backslash]$

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

$\backslash\mathrm{openlineintegral}\{\langle pathname \rangle\}\{\langle vectormame \rangle\}$

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

 $\backslash[\ \mathrm{openlineintegral}\{C\}\{\mathrm{vect}\{E\}\}\ \backslash]$

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

$\backslash\mathrm{closedlineintegral}\{\langle pathname \rangle\}\{\langle vectormame \rangle\}$

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

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

$$\oint_C \vec{E} \bullet \hat{t} d\ell$$

For line integrals, I have not employed the common $d\vec{\ell}$ symbol. Instead, I use $\hat{t} d\ell$ 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{\langle volumename \rangle}{\langle integrand \rangle}`

Integral over a volume.

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

$$\iiint_V \rho dV$$

`\dbydt[\langle operand \rangle]`

First time derivative operator.

`\DbyDt[\langle operand \rangle]`

Identical to `\dbydt` but uses Δ .

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

$$\frac{d}{dt} \text{ or } \frac{d}{dt}x \text{ or } \frac{dx}{dt} \\ \frac{\Delta}{\Delta t} \text{ or } \frac{\Delta}{\Delta t}x \text{ or } \frac{\Delta x}{\Delta t}$$

`\ddbydt[\langle operand \rangle]`

Second time derivative operator.

`\DDbyDt[\langle operand \rangle]`

Identical to `\ddbydt` but uses Δ .

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

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

`\pbypt[\langle operand \rangle]`

First partial time derivative operator.

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

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

`\ppbypt[\langle operand \rangle]`

Second partial time derivative operator.

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

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

`\dbyd{\langle dependentvariable \rangle}{\langle indvar \rangle}`

Generic first derivative operator.

`\DbyD{\langle dependentvariable \rangle}{\langle indvar \rangle}`

Identical to `\dbyd` but uses Δ .

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

$$\frac{df}{dy}$$

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

`\ddbyd{<dependentvariable>}{<indvar>}`

Generic second derivative operator.

`\DDbyD{<dependentvariable>}{<indvar>}`

Identical to `\ddbyd` but uses Δ .

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

$$\frac{d^2 f}{dy^2}$$

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

`\pbyp{<dependentvariable>}{<indvar>}`

Generic first partial derivative operator.

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

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

`\ppbyp{<dependentvariable>}{<indvar>}`

Generic second partial derivative operator.

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

$$\frac{\partial^2 f}{\partial y^2}$$

`\gradient`

Gibbs' gradient operator. It's just an alias for `\nabla`.

`\gradient`

$$\nabla$$

`\divergence`

Gibbs' divergence operator.

`\divergence`

$$\nabla \cdot$$

`\curl`

Gibbs' curl operator.

`\curl`

$$\nabla \times$$

`\taigrad`

Tai's gradient operator. It's just an alias for `\nabla`.

`\taigrad`

$$\nabla$$

`\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`

∇^2

`\dalembertian`

D'Alembertian operator.

`\dalembertian`

\square

`\seriesfofx`

Series expansion of $f(x)$ around $x = a$.

`\seriesfofx`

$$f(x) \approx f(a) + \frac{f'(a)}{1!}(x-a) + \frac{f''(a)}{2!}(x-a)^2 + \frac{f'''(a)}{3!}(x-a)^3 + \dots$$

`\seriesexp`

Series expansion of e^x .

`\seriesexp`

$$e^x \approx 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$$

`\seriesinx`

Series expansion of $\sin x$.

`\seriesinx`

$$\sin x \approx x - \frac{x^3}{3!} + \frac{x^5}{5!} - \dots$$

`\seriescosx`

Series expansion of $\cos x$.

`\seriescosx`

$$\cos x \approx 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \dots$$

`\seriesanx`

Series expansion of $\tan x$.

`\seriesanx`

$$\tan x \approx x + \frac{x^3}{3} + \frac{2x^5}{15} + \dots$$

`\seriesatox`

Series expansion of a^x .

`\seriesatox`

$$a^x \approx 1 + x \ln a + \frac{(x \ln a)^2}{2!} + \frac{(x \ln a)^3}{3!} + \dots$$

`\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}`

$$\delta(x)$$

`\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 `\(\Eulerlagrange[x] \)`

$$\frac{\partial \mathcal{L}}{\partial q_i} - \frac{d}{dt} \left(\frac{\partial \mathcal{L}}{\partial \dot{q}_i} \right) = 0 \text{ or } \frac{\partial \mathcal{L}}{\partial x} - \frac{d}{dt} \left(\frac{\partial \mathcal{L}}{\partial \dot{x}} \right) = 0$$
$$\frac{\Delta \mathcal{L}}{\Delta q_i} - \frac{\Delta}{\Delta t} \left(\frac{\Delta \mathcal{L}}{\Delta \dot{q}_i} \right) = 0 \text{ or } \frac{\Delta \mathcal{L}}{\Delta x} - \frac{\Delta}{\Delta t} \left(\frac{\Delta \mathcal{L}}{\Delta \dot{x}} \right) = 0$$

5.9 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 L^AT_EX.

`\csch`

`\asinh`

`\acosh`

`\atanh`

`\asech`

`\acsch`

`\acoth`

`\(\sech, \csch, \asinh, \acosh, \atanh, \asech, \acsch, \acoth \)`

$\operatorname{sech}, \operatorname{csch}, \sinh^{-1}, \cosh^{-1}, \tanh^{-1}, \operatorname{sech}^{-1}, \operatorname{csch}^{-1}, \operatorname{coth}^{-1}$

`\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}`

$\mathcal{CB}, \vec{\mathcal{CB}}$

`\newpi`

Bob Palais' symbol for 2π .

`\newpi`

π

`\scripty{<kernel>}`

Command to get fonts in Griffiths' electrodynamics textbook.

`\scripty{r}`

\mathcal{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

`\inparens{<arg>}`

Surrounds with argument with parentheses. A blank argument generates a placeholder.

`\inparens{\onehalf}, \inparens{-3}, \inparens{}`

$(\frac{1}{2}), (-3), (_)$

`\absof{<arg>}`

Absolute value function. A blank argument generates a placeholder.

`\absof{-4}, \absof{}`

$|-4|, | _ |$

`\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{}`

$\|\vec{E}\|, \| _ \|$

`\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{}
```

$$[\vec{v}]_u = \text{m/s}, [_]_u$$

`\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}
```

$$2.99 \times 10^8 \text{ m/s}$$
$$2.99 \times 10^{-4}$$

`\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}
```

$$2.99\text{e}8$$
$$2.99\text{E}8$$

`\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}
```

$$23^\circ 34' 10.27''$$
$$23^{\text{h}} 34^{\text{m}} 10.27^{\text{s}}$$

`\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}
```

$$23^{\text{h}} 34^{\text{m}} 10.27^{\text{s}}$$

`\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.

<code>\latitude{+35}, \latitudeN{35}, \latitudeS{35}</code>	$+35^\circ, 35^\circ \text{ N}, 35^\circ \text{ S}$
---	---

`\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.

<code>\longitude{-81}, \longitudeE{81}, \longitudeW{81}</code>	$-81^\circ, 81^\circ \text{ E}, 81^\circ \text{ W}$
--	---

`\ssup{<kernel>}{<sup>}`

Command for typesetting text superscripts.

<code>\ssup{N}{contact}</code>	N^{contact}
--------------------------------	----------------------

`\ssub{<kernel>}{<sub>}`

Command for typesetting text subscripts.

<code>\ssub{N}{AB}</code>	N_{AB}
---------------------------	-----------------

`\ssud{<sup>}{<sub>}`

Command for typesetting text superscripts and subscripts.

<code>\ssud{N}{contact}{AB}</code>	$N^{\text{contact}}_{\text{AB}}$
------------------------------------	----------------------------------

`\msub{<kernel>}{<sub>}`

Command for typesetting mathematical subscripts.

<code>\msub{R}{\alpha\beta}</code>	$R_{\alpha\beta}$
------------------------------------	-------------------

`\msud{<kernel>}{<sup>}{<sub>}`

Command for typesetting mathematical superscripts and subscripts.

<code>\msud{\Gamma}{\gamma}{\alpha\beta}</code>	$\Gamma_{\alpha\beta}^\gamma$
---	-------------------------------

`\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 of **o**ne **m**inus **x** squared. Say that out loud and you will see where the name comes from.

`\oosqrtomx{<arg>}`

Commands for **one over square root of one minus x**. Say that out loud and you will see where the name comes from.

`\oomx{<arg>}`

Commands for **one over square root of one minus x**. Say that out loud and you will see where the name comes from.

`\oopx{<arg>}`

Commands for **one over square root of one plus x**. Say that out loud and you will see where the name comes from.

```
\oosqrtomxs{0.22} \\  
\oosqrtomx{0.22}  \\  
\oomx{0.22}       \\  
\oopx{0.11}
```

$$\frac{1}{\sqrt{1-0.22^2}}$$
$$\frac{1}{\sqrt{1-0.22}}$$
$$\frac{1}{1-0.22}$$
$$\frac{1}{1+0.11}$$

5.10 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}
```

$$\begin{array}{c} \text{added} \\ \text{to} \\ \text{(added)} \\ \text{to} \end{array}$$

`\definedas`

Operator representing a definition.

`\pdefinedas`

Same as `\definedas` but puts parentheses around the operator.

`\earliertan`

Operator useful for comparing times and clock readings.

`\pearliertan`

Same as `\earliertan` 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 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.

<code>\definedas</code>	<code>\\</code>	defined
<code>\pdefinedas</code>	<code>\\</code>	as
<code>\earliertan</code>	<code>\\</code>	(defined)
<code>\pearliertan</code>	<code>\\</code>	as
<code>\laterthan</code>	<code>\\</code>	earlier
<code>\platerthan</code>	<code>\\</code>	than
<code>\adjustedby</code>	<code>\\</code>	(earlier)
<code>\padjustedby</code>	<code>\\</code>	(than)
<code>\forevery</code>	<code>\\</code>	later
<code>\pforevery</code>	<code>\\</code>	than
<code>\associated</code>	<code>\\</code>	(later)
<code>\passociated</code>	<code>\\</code>	(than/adjusted)

`\defines`

Command for *defines* or *defined by* operator.

<code>\vect{p} \defines \(\gamma m\)\vect{v}</code>	$\vec{p} \stackrel{\text{def}}{=} \gamma m \vec{v}$
---	---

`\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}}
```

$$\vec{p} \xrightarrow{S} \langle 1, 2, 3 \rangle \text{ kg} \cdot \text{m/s}$$

$$\vec{p} \xrightarrow{S'} \langle \sqrt{14}, 0, 0 \rangle \text{ kg} \cdot \text{m/s}$$

\associates

Command for *associated with* or *associates with* operator (for verbal concepts). This is conceptually different from the `\associated`^{P.81} or `\passociated`^{P.81} operators.

```
kinetic energy \associates velocity
```

```
kinetic energy \assoc velocity
```

\becomes

Command for *becomes* operator.

```
\(\gamma m\)\vect{v} \becomes \(\gamma m\)\vect{v}
```

```
\(\gamma m\)\vect{v} \becomes \(\gamma m\)\vect{v}
```

\rrelatedto{<leftoperation>}

Command for left-to-right relationship.

```
(flux ratio) \rrelatedto{taking logarithm} (mag diff)
```

```
(flux ratio) \rrelatedto{taking logarithm} (mag diff)
```

\lrelatedto{<roperation>}

Command for right-to-left relationship.

```
(flux ratio) \lrelatedto{exponentiation} (mag diff)
```

```
(flux ratio) \lrelatedto{exponentiation} (mag diff)
```

\brelatedto{<leftoperation>}{<roperation>}

Command for bidirectional relationship.

```
(mag diff) \brelatedto{taking logarithm}{exponentiation}(flux ratio)
```

```
(mag diff) \brelatedto{taking logarithm}{exponentiation}(flux ratio)
```

5.11 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
```

$$\begin{aligned}\vec{p}_{\text{sys,final}} &= \vec{p}_{\text{sys,initial}} + \vec{F}_{\text{net,sys}}\Delta t \\ \vec{p}_{\text{sys,final}} \\ \vec{p}_{\text{sys,initial}} + \vec{F}_{\text{net,sys}}\Delta t\end{aligned}$$

`\momentumprinciplediff`

Expression for the momentum principle in differential form.

```
\momentumprinciplediff
```

$$\Delta \vec{p}_{\text{sys}} = \vec{F}_{\text{net,sys}}\Delta t$$

`\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
```

$$\begin{aligned}E_{\text{sys,final}} &= E_{\text{sys,initial}} + W + Q \\ E_{\text{sys,final}} \\ E_{\text{sys,initial}} + W + Q\end{aligned}$$

`\energyprinciplediff`

Expression for the energy principle in differential form.

```
\energyprinciplediff
```

$$\Delta E_{\text{sys}} = W + Q$$

`\angularmomentumprinciple`

Expression for the angular momentum principle.

`\LHSangularmomentumprinciple`

Just the left hand side.

`\RHSangularmomentumprinciple`

Just the right hand side.

```
\angularmomentumprinciple  \\  
\LHSangularmomentumprinciple \\  
\RHSangularmomentumprinciple
```

$$\begin{aligned}\vec{L}_{A,\text{sys,final}} &= \vec{L}_{A,\text{sys,initial}} + \vec{\tau}_{A,\text{net}}\Delta t \\ \vec{L}_{A,\text{sys,final}} \\ \vec{L}_{A,\text{sys,initial}} + \vec{\tau}_{A,\text{net}}\Delta t\end{aligned}$$

`\angularmomentumprinciplediff`

Expression for the angular momentum principle in differential form.

`\angularmomentumprinciplediff`

$$\Delta \vec{L}_{A,\text{sys}} = \vec{\tau}_{A,\text{net}} \Delta t$$

`\gravitationalinteraction`

Expression for gravitational interaction.

`\gravitationalinteraction`

$$G \frac{M_1 M_2}{\|\vec{r}_{12}\|^2} (-\hat{r}_{12})$$

`\electricinteraction`

Expression for electric interaction.

`\electricinteraction`

$$\frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{\|\vec{r}_{12}\|^2} \hat{r}_{12}$$

`\springinteraction`

Expression for spring interaction.

`\springinteraction`

$$k_s \|\vec{s}\| (-\hat{s})$$

`\gfieldofparticle`

Expression for a particle's gravitational field.

`\gfieldofparticle`

$$G \frac{M}{\|\vec{r}\|^2} (-\hat{r})$$

`\Efieldofparticle`

Expression for a particle's electric field.

`\Efieldofparticle`

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

`\Bfieldofparticle`

Expression for a particle's magnetic field.

`\Bfieldofparticle`

$$-\frac{\mu_0}{4\pi} \frac{Q \|\vec{v}\|}{\|\vec{r}\|^2} \hat{v} \times \hat{r}$$

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]`

$$E_{\text{sys}}, E_{\text{sys,final}}, E_{\text{sys,initial}}$$

`\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]`

$K_{\text{trans}}, K_{\text{trans},\text{final}}, K_{\text{trans},\text{initial}}$

`\Krot[⟨label⟩]`

Symbol for rotational kinetic energy.

`\Krot, \Krot[final], \Krot[initial]`

$K_{\text{rot}}, K_{\text{rot},\text{final}}, K_{\text{rot},\text{initial}}$

`\Kvib[⟨label⟩]`

Symbol for vibrational kinetic energy.

`\Kvib, \Evib[final], \Evib[initial]`

$K_{\text{vib}}, E_{\text{vib},\text{final}}, E_{\text{vib},\text{initial}}$

`\Eparticle[⟨label⟩]`

Symbol for particle energy.

`\Eparticle, \Eparticle[final], \Eparticle[initial]`

$E_{\text{particle}}, E_{\text{particle},\text{final}}, E_{\text{particle},\text{initial}}$

`\Einternal[⟨label⟩]`

Symbol for internal energy.

`\Einternal, \Einternal[final], \Einternal[initial]`

$E_{\text{internal}}, E_{\text{internal},\text{final}}, E_{\text{internal},\text{initial}}$

`\Erest[⟨label⟩]`

Symbol for rest energy.

`\Erest, \Erest[final], \Erest[initial]`

$E_{\text{rest}}, E_{\text{rest},\text{final}}, E_{\text{rest},\text{initial}}$

`\Echem[⟨label⟩]`

Symbol for chemical energy.

`\Echem, \Echem[final], \Echem[initial]`

$E_{\text{chem}}, E_{\text{chem,final}}, E_{\text{chem,initial}}$

`\Etherm[⟨label⟩]`

Symbol for thermal energy.

`\Etherm, \Etherm[final], \Etherm[initial]`

$E_{\text{therm}}, E_{\text{therm,final}}, E_{\text{therm,initial}}$

`\Evib[⟨label⟩]`

Symbol for vibrational energy.

`\Evib, \Evib[final], \Evib[initial]`

$E_{\text{vib}}, E_{\text{vib,final}}, E_{\text{vib,initial}}$

`\Ephoton[⟨label⟩]`

Symbol for photon energy.

`\Ephoton, \Ephoton[final], \Ephoton[initial]`

$E_{\text{photon}}, E_{\text{photon,final}}, E_{\text{photon,initial}}$

`\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`

$$\frac{1}{2} k_s \|\vec{s}\|^2$$

`\finalspringpotentialenergy`

Expression for final spring potential energy.

`\finalspringpotentialenergy`

$$\left(\frac{1}{2} k_s \|\vec{s}\|^2 \right)_{\text{final}}$$

`\initialspringpotentialenergy`

Expression for initial spring potential energy.

`\initialspringpotentialenergy`

$$\left(\frac{1}{2} k_s \|\vec{s}\|^2 \right)_{\text{initial}}$$

`\electricpotentialenergy`

Expression for electric potential energy.

`\electricpotentialenergy`

$$\frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{\|\vec{r}_{12}\|}$$

`\finalelectricpotentialenergy`

Expression for final electric potential energy.

`\finalelectricpotentialenergy`

$$\left(\frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{\|\vec{r}_{12}\|} \right)_{\text{final}}$$

`\initialelectricpotentialenergy`

Expression for initial electric potential energy.

`\initialelectricpotentialenergy`

$$\left(\frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{\|\vec{r}_{12}\|} \right)_{\text{initial}}$$

`\gravitationalpotentialenergy`

Expression for gravitational potential energy.

`\gravitationalpotentialenergy`

$$-G \frac{M_1 M_2}{\|\vec{r}_{12}\|}$$

`\finalgravitationalpotentialenergy`

Expression for final gravitational potential energy.

`\finalgravitationalpotentialenergy`

$$\left(-G \frac{M_1 M_2}{\|\vec{r}_{12}\|} \right)_{\text{final}}$$

`\initialgravitationalpotentialenergy`

Expression for initial gravitational potential energy.

`\initialgravitationalpotentialenergy`

$$\left(-G \frac{M_1 M_2}{\|\vec{r}_{12}\|} \right)_{\text{initial}}$$

\ks

Symbol for spring stiffness.

`\ks`

k_s

\Fnet

Various symbols for net force.

`\Fnet`, `\Fnetext`, `\Fnetsys`, `\Fsub{ball,bat}`

\vec{F}_{net} , $\vec{F}_{\text{net,ext}}$, $\vec{F}_{\text{net,sys}}$, $\vec{F}_{\text{ball,bat}}$

\Tnet

Various symbols for net torque.

`\Tnet`, `\Tnetext`, `\Tnetsys`, `\Tsub{ball}`

$\vec{\tau}_{A,\text{net}}$, $\vec{\tau}_{A,\text{net,ext}}$, $\vec{\tau}_{A,\text{net,sys}}$, $\vec{\tau}_{A,\text{ball}}$

\Ltotal

Various symbols for total angular momentum.

`\Ltotal`, `\Lsys`, `\Lsub{ball}`

$\vec{L}_{A,\text{total}}$, $\vec{L}_{A,\text{sys}}$, $\vec{L}_{A,\text{ball}}$

\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*}`

$\oiint_{\partial V} \vec{E} \cdot \hat{n} \, dA$
 $\oiint_S \vec{E} \cdot \hat{n} \, dA$

\RHSmaxwelliint

Right hand side of Maxwell's first equation in integral form.

`\[\RHSmaxwelliint \]`

$\frac{Q_{e,\text{net}}}{\epsilon_0}$

\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*}`

$\frac{1}{\epsilon_0} \iiint_V \rho_e \, dV$
 $\frac{1}{\epsilon_0} \iiint_v \rho_e \, dV$

\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*}`

$$\oiint_{\partial V} \vec{E} \cdot \hat{n} dA = \frac{Q_{e,\text{net}}}{\epsilon_0}$$

$$\oiint_S \vec{E} \cdot \hat{n} dA = \frac{Q_{e,\text{net}}}{\epsilon_0}$$

`\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*}`

$$\oiint_{\partial V} \vec{E} \cdot \hat{n} dA = \frac{1}{\epsilon_0} \iiint_V \rho_e dV$$

$$\oiint_S \vec{E} \cdot \hat{n} dA = \frac{1}{\epsilon_0} \iiint_v \rho_e dV$$

`\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*}`

$$\oiint_{\partial V} \vec{E} \cdot \hat{n} dA = 0$$

$$\oiint_S \vec{E} \cdot \hat{n} dA = 0$$

`\LHSmaxwelliint[⟨surfacename⟩]`

Left hand side of Maxwell's second equation in integral form. Note the default value of the optional argument.

`\begin{mysolution*}`
`&\LHSmaxwelliint \\\`
`&\LHSmaxwelliint[S]`
`\end{mysolution*}`

$$\oiint_{\partial V} \vec{B} \cdot \hat{n} dA$$

$$\oiint_S \vec{B} \cdot \hat{n} dA$$

`\RHSmaxwelliint`

Right hand side of Maxwell's second equation in integral form.

`\[\RHSmaxwelliint \]`

0

`\RHSmaxwelliintm`

Right hand side of Maxwell's second equation in integral form with magnetic monopoles.

`\[\RHSmaxwelliintm \]`

$\mu_0 Q_{m,\text{net}}$

`\RHSmaxwelliintma[⟨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*}
  &\RHSmaxwelliintma      \\
  &\RHSmaxwelliintma[\upsilon]
\end{mysolution*}
```

$$\mu_0 \iiint_V \rho_m \, dV$$
$$\mu_0 \iiint_v \rho_m \, dV$$

`\RHSmaxwelliintfree`

Right hand side of Maxwell's second equation in integral form in free space.

```
\[ \RHSmaxwelliintfree \]
```

$$0$$

`\maxwelliint[⟨surfacename⟩]`

Maxwell's second equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\maxwelliint      \\
  &\maxwelliint[S]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{B} \bullet \hat{n} \, dA = 0$$
$$\oiint_S \vec{B} \bullet \hat{n} \, dA = 0$$

`\maxwelliintm[⟨surfacename⟩]`

Maxwell's second equation in integral form with magnetic monopoles. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\maxwelliintm      \\
  &\maxwelliintm[S]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{B} \bullet \hat{n} \, dA = \mu_0 Q_{m,\text{net}}$$
$$\oiint_S \vec{B} \bullet \hat{n} \, dA = \mu_0 Q_{m,\text{net}}$$

`\maxwelliintma[⟨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*}
  &\maxwelliintma      \\
  &\maxwelliintma[S][\upsilon]
\end{mysolution*}
```

$$\oiint_{\partial V} \vec{B} \bullet \hat{n} \, dA = \mu_0 \iiint_V \rho_m \, dV$$
$$\oiint_S \vec{B} \bullet \hat{n} \, dA = \mu_0 \iiint_v \rho_m \, dV$$

`\maxwelliintfree[⟨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*}
```

$$\oiint_{\partial V} \vec{B} \bullet \hat{n} dA = 0$$

$$\oiint_S \vec{B} \bullet \hat{n} dA = 0$$

`\LHSmaxwelliiint[<boundaryname>]`

Left hand side of Maxwell's third equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\LHSmaxwelliiint \\
  &\LHSmaxwelliiint[C]
\end{mysolution*}
```

$$\oint_{\partial \Omega} \vec{E} \bullet \hat{t} d\ell$$

$$\oint_C \vec{E} \bullet \hat{t} d\ell$$

`\RHSmaxwelliiint[<surfacename>]`

Right hand side of Maxwell's third equation in integral form. Note the default value of the optional argument.

```
\begin{mysolution*}
  &\RHSmaxwelliiint \\
  &\RHSmaxwelliiint[S]
\end{mysolution*}
```

$$-\frac{d}{dt} \iint_{\Omega} \vec{B} \bullet \hat{n} dA$$

$$-\frac{d}{dt} \iint_S \vec{B} \bullet \hat{n} dA$$

`\RHSmaxwelliiintm[<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*}
  &\RHSmaxwelliiintm \\
  &\RHSmaxwelliiintm[S]
\end{mysolution*}
```

$$-\frac{d}{dt} \iint_{\Omega} \vec{B} \bullet \hat{n} dA - \mu_0 I_{m,\text{net}}$$

$$-\frac{d}{dt} \iint_S \vec{B} \bullet \hat{n} dA - \mu_0 I_{m,\text{net}}$$

`\RHSmaxwelliiintma[<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*}
  &\RHSmaxwelliiintma \\
  &\RHSmaxwelliiintma[S]
\end{mysolution*}
```

$$-\frac{d}{dt} \iint_{\Omega} \vec{B} \bullet \hat{n} dA - \mu_0 \iint_{\Omega} \vec{J}_m \bullet \hat{n} dA$$

$$-\frac{d}{dt} \iint_S \vec{B} \bullet \hat{n} dA - \mu_0 \iint_S \vec{J}_m \bullet \hat{n} dA$$

`\RHSmaxwelliiintfree[<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*}
  &\RHSmaxwelliiintfree \\
  &\RHSmaxwelliiintfree[S]
\end{mysolution*}
```

$$-\frac{d}{dt} \iint_{\Omega} \vec{B} \bullet \hat{n} dA$$

$$-\frac{d}{dt} \iint_S \vec{B} \bullet \hat{n} dA$$

`\maxwelliiint[⟨boundaryname⟩][⟨surfacename⟩]`

Maxwell's third equation in integral form. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwelliiint \\
  &\maxwelliiint[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{E} \bullet \hat{t} d\ell = -\frac{d}{dt} \iint_{\Omega} \vec{B} \bullet \hat{n} dA$$

$$\oint_C \vec{E} \bullet \hat{t} d\ell = -\frac{d}{dt} \iint_S \vec{B} \bullet \hat{n} dA$$

`\maxwelliiintm[⟨boundaryname⟩][⟨surfacename⟩]`

Maxwell's third equation in integral form with magnetic monopoles. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwelliiintm \\
  &\maxwelliiintm[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{E} \bullet \hat{t} d\ell = -\frac{d}{dt} \iint_{\Omega} \vec{B} \bullet \hat{n} dA - \mu_0 I_{m,net}$$

$$\oint_C \vec{E} \bullet \hat{t} d\ell = -\frac{d}{dt} \iint_S \vec{B} \bullet \hat{n} dA - \mu_0 I_{m,net}$$

`\maxwelliiintma[⟨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*}
  &\maxwelliiintma \\
  &\maxwelliiintma[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{E} \bullet \hat{t} d\ell = -\frac{d}{dt} \iint_{\Omega} \vec{B} \bullet \hat{n} dA - \mu_0 \iint_{\Omega} \vec{J}_m \bullet \hat{n} dA$$

$$\oint_C \vec{E} \bullet \hat{t} d\ell = -\frac{d}{dt} \iint_S \vec{B} \bullet \hat{n} dA - \mu_0 \iint_S \vec{J}_m \bullet \hat{n} dA$$

`\maxwelliiintfree[⟨boundaryname⟩][⟨surfacename⟩]`

Maxwell's third equation in integral form in free space. Note the default values of the optional arguments.

```
\begin{mysolution*}
  &\maxwelliiintfree \\
  &\maxwelliiintfree[C][S]
\end{mysolution*}
```

$$\oint_{\partial\Omega} \vec{E} \bullet \hat{t} d\ell = -\frac{d}{dt} \iint_{\Omega} \vec{B} \bullet \hat{n} dA$$

$$\oint_C \vec{E} \bullet \hat{t} d\ell = -\frac{d}{dt} \iint_S \vec{B} \bullet \hat{n} dA$$

`\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*}
```

$$\oint_{\partial\Omega} \vec{B} \bullet \hat{t} d\ell$$

$$\oint_C \vec{B} \bullet \hat{t} d\ell$$

\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*}
```

$$\mu_0\epsilon_0 \frac{d}{dt} \iint_{\Omega} \vec{E} \bullet \hat{n} dA + \mu_0 I_{e,\text{net}}$$

$$\mu_0\epsilon_0 \frac{d}{dt} \iint_S \vec{E} \bullet \hat{n} dA + \mu_0 I_{e,\text{net}}$$

\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*}
```

$$\mu_0\epsilon_0 \frac{d}{dt} \iint_{\Omega} \vec{E} \bullet \hat{n} dA + \mu_0 \iint_{\Omega} \vec{J}_e \bullet \hat{n} dA$$

$$\mu_0\epsilon_0 \frac{d}{dt} \iint_S \vec{E} \bullet \hat{n} dA + \mu_0 \iint_S \vec{J}_e \bullet \hat{n} dA$$

\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*}
```

$$\mu_0\epsilon_0 \frac{d}{dt} \iint_{\Omega} \vec{E} \bullet \hat{n} dA$$

$$\mu_0\epsilon_0 \frac{d}{dt} \iint_S \vec{E} \bullet \hat{n} dA$$

\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*}
```

$$\oint_{\partial\Omega} \vec{B} \bullet \hat{t} d\ell = \mu_0\epsilon_0 \frac{d}{dt} \iint_{\Omega} \vec{E} \bullet \hat{n} dA + \mu_0 I_{e,\text{net}}$$

$$\oint_C \vec{B} \bullet \hat{t} d\ell = \mu_0\epsilon_0 \frac{d}{dt} \iint_S \vec{E} \bullet \hat{n} dA + \mu_0 I_{e,\text{net}}$$

\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*}
```

$$\oint_{\partial\Omega} \vec{B} \cdot \hat{t} d\ell = \mu_0 \epsilon_0 \frac{d}{dt} \iint_{\Omega} \vec{E} \cdot \hat{n} dA + \mu_0 \iint_{\Omega} \vec{J}_e \cdot \hat{n} dA$$

$$\oint_C \vec{B} \cdot \hat{t} d\ell = \mu_0 \epsilon_0 \frac{d}{dt} \iint_S \vec{E} \cdot \hat{n} dA + \mu_0 \iint_S \vec{J}_e \cdot \hat{n} dA$$

\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*}
```

$$\oint_{\partial\Omega} \vec{B} \cdot \hat{t} d\ell = \mu_0 \epsilon_0 \frac{d}{dt} \iint_{\Omega} \vec{E} \cdot \hat{n} dA$$

$$\oint_C \vec{B} \cdot \hat{t} d\ell = \mu_0 \epsilon_0 \frac{d}{dt} \iint_S \vec{E} \cdot \hat{n} dA$$

\LHSmaxwellidif

Left hand side of Maxwell's first equation in differential form.

```
\[ \LHSmaxwellidif \]
```

$$\nabla \cdot \vec{E}$$

\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.

```
\[ \maxwellidif \]
```

$$\nabla \cdot \vec{E} = \frac{\rho_e}{\epsilon_0}$$

\maxwellidiffree

Maxwell's first equation in differential form in free space.

```
\[ \maxwellidiffree \]
```

$$\nabla \cdot \vec{E} = 0$$

\LHSmaxwelliidif

Left hand side of Maxwell's second equation in differential form.

```
\[ \LHSmaxwelliidif \]
```

$$\nabla \cdot \vec{B}$$

`\RHSmaxwelliif`

Right hand side of Maxwell's second equation in differential form.

`\[\RHSmaxwelliif \]`

$$0$$

`\RHSmaxwelliifm`

Right hand side of Maxwell's second equation in differential form with magnetic monopoles.

`\[\RHSmaxwelliifm \]`

$$\mu_0 \rho_m$$

`\RHSmaxwelliiffree`

Right hand side of Maxwell's second equation in differential form in free space.

`\[\RHSmaxwelliiffree \]`

$$0$$

`\maxwelliif`

Maxwell's second equation in differential form.

`\[\maxwelliif \]`

$$\nabla \bullet \vec{B} = 0$$

`\maxwelliifm`

Maxwell's second equation in differential form with magnetic monopoles.

`\[\maxwelliifm \]`

$$\nabla \bullet \vec{B} = \mu_0 \rho_m$$

`\maxwelliiffree`

Maxwell's second equation in differential form in free space.

`\[\maxwelliiffree \]`

$$\nabla \bullet \vec{B} = 0$$

`\LHSmaxwelliif`

Left hand side of Maxwell's third equation in differential form.

`\[\LHSmaxwelliif \]`

$$\nabla \times \vec{E}$$

`\RHSmaxwelliif`

Right hand side of Maxwell's third equation in differential form.

`\[\RHSmaxwelliif \]`

$$-\frac{\partial \vec{B}}{\partial t}$$

`\RHSmaxwelliifm`

Right hand side of Maxwell's third equation in differential form with magnetic monopoles.

`\[\RHSmaxwelliifm \]`

$$-\frac{\partial \vec{B}}{\partial t} - \mu_0 \vec{J}_m$$

`\RHSmaxwelliiddiffree`

Right hand side of Maxwell's third equation in differential form in free space.

`\[\RHSmaxwelliiddiffree \]`

$$-\frac{\partial \vec{B}}{\partial t}$$

`\maxwelliiddif`

Maxwell's third equation in differential form.

`\[\maxwelliiddif \]`

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

`\maxwelliiddifm`

Maxwell's third equation in differential form with magnetic monopoles.

`\[\maxwelliiddifm \]`

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} - \mu_0 \vec{J}_m$$

`\maxwelliiddiffree`

Maxwell's third equation in differential form in free space.

`\[\maxwelliiddiffree \]`

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

`\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.

`\[\RHSlorentzforcem \]`

$$q_e \left(\vec{E} + \vec{v} \times \vec{B} \right) + q_m \left(\vec{B} - \vec{v} \times \frac{\vec{E}}{c^2} \right)$$

5.12 VPython and GlowScript Code

There are three ways to deal with VPython² and GlowScript³ 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 `glowsript` in their names.

`\vpythonline{<vpythoncode>}`

Command for a single line of VPython or GlowScript code used inline.

`\vpythonline{from __future__ import division, print_function}`

`from __future__ import division, print_function`

`\glowsriptline{<glowsriptcode>}`

Command for a single line of GlowScript code used inline. Note that with very few exceptions, GlowScript code is identical to VPython code.

`\glowsriptline{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.

²See the VPython home page at <http://vpython.org/> for more information.

³See the GlowScript home page at <http://glowsript.org/> for more information.

```
\begin{vpythonblock}[Example VPython Listing]
  from __future__ import division, print_function
  from visual 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}
```

```
1  from __future__ import division, print_function
2  from visual import *
3  sphere(pos=vector(1,2,3), color=color.green)
4  # create a named arrow
5  MyArrow=arrow(pos=earth.pos, axis=fscale*Fnet, color=color.green)
6  print ("arrow.pos = "), arrow.pos
```

Listing 1: Example VPython Listing

```
\begin{glowscripblock}[<caption>]
  <environment content>
\end{glowscripblock}
```

Environment for a block of GlowScript code.

```
\begin{glowscripblock}[Example GlowScript Listing]
GlowScript 2.1 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{glowscripblock}
```

```
1  GlowScript 2.1 VPython
2
3  Aarr = arrow(pos=vector(0,0,0), axis=A, color=color.red)
4  label(pos=Aarr.axis, text='A')
5  Barr = arrow(pos=vector(0,0,0), axis=B, color=color.blue)
6  label(pos=Barr.axis, text='B')
7  Carr = arrow(pos=vector(0,0,0), axis=C, color=color.green)
8  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.

```
\glowscripfile[<caption>](filename)
```

Functionally identical to `\vpythonfile`.

\vpythonfile[vdemo.py]{vdemo.py}

```

1 from __future__ import division , print_function
2 from visual import *
3
4 G = 6.7e-11
5
6 # create objects
7 giant = sphere(pos=vector(-1e11,0,0),radius=2e10,mass=2e30,color=color.red)
8 giant.p = vector(0,0,-1e4) * giant.mass
9 dwarf = sphere(pos=vector(1.5e11,0,0),radius=1e10,mass=1e30,color=color.yellow)
10 dwarf.p = -giant.p
11
12 for a in [giant,dwarf]:
13     a.orbit = curve(color=a.color,radius=2e9)
14
15 dt = 86400
16 while 1:
17     rate(100)
18     dist = dwarf.pos - giant.pos
19     force = G * giant.mass * dwarf.mass * dist / mag(dist)**3
20     giant.p = giant.p + force*dt
21     dwarf.p = dwarf.p - force*dt
22     for a in [giant,dwarf]:
23         a.pos = a.pos + a.p/a.mass * dt
24         a.orbit.append(pos=a.pos)

```

Listing 3: vdemo.py

5.13 Boxes and Environments

`\emptyanswer[⟨width⟩][⟨hght⟩]`

Typesets empty space for filling answer boxes, so there is nothing to see.

\emptyanswer[0.75][0.2]

`\begin{activityanswer}[⟨bgclr⟩][⟨frmclr⟩][⟨txtclr⟩][⟨width⟩][⟨hght⟩]`
`⟨environment content⟩`
`\end{activityanswer}`

Main environment for typesetting boxed answers.

```
\begin{activityanswer}
  Lorem ipsum dolor sit amet, consectetur 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, consectetur adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

```
\begin{adjactivityanswer}[\langle bgclr \rangle][\langle frmclr \rangle][\langle txtclr \rangle][\langle width \rangle][\langle hght \rangle]
  \langle environment content \rangle
\end{adjactivityanswer}
```

Like `activityanswer`^{P.100} but adjusts vertically to tightly surround text.

```
\begin{adjactivityanswer}
  Lorem ipsum dolor sit amet, consectetur 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 consectetur. 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, consectetur 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 consectetur. 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[\langle txt \rangle][\langle bgclr \rangle][\langle frmclr \rangle][\langle txtclr \rangle][\langle width \rangle][\langle hght \rangle]
```

Provides a fixed-size box with optional text.

```
\emptybox[Lorem ipsum dolor sit amet, consectetur 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, consectetur 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. 101} but adjusts vertically to tightly surround text.

```
\adjemptybox[Lorem ipsum dolor sit amet, consectetur 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, consectetur 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. 101}.

```
\answerbox[Lorem ipsum dolor sit amet, consectetur 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, consectetur 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, consectetur 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, consectetur 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.]
```

`\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.]`

`\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, consectetur et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetur 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, consectetur et, lacinia sit amet, quam. Suspendisse wisi quam, consectetur 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, consectetur et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetur 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, consectetur et, lacinia sit amet, quam. Suspendisse wisi quam, consectetur 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.110} for how to handle long lines in this environment.

```

\begin{miderivation*}
  <environment content>
\end{miderivation*}

```

Like `miderivation` but suppresses line numbers.

```

\begin{miderivation}
\gamma &= \relgamma{\magvect{v}} && \text{given} && \\
\gamma^2 &= \ooomx{\inparens{\frac{\magvect{v}}{c}}\squared} && && \\
&&\text{square both sides} && \\
\frac{1}{\gamma^2} &= 1 - \inparens{\frac{\magvect{v}}{c}}\squared && && \\
&&\text{reciprocal of both sides} && \\
\inparens{\frac{\magvect{v}}{c}}\squared &= 1 - \frac{1}{\gamma^2} && && \\
&&\text{rearrange} && \\
\frac{\magvect{v}}{c} &= \sqrt{1 - \frac{1}{\gamma^2}} && && \\
&&\text{square root of both sides} && \\
\end{miderivation}

```

DERIVATION

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{\|\vec{v}\|}{c}\right)^2}} \quad \text{given} \quad (1)$$

$$\gamma^2 = \frac{1}{1 - \left(\frac{\|\vec{v}\|}{c}\right)^2} \quad \text{square both sides} \quad (2)$$

$$\frac{1}{\gamma^2} = 1 - \left(\frac{\|\vec{v}\|}{c}\right)^2 \quad \text{reciprocal of both sides} \quad (3)$$

$$\left(\frac{\|\vec{v}\|}{c}\right)^2 = 1 - \frac{1}{\gamma^2} \quad \text{rearrange} \quad (4)$$

$$\frac{\|\vec{v}\|}{c} = \sqrt{1 - \frac{1}{\gamma^2}} \quad \text{square root of both sides} \quad (5)$$

```

\begin{bwinstructornote}
<environment content>
\end{bwinstructornote}

```

Like `miinstructornote` ^{→ P. 106} 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, consectetur et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetur 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, consectetur et, lacinia sit amet, quam. Suspendisse wisi quam, consectetur 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. 106} 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, consectetur et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetur 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, consectetur et, lacinia sit amet, quam. Suspendisse wisi quam, consectetur 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.107} but in black and grey. See `mysolution` ^{→P.110} 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^2 &= \ooomx{\inparens{\frac{\magvect{v}}{c}}\squared} && && \\
  &&\text{square both sides} && \\
  \frac{1}{\gamma^2} &= 1 - \inparens{\frac{\magvect{v}}{c}}\squared && && \\
  &&\text{reciprocal of both sides} && \\
  \inparens{\frac{\magvect{v}}{c}}\squared &= 1 - \frac{1}{\gamma^2} && && \\
  &&\text{rearrange} && \\
  \frac{\magvect{v}}{c} &= \sqrt{1 - \frac{1}{\gamma^2}} && && \\
  &&\text{square root of both sides} && \\
\end{bwderivation}
```

DERIVATION

$\gamma = \frac{1}{\sqrt{1 - \left(\frac{\ \vec{v}\ }{c}\right)^2}}$	given	(1)
$\gamma^2 = \frac{1}{1 - \left(\frac{\ \vec{v}\ }{c}\right)^2}$	square both sides	(2)
$\frac{1}{\gamma^2} = 1 - \left(\frac{\ \vec{v}\ }{c}\right)^2$	reciprocal of both sides	(3)
$\left(\frac{\ \vec{v}\ }{c}\right)^2 = 1 - \frac{1}{\gamma^2}$	rearrange	(4)
$\frac{\ \vec{v}\ }{c} = \sqrt{1 - \frac{1}{\gamma^2}}$	square root of both sides	(5)

```
\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.

```

\begin{mysolution}
\gamma &= \relgamma{\magvect{v}}
&& \text{given} \\
\gamma^2 &= \ooomx{\inparen{\frac{\magvect{v}}{c}}^2}
&& \text{square both sides} \\
\frac{1}{\gamma^2} &= 1 - \inparen{\frac{\magvect{v}}{c}}^2
&& \text{reciprocal of both sides} \\
\inparen{\frac{\magvect{v}}{c}}^2 &= 1 - \frac{1}{\gamma^2}
&& \text{rearrange} \\
\frac{\magvect{v}}{c} &= \sqrt{1 - \frac{1}{\gamma^2}}
&& \text{square root of both sides}
\end{mysolution}
\begin{mysolution*}
\vec{E} &= \electricfield{\mivector{1,2,3}} + \electricfield{\mivector{2,4,6}}
&& \text{superposition} \\
&& \text{nonnumber} \\
\vec{E} &= \electricfield{\mivector{2,3,4}} + \electricfield{\mivector{2,4,6}}
&& \text{superposition again} \\
&& \text{nonnumber} \\
&+ \electricfield{\mivector{1,1,1}} + \electricfield{\mivector{3,5,6}}
&& \text{more superposition} \\
&& \text{nonnumber}
\end{mysolution*}

```

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{\|\vec{v}\|}{c}\right)^2}} \quad \text{given} \quad (1)$$

$$\gamma^2 = \frac{1}{1 - \left(\frac{\|\vec{v}\|}{c}\right)^2} \quad \text{square both sides} \quad (2)$$

$$\frac{1}{\gamma^2} = 1 - \left(\frac{\|\vec{v}\|}{c}\right)^2 \quad \text{reciprocal of both sides} \quad (3)$$

$$\left(\frac{\|\vec{v}\|}{c}\right)^2 = 1 - \frac{1}{\gamma^2} \quad \text{rearrange} \quad (4)$$

$$\frac{\|\vec{v}\|}{c} = \sqrt{1 - \frac{1}{\gamma^2}} \quad \text{square root of both sides} \quad (5)$$

$$\begin{aligned} \vec{E} &= \langle 1, 2, 3 \rangle \text{ N/C} + \langle 2, 4, 6 \rangle \text{ N/C} \\ &\quad + \langle 3, 5, 6 \rangle \text{ N/C} && \text{superposition} \\ \vec{E} &= \langle 2, 3, 4 \rangle \text{ N/C} + \langle 2, 4, 6 \rangle \text{ N/C} \\ &\quad + \langle 1, 1, 1 \rangle \text{ N/C} + \langle 3, 5, 6 \rangle \text{ N/C} && \text{superposition again} \\ \vec{E} &= \langle 2, 3, 4 \rangle \text{ N/C} + \langle 2, 4, 6 \rangle \text{ N/C} \\ &\quad + \langle 1, 1, 1 \rangle \text{ N/C} + \langle 3, 5, 6 \rangle \text{ N/C} && \text{more superposition} \end{aligned}$$

```
\begin{problem}{\langle problemname \rangle}
\langle environment content \rangle
\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 `\problem part` to, again, help with organization for newcomers to L^AT_EX. A typical example would be structured as follows.

```
\begin{problem}{Chapter 2 Problem 1}
This problem has two parts.
\begin{parts}
\problem part
This is the first part
\problem part
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{\langle text \rangle}
```

In a `mysolution` ^{→ P. 110} 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}
```

$$c^2 = a^2 + b^2 \quad \text{given} \quad (1)$$

$$a^2 = c^2 - b^2 \quad \text{Rearrange, and add some extra text just for fun.} \quad (2)$$

$$a = \sqrt{c^2 - b^2} \quad \text{Take square root of both sides.} \quad (3)$$

5.14 Miscellaneous Commands

`\checkpoint`

Centered checkpoint for student discussion.

```
\checkpoint
```

|—— CHECKPOINT ——|

`\image{\imagefilename}\caption{caption}`

Centered figure displayed actual size with caption.

```
\image{satellite.pdf}{Photograph of satellite}
```

`\sneakyone{thing}`

Shows argument as a sneaky one.

```
\sneakyone{\frac{m}{m}}
```

$\frac{m}{m}$

`\qed`

Command for QED symbol.

```
\qed
```

Q.E.D.

6 Source Code

Note the packages that must be present.

```
1 \RequirePackage{amsmath}
2 \RequirePackage{amssymb}
3 \RequirePackage{array}
4 \RequirePackage{cancel}
5 \RequirePackage[dvipsnames]{xcolor}
6 \RequirePackage{enumitem}
7 \RequirePackage{environ}
8 \RequirePackage{esint}
9 \RequirePackage[g]{esvect}
10 \RequirePackage{etoolbox}
11 \RequirePackage{filehook}
12 \RequirePackage{extarrows}
13 \RequirePackage[T1]{fontenc}
14 \RequirePackage{graphicx}
15 \RequirePackage{epstopdf}
16 \RequirePackage{textcomp}
17 \RequirePackage{letltxmacro}
18 \RequirePackage{listings}
19 \RequirePackage{mathtools}
20 \RequirePackage[framemethod=TikZ]{mdframed}
21 \RequirePackage{stackengine}
22 \RequirePackage{suffix}
23 \RequirePackage{tensor}
24 \RequirePackage{xargs}
25 \RequirePackage{xparse}
26 \RequirePackage{xspace}
27 \RequirePackage{ifthen}
28 \RequirePackage{calligra}
29 \RequirePackage{hyperref}
30 \hypersetup{colorlinks=true,urlcolor=blue}
31 \DeclareMathAlphabet{\mathcalligra}{T1}{calligra}{m}{n}
32 \DeclareFontShape{T1}{calligra}{m}{n}{<->s*[2.2]callig15}{}
33 \DeclareGraphicsRule{.tif}{png}{.png}{'convert #1 'basename #1 .tif'.png}
34 \DeclareMathAlphabet{\mathpzc}{OT1}{pzc}{m}{it}
35 \usetikzlibrary{shadows}
36 \definecolor{vbgcolor}{rgb}{1,1,1} % background for code listings
37 \definecolor{vshadowcolor}{rgb}{0.5,0.5,0.5} % shadow for code listings
38 \lstdefinestyle{vpython}{% % style for code listings
39   language=Python,% % select language
40   morekeywords={__future__,division,append, % VPython/GlowScript specific keywords
41     arange,arrow,astuple,axis,background,black,blue,cyan,green,%
42     magenta,orange,red,white,yellow,border,box,color,comp,%
43     cone,convex,cross,curve,cylinder,degrees,diff_angle,dot,ellipsoid,extrusion,faces,%
44     font,frame,graphs,headlength,height,headwidth,helix,index,interval,label,length,%
45     line,linecolor,mag,mag2,make_trail,material,norm,normal,objects,opacity,points,pos,%
46     print,print_function,proj,pyramid,radians,radius,rate,retain,ring,rotate,scene,%
```

```

47 shaftwidth,shape,sign,size,space,sphere,text,trail_object,trail_type,True,twist,up,%
48 vector,visual,width,offset,yoffset,GlowScript,VPython,trail_color,trail_radius,%
49 pps,clear,False,CoffeeScript,graph,gdisplay,canvas,pause,vec,clone,compound,%
50 vertex,triangle,quad,attach_trail,attach_arrow,textures,bumpmaps,print_options,%
51 get_library,read_local_file},%
52 captionpos=b,% % position caption
53 frame=shadowbox,% % shadowbox around listing
54 rulesepcolor=\color{vshadowcolor},% % shadow color
55 basicstyle=\footnotesize,% % basic font for code listings
56 commentstyle=\bfseries\color{red}, % font for comments
57 keywordstyle=\bfseries\color{blue},% % font for keywords
58 showstringspaces=true,% % show spaces in strings
59 stringstyle=\bfseries\color{green},% % color for strings
60 numbers=left,% % where to put line numbers
61 numberstyle=\tiny,% % set to 'none' for no line numbers
62 xleftmargin=20pt,% % extra left margin
63 backgroundcolor=\color{vbgcolor},% % some people find this annoying
64 upquote=true,% % how to typeset quotes
65 breaklines=true}% % break long lines
66 \definecolor{formcolor}{gray}{0.90} % color for form background
67 \newcolumntype{C}[1]{>{\centering}m{#1}}
68 \newboolean{@optromanvectors}
69 \newboolean{@optboldvectors}
70 \newboolean{@optsinglemagbars}
71 \newboolean{@optbaseunits}
72 \newboolean{@optdrvdunits}
73 \newboolean{@optapproxconsts}
74 \newboolean{@optuseradians}
75 \setboolean{@optromanvectors}{false} % this is where you set the default option
76 \setboolean{@optboldvectors}{false} % this is where you set the default option
77 \setboolean{@optsinglemagbars}{false} % this is where you set the default option
78 \setboolean{@optbaseunits}{false} % this is where you set the default option
79 \setboolean{@optdrvdunits}{false} % this is where you set the default option
80 \setboolean{@optapproxconsts}{false} % this is where you set the default option
81 \setboolean{@optuseradians}{false} % this is where you set the default option
82 \DeclareOption{romanvectors}{\setboolean{@optromanvectors}{true}}
83 \DeclareOption{boldvectors}{\setboolean{@optboldvectors}{true}}
84 \DeclareOption{singlemagbars}{\setboolean{@optsinglemagbars}{true}}
85 \DeclareOption{baseunits}{\setboolean{@optbaseunits}{true}}
86 \DeclareOption{drvdunits}{\setboolean{@optdrvdunits}{true}}
87 \DeclareOption{approxconsts}{\setboolean{@optapproxconsts}{true}}
88 \DeclareOption{useradians}{\setboolean{@optuseradians}{true}}
89 \ProcessOptions\relax

90 \newcommand*{\mandiversion}{2.6.0 dated 2016/06/29}
91 \typeout{mandi: You're using mandi version \mandiversion.}

```

This block of code fixes a conflict with the amssymb package.

```

92 \@ifpackageloaded{amssymb}{%
93   \csundef{square}

```

```

94 \typeout{mandi: Package amssymb detected. Its \protect\square\space
95 has been redefined.}
96 }{%
97 \typeout{mandi: Package amssymb not detected.}
98 }%

```

This block of code defines unit names and symbols.

```

99 \newcommand*{\per}{\ensuremath{/}}
100 \newcommand*{\usk}{\ensuremath{\cdot}}
101 \newcommand*{\unit}[2]{\ensuremath{\{#1\}\, \{#2\}}}
102 \newcommand*{\ampere}{\ensuremath{\mathrm{A}}}
103 \newcommand*{\arcminute}{\ensuremath{'}}
104 \newcommand*{\arcsecond}{\ensuremath{''}}
105 \newcommand*{\atomicmassunit}{\ensuremath{\mathrm{u}}}
106 \newcommand*{\candela}{\ensuremath{\mathrm{cd}}}
107 \newcommand*{\coulomb}{\ensuremath{\mathrm{C}}}
108 \newcommand*{\degree}{\ensuremath{^\circ}}
109 \newcommand*{\electronvolt}{\ensuremath{\mathrm{eV}}}
110 \newcommand*{\eV}{\electronvolt}
111 \newcommand*{\farad}{\ensuremath{\mathrm{F}}}
112 \newcommand*{\henry}{\ensuremath{\mathrm{H}}}
113 \newcommand*{\hertz}{\ensuremath{\mathrm{Hz}}}
114 \newcommand*{\hour}{\ensuremath{\mathrm{h}}}
115 \newcommand*{\joule}{\ensuremath{\mathrm{J}}}
116 \newcommand*{\kelvin}{\ensuremath{\mathrm{K}}}
117 \newcommand*{\kilogram}{\ensuremath{\mathrm{kg}}}
118 \newcommand*{\metre}{\ensuremath{\mathrm{m}}}
119 \newcommand*{\minute}{\ensuremath{\mathrm{min}}}
120 \newcommand*{\mole}{\ensuremath{\mathrm{mol}}}
121 \newcommand*{\newton}{\ensuremath{\mathrm{N}}}
122 \newcommand*{\ohm}{\ensuremath{\Omega}}
123 \newcommand*{\pascal}{\ensuremath{\mathrm{Pa}}}
124 \newcommand*{\radian}{\ensuremath{\mathrm{rad}}}
125 \newcommand*{\second}{\ensuremath{\mathrm{s}}}
126 \newcommand*{\siemens}{\ensuremath{\mathrm{S}}}
127 \newcommand*{\steradian}{\ensuremath{\mathrm{sr}}}
128 \newcommand*{\tesla}{\ensuremath{\mathrm{T}}}
129 \newcommand*{\volt}{\ensuremath{\mathrm{V}}}
130 \newcommand*{\watt}{\ensuremath{\mathrm{W}}}
131 \newcommand*{\weber}{\ensuremath{\mathrm{Wb}}}
132 \newcommand*{\C}{\coulomb}
133 \newcommand*{\F}{\farad}
134 %H is already defined as a LaTeX accent
135 \newcommand*{\J}{\joule}
136 \newcommand*{\N}{\newton}
137 \newcommand*{\Pa}{\pascal}
138 \newcommand*{\rad}{\radian}
139 \newcommand*{\sr}{\steradian}
140 %S is already defined as a LaTeX symbol
141 \newcommand*{\T}{\tesla}

```

```

142 \newcommand*\V{\volt}
143 \newcommand*\W{\watt}
144 \newcommand*\Wb{\weber}
145 \newcommand*\square[1]{\ensuremath{\{#1\}^2}} % prefix 2
146 \newcommand*\cubic[1]{\ensuremath{\{#1\}^3}} % prefix 3
147 \newcommand*\quartic[1]{\ensuremath{\{#1\}^4}} % prefix 4
148 \newcommand*\reciprocal[1]{\ensuremath{\{#1\}^{-1}}} % prefix -1
149 \newcommand*\reciprocalsquare[1]{\ensuremath{\{#1\}^{-2}}} % prefix -2
150 \newcommand*\reciprocalcubic[1]{\ensuremath{\{#1\}^{-3}}} % prefix -3
151 \newcommand*\reciprocalquartic[1]{\ensuremath{\{#1\}^{-4}}} % prefix -4
152 \newcommand*\squared{\ensuremath{\{^2\}}} % postfix 2
153 \newcommand*\cubed{\ensuremath{\{^3\}}} % postfix 3
154 \newcommand*\quarted{\ensuremath{\{^4\}}} % postfix 4
155 \newcommand*\reciprocald{\ensuremath{\{^{-1}\}}} % postfix -1
156 \newcommand*\reciprocalsquared{\ensuremath{\{^{-2}\}}} % postfix -2
157 \newcommand*\reciprocalcubed{\ensuremath{\{^{-3}\}}} % postfix -3
158 \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.

```

159 \newcommand*\mi@exchangeargs[2]{#2#1}%
160 \newcommand*\mi@name{}%
161 \long\def\mi@name#1#{\romannumeral0\mi@innername{#1}}%
162 \newcommand*\mi@innername[2]{%
163   \expandafter\mi@exchangeargs\expandafter{\csname#2\endcsname}{#1}}%
164 \begingroup
165 \@firstofone{%
166   \endgroup
167   \newcommand*\mi@forkifnull[3]{%
168     \romannumeral\iffalse{\fi\expandafter\@secondoftwo\expandafter%
169       {\expandafter{\string#1}\expandafter\@secondoftwo\string}%
170     \expandafter\@firstoftwo\expandafter{\iffalse}\fi0 #3}{0 #2}}}%
171 \newcommand*\selectbaseunit[3]{#1}
172 \newcommand*\selectdrvdunit[3]{#2}
173 \newcommand*\selecttradunit[3]{#3}
174 \newcommand*\selectunit{}
175 \newcommand*\perpusebaseunit{\let\selectunit=\selectbaseunit}
176 \newcommand*\perpusedrvdunit{\let\selectunit=\selectdrvdunit}
177 \newcommand*\perpusetradunit{\let\selectunit=\selecttradunit}
178 \newcommand*\hereusebaseunit[1]{%
179   \begingroup\perpusebaseunit#1\endgroup}%
180 \newcommand*\hereusedrvdunit[1]{%
181   \begingroup\perpusedrvdunit#1\endgroup}%
182 \newcommand*\hereusetradunit[1]{%
183   \begingroup\perpusetradunit#1\endgroup}%
184 \newenvironment{usebaseunit}{\perpusebaseunit}{}%
185 \newenvironment{usedrvdunit}{\perpusedrvdunit}{}%
186 \newenvironment{usetradunit}{\perpusetradunit}{}%
187 \newcommand*\newphysicsquantity{\definephysicsquantity{\newcommand}}
188 \newcommand*\redefinephysicsquantity{\definephysicsquantity{\renewcommand}}

```

```

189 \newcommandx*\definephysicsquantity[5][4=,5=]{%
190   \innerdefinewhatsoeverquantityfork{#3}{#4}{#5}{#1}{#2}{\{1\}{##1}}%
191 \newcommand*\newphysicsconstant{\definephysicsconstant{\newcommand}}
192 \newcommand*\redefinephysicsconstant{\definephysicsconstant{\renewcommand}}
193 \newcommandx*\definephysicsconstant[7][6=,7=]{%
194   \innerdefinewhatsoeverquantityfork{#5}{#6}{#7}{#1}{#2}{#3}{\{#4\}}%
195 \newcommand*\innerdefinewhatsoeverquantityfork[3]{%
196   \expandafter\innerdefinewhatsoeverquantity\romannumeral0%
197   \mi@forkifnull{#3}{\mi@forkifnull{#2}{\{#1\}}{\{#2\}{#1}}}%
198   {\mi@forkifnull{#2}{\{#1\}}{\{#2\}{#3}{#1}}}%
199 \newcommand*\innerdefinewhatsoeverquantity[8]{%
200   \mi@name#4{#5}#7{\unit{#8}{\selectunit{#3}{#1}{#2}}}%
201   \mi@name#4{#5baseunit}#7{\unit{#8}{#3}}%
202   \mi@name#4{#5drvdunit}#7{\unit{#8}{#1}}%
203   \mi@name#4{#5tradunit}#7{\unit{#8}{#2}}%
204   \mi@name#4{#5onlyunit}{\selectunit{#3}{#1}{#2}}%
205   \mi@name#4{#5onlybaseunit}{\ensuremath{#3}}%
206   \mi@name#4{#5onlydrvdunit}{\ensuremath{#1}}%
207   \mi@name#4{#5onlytradunit}{\ensuremath{#2}}%
208   \mi@name#4{#5value}#7{\ensuremath{#8}}%
209   \mi@forkifnull{#7}{%
210     \ifx#4\renewcommand\mi@name\let{#5mathsymbol}=\relax\fi
211     \mi@name\newcommand*{#5mathsymbol}{\ensuremath{#6}}{}}%

```

This block of code processes the options.

```

212 \ifthenelse{\boolean{@optboldvectors}}{
213   {\typeout{mandi: You'll get bold vectors.}}
214   {\ifthenelse{\boolean{@optromanvectors}}{
215     {\typeout{mandi: You'll get Roman vectors.}}
216     {\typeout{mandi: You'll get italic vectors.}}}
217 \ifthenelse{\boolean{@optsinglemagbars}}{
218   {\typeout{mandi: You'll get single magnitude bars.}}
219   {\typeout{mandi: You'll get double magnitude bars.}}
220 \ifthenelse{\boolean{@optbaseunits}}{
221   {\perpusebaseunit %
222     \typeout{mandi: You'll get base units.}}
223   {\ifthenelse{\boolean{@optdrvdunits}}{
224     {\perpusedrvdunit %
225       \typeout{mandi: You'll get derived units.}}
226     {\perpusetradunit %
227       \typeout{mandi: You'll get traditional units.}}}
228 \ifthenelse{\boolean{@optapproxconsts}}{
229   {\typeout{mandi: You'll get approximate constants.}}
230   {\typeout{mandi: You'll get precise constants.}}
231 \ifthenelse{\boolean{@optuseradians}}{
232   {\typeout{mandi: You'll get radians in ang mom, ang impulse, and torque.}}
233   {\typeout{mandi: You won't get radians in ang mom, ang impulse, and torque.}}

```

This is a utility command for picking constants.

```

234 \ifthenelse{\boolean{@optapproxconsts}}
235   {\newcommand*\mi@p}[2]{#1}} % approximate value
236   {\newcommand*\mi@p}[2]{#2}} % precise value

SI base unit of length or spatial displacement

237 \newcommand*\m{\metre}

SI base unit of mass

238 \newcommand*\kg{\kilogram}

SI base unit of time or temporal displacement

239 \newcommand*\s{\second}

SI base unit of electric current

240 \newcommand*\A{\ampere}

SI base unit of thermodynamic temperature

241 \newcommand*\K{\kelvin}

SI base unit of amount

242 \newcommand*\mol{\mole}

SI base unit of luminous intensity

243 \newcommand*\cd{\candela}

244 \newcommand*\dimdisplacement{\ensuremath{\mathrm{L}}}
245 \newcommand*\dimmass{\ensuremath{\mathrm{M}}}
246 \newcommand*\dimduration{\ensuremath{\mathrm{T}}}
247 \newcommand*\dimcurrent{\ensuremath{\mathrm{I}}}
248 \newcommand*\dimtemperature{\ensuremath{\mathrm{\Theta}}}
249 \newcommand*\dimamount{\ensuremath{\mathrm{N}}}
250 \newcommand*\dimluminous{\ensuremath{\mathrm{J}}}
251 \newcommand*\indegrees[1]{\unit{#1}{\degree}}
252 \newcommand*\inFahrenheit[1]{\unit{#1}{\degree\mathrm{F}}}
253 \newcommand*\inCelsius[1]{\unit{#1}{\degree\mathrm{C}}}
254 \newcommand*\inarcminutes[1]{\unit{#1}{\arcminute}}
255 \newcommand*\inarcseconds[1]{\unit{#1}{\arcsecond}}
256 \newcommand*\ineV[1]{\unit{#1}{\electronvolt}}
257 \newcommand*\ineVocs[1]{\unit{#1}{\mathrm{eV}\per c^2}}
258 \newcommand*\ineVoc[1]{\unit{#1}{\mathrm{eV}\per c}}
259 \newcommand*\inMeV[1]{\unit{#1}{\mathrm{MeV}}}
260 \newcommand*\inMeVocs[1]{\unit{#1}{\mathrm{MeV}\per c^2}}
261 \newcommand*\inMeVoc[1]{\unit{#1}{\mathrm{MeV}\per c}}
262 \newcommand*\inGeV[1]{\unit{#1}{\mathrm{GeV}}}
263 \newcommand*\inGeVocs[1]{\unit{#1}{\mathrm{GeV}\per c^2}}
264 \newcommand*\inGeVoc[1]{\unit{#1}{\mathrm{GeV}\per c}}

```

```

265 \newcommand*{\inamu}[1]{\unit{#1}{\mathrm{u}}}
266 \newcommand*{\ingram}[1]{\unit{#1}{\mathrm{g}}}
267 \newcommand*{\ingrampercubiccm}[1]{\unit{#1}{\mathrm{g}\per\cubic\mathrm{cm}}}
268 \newcommand*{\inAU}[1]{\unit{#1}{\mathrm{AU}}}
269 \newcommand*{\inly}[1]{\unit{#1}{\mathrm{ly}}}
270 \newcommand*{\incyr}[1]{\unit{#1}{\mathrm{c}\usk\mathrm{year}}}
271 \newcommand*{\inpc}[1]{\unit{#1}{\mathrm{pc}}}
272 \newcommand*{\insolarL}[1]{\unit{#1}{\mathrm{Lsolar}}}
273 \newcommand*{\insolarT}[1]{\unit{#1}{\mathrm{Tsolar}}}
274 \newcommand*{\insolarR}[1]{\unit{#1}{\mathrm{Rsolar}}}
275 \newcommand*{\insolarM}[1]{\unit{#1}{\mathrm{Msolar}}}
276 \newcommand*{\insolarF}[1]{\unit{#1}{\mathrm{Fsolar}}}
277 \newcommand*{\insolarf}[1]{\unit{#1}{\mathrm{fsolar}}}
278 \newcommand*{\insolarMag}[1]{\unit{#1}{\mathrm{Magsolar}}}
279 \newcommand*{\insolarmag}[1]{\unit{#1}{\mathrm{magsolar}}}
280 \newcommand*{\insolarD}[1]{\unit{#1}{\mathrm{Dsolar}}}
281 \newcommand*{\insoldard}[1]{\unit{#1}{\mathrm{dsolar}}}
282 \newcommand*{\velocityc}[1]{\ensuremath{#1c}}
283 \newcommand*{\lorentz}[1]{\ensuremath{#1}}
284 \newcommand*{\speed}{\velocity}
285 \newphysicsquantity{displacement}%
286   {\m}%
287   [\m]%
288   [\m]
289 \newphysicsquantity{mass}%
290   {\kg}%
291   [\kg]%
292   [\kg]
293 \newphysicsquantity{duration}%
294   {\s}%
295   [\s]%
296   [\s]
297 \newphysicsquantity{current}%
298   {\A}%
299   [\A]%
300   [\A]
301 \newphysicsquantity{temperature}%
302   {\K}%
303   [\K]%
304   [\K]
305 \newphysicsquantity{amount}%
306   {\mol}%
307   [\mol]%
308   [\mol]
309 \newphysicsquantity{luminous}%
310   {\cd}%
311   [\cd]%
312   [\cd]
313 \newphysicsquantity{planeangle}%
314   {\m\usk\reciprocal\m}%

```



```

315 [\rad]%
316 []
317 \newphysicsquantity{solidangle}%
318 {\m\squared\usk\reciprocalsquare\m}%
319 [\sr]%
320 []
321 \newphysicsquantity{velocity}%
322 {\m\usk\reciprocal\s}%
323 [\m\usk\reciprocal\s]%
324 [\m\per\s]
325 \newphysicsquantity{acceleration}%
326 {\m\usk\s\reciprocalsquared}%
327 [\N\per\kg]%
328 [\m\per\s\squared]
329 \newphysicsquantity{gravitationalfield}%
330 {\m\usk\s\reciprocalsquared}%
331 [\N\per\kg]%
332 [\N\per\kg]
333 \newphysicsquantity{gravitationalpotential}%
334 {\square\m\usk\reciprocalsquare\s}%
335 [\J\per\kg]%
336 [\J\per\kg]
337 \newphysicsquantity{momentum}%
338 {\m\usk\kg\usk\reciprocal\s}%
339 [\N\usk\s]%
340 [\kg\usk\m\per\s]
341 \newphysicsquantity{impulse}%
342 {\m\usk\kg\usk\reciprocal\s}%
343 [\N\usk\s]%
344 [\N\usk\s]
345 \newphysicsquantity{force}%
346 {\m\usk\kg\usk\s\reciprocalsquared}%
347 [\N]%
348 [\N]
349 \newphysicsquantity{springstiffness}%
350 {\kg\usk\s\reciprocalsquared}%
351 [\N\per\m]%
352 [\N\per\m]
353 \newphysicsquantity{springstretch}%
354 {\m}%
355 []%
356 []
357 \newphysicsquantity{area}%
358 {\m\squared}%
359 []%
360 []
361 \newphysicsquantity{volume}%
362 {\cubic\m}%
363 []%
364 []

```

```

365 \newphysicsquantity{linearmassdensity}%
366   {\reciprocal\m\usk\kg}%
367   [\kg\per\m]%
368   [\kg\per\m]
369 \newphysicsquantity{areamassdensity}%
370   {\m\reciprocalssquared\usk\kg}%
371   [\kg\per\m\squared]%
372   [\kg\per\m\squared]
373 \newphysicsquantity{volumemassdensity}%
374   {\m\reciprocalcubed\usk\kg}%
375   [\kg\per\m\cubed]%
376   [\kg\per\m\cubed]
377 \newphysicsquantity{youngsmodulus}%
378   {\reciprocal\m\usk\kg\usk\s\reciprocalssquared}%
379   [\N\per\m\squared]%
380   [\Pa]
381 \newphysicsquantity{stress}%
382   {\reciprocal\m\usk\kg\usk\s\reciprocalssquared}%
383   [\N\per\m\squared]%
384   [\Pa]
385 \newphysicsquantity{pressure}%
386   {\reciprocal\m\usk\kg\usk\s\reciprocalssquared}%
387   [\N\per\m\squared]%
388   [\Pa]
389 \newphysicsquantity{strain}%
390   {}%
391   []%
392   []
393 \newphysicsquantity{work}%
394   {\m\squared\usk\kg\usk\s\reciprocalssquared}%
395   [\N\usk\m]%
396   [\J]
397 \newphysicsquantity{energy}%
398   {\m\squared\usk\kg\usk\s\reciprocalssquared}%
399   [\N\usk\m]%
400   [\J]
401 \newphysicsquantity{power}%
402   {\m\squared\usk\kg\usk\s\reciprocalcubed}%
403   [\J\per\s]%
404   [\W]
405 \newphysicsquantity{specificheatcapacity}%
406   {\J\per\K\usk\kg}%
407   [\J\per\K\usk\kg]%
408   [\J\per\K\usk\kg]
409 \newphysicsquantity{angularvelocity}%
410   {\rad\usk\reciprocal\s}%
411   [\rad\per\s]%
412   [\rad\per\s]
413 \newphysicsquantity{angularacceleration}%
414   {\rad\usk\s\reciprocalssquared}%

```

```

415 [\rad\per\s\squared]%
416 [\rad\per\s\squared]
417 \newphysicsquantity{momentofinertia}%
418 {\m\squared\usk\kg}%
419 [\m\usk\kg\squared]%
420 [\J\usk\s\squared]
421 \ifthenelse{\boolean{@optuseradians}}
422 {%
423 \newphysicsquantity{angularmomentum}%
424 {\m\squared\usk\kg\usk\reciprocal\s\usk\reciprocal\rad}%
425 [\N\usk\m\usk\s\per\rad]%
426 [\m\squared\usk\kg\usk\reciprocal\s\usk\reciprocal\rad]
427 \newphysicsquantity{angularimpulse}%
428 {\m\squared\usk\kg\usk\reciprocal\s\usk\reciprocal\rad}%
429 [\N\usk\m\usk\s\per\rad]%
430 [\J\usk\s\per\rad]
431 \newphysicsquantity{torque}%
432 {\m\squared\usk\kg\usk\s\reciprocalsquared\usk\reciprocal\rad}%
433 [\N\usk\m\per\rad]%
434 [\J\per\rad]
435 }%
436 {%
437 \newphysicsquantity{angularmomentum}%
438 {\m\squared\usk\kg\usk\reciprocal\s}%
439 [\N\usk\m\usk\s]%
440 [\m\squared\usk\kg\usk\reciprocal\s]
441 \newphysicsquantity{angularimpulse}%
442 {\m\squared\usk\kg\usk\reciprocal\s}%
443 [\N\usk\m\usk\s]%
444 [\J\usk\s]
445 \newphysicsquantity{torque}%
446 {\m\squared\usk\kg\usk\s\reciprocalsquared}%
447 [\N\usk\m]%
448 [\J]
449 }%
450 \newphysicsquantity{entropy}%
451 {\m\squared\usk\kg\usk\s\reciprocalsquared\usk\reciprocal\K}%
452 [\J\per\K]%
453 [\J\per\K]
454 \newphysicsquantity{wavelength}%
455 {\m}%
456 [\m]%
457 [\m]
458 \newphysicsquantity{wavenumber}%
459 {\reciprocal\m}%
460 [\per\m]%
461 [\per\m]
462 \newphysicsquantity{frequency}%
463 {\reciprocal\s}%
464 [\hertz]%

```

```

465 [\hertz]
466 \newphysicsquantity{angularfrequency}%
467 {\rad\usk\reciprocal\s}%
468 [\rad\per\s]%
469 [\rad\per\s]
470 \newphysicsquantity{charge}%
471 {\A\usk\s}%
472 [\C]%
473 [\C]
474 \newphysicsquantity{permittivity}%
475 {\m\reciprocalcubed\usk\reciprocal\kg\usk\s\reciprocalquarted\usk\A\squared}%
476 [\F\per\m]%
477 [\C\squared\per\N\usk\m\squared]
478 \newphysicsquantity{permeability}%
479 {\m\usk\kg\usk\s\reciprocal\squared\usk\A\reciprocal\squared}%
480 [\henry\per\m]%
481 [\T\usk\m\per\A]
482 \newphysicsquantity{electricfield}%
483 {\m\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}%
484 [\V\per\m]%
485 [\N\per\C]
486 \newphysicsquantity{electricdipolemoment}%
487 {\m\usk\s\usk\A}%
488 [\C\usk\m]%
489 [\C\usk\m]
490 \newphysicsquantity{electricflux}%
491 {\m\cubed\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}%
492 [\V\usk\m]%
493 [\N\usk\m\squared\per\C]
494 \newphysicsquantity{magneticfield}%
495 {\kg\usk\s\reciprocal\squared\usk\reciprocal\A}%
496 [\T]%
497 [\N\per\C\usk(\m\per\s)] % also \Wb\per\m\squared
498 \newphysicsquantity{magneticflux}%
499 {\m\squared\usk\kg\usk\s\reciprocal\squared\usk\reciprocal\A}%
500 [\volt\usk\s]%
501 [\T\usk\m\squared] % also \Wb and \J\per\A
502 \newphysicsquantity{cmagneticfield}%
503 {\m\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}%
504 [\V\per\m]%
505 [\N\per\C]
506 \newphysicsquantity{linearchargedensity}%
507 {\reciprocal\m\usk\s\usk\A}%
508 [\C\per\m]%
509 [\C\per\m]
510 \newphysicsquantity{areachargedensity}%
511 {\reciprocal\square\m\usk\s\usk\A}%
512 [\C\per\square\m]%
513 [\C\per\square\m]
514 \newphysicsquantity{volumechargeddensity}%

```

515 $\{\text{\reciprocalcubic}\text{m}\text{\usk}\text{s}\text{\usk}\text{A}\}\%$
 516 $[\text{\C}\text{\per}\text{\cubic}\text{m}]\%$
 517 $[\text{\C}\text{\per}\text{\cubic}\text{m}]$
 518 $\text{\newphysicsquantity}\{\text{mobility}\}\%$
 519 $\{\text{m}\text{\squared}\text{\usk}\text{kg}\text{\usk}\text{s}\text{\reciprocalquarted}\text{\usk}\text{\reciprocal}\text{A}\}\%$
 520 $[\text{m}\text{\squared}\text{\per}\text{\volt}\text{\usk}\text{s}]\%$
 521 $[(\text{m}\text{\per}\text{s})\text{\per}(\text{N}\text{\per}\text{C})]$
 522 $\text{\newphysicsquantity}\{\text{numberdensity}\}\%$
 523 $\{\text{\reciprocalcubic}\text{m}\}\%$
 524 $[\text{\per}\text{\cubic}\text{m}]\%$
 525 $[\text{\per}\text{\cubic}\text{m}]$
 526 $\text{\newphysicsquantity}\{\text{polarizability}\}\%$
 527 $\{\text{\reciprocal}\text{kg}\text{\usk}\text{s}\text{\quarted}\text{\usk}\text{\square}\text{A}\}\%$
 528 $[\text{\C}\text{\usk}\text{\square}\text{m}\text{\per}\text{V}]\%$
 529 $[\text{\C}\text{\usk}\text{m}\text{\per}(\text{N}\text{\per}\text{C})]$
 530 $\text{\newphysicsquantity}\{\text{electricpotential}\}\%$
 531 $\{\text{\square}\text{m}\text{\usk}\text{kg}\text{\usk}\text{\reciprocalcubic}\text{s}\text{\usk}\text{\reciprocal}\text{A}\}\%$
 532 $[\text{J}\text{\per}\text{C}]\%$
 533 $[\text{V}]$
 534 $\text{\newphysicsquantity}\{\text{emf}\}\%$
 535 $\{\text{\square}\text{m}\text{\usk}\text{kg}\text{\usk}\text{\reciprocalcubic}\text{s}\text{\usk}\text{\reciprocal}\text{A}\}\%$
 536 $[\text{J}\text{\per}\text{C}]\%$
 537 $[\text{V}]$
 538 $\text{\newphysicsquantity}\{\text{dielectricconstant}\}\%$
 539 $\{\}\%$
 540 $[\]\%$
 541 $[\]$
 542 $\text{\newphysicsquantity}\{\text{indexofrefraction}\}\%$
 543 $\{\}\%$
 544 $[\]\%$
 545 $[\]$
 546 $\text{\newphysicsquantity}\{\text{relativepermittivity}\}\%$
 547 $\{\}\%$
 548 $[\]\%$
 549 $[\]$
 550 $\text{\newphysicsquantity}\{\text{relativepermeability}\}$
 551 $\{\}\%$
 552 $[\]\%$
 553 $[\]$
 554 $\text{\newphysicsquantity}\{\text{energydensity}\}\%$
 555 $\{\text{m}\text{\reciprocaled}\text{\usk}\text{kg}\text{\usk}\text{\reciprocalsquare}\text{s}\}\%$
 556 $[\text{J}\text{\per}\text{\cubic}\text{m}]\%$
 557 $[\text{J}\text{\per}\text{\cubic}\text{m}]$
 558 $\text{\newphysicsquantity}\{\text{energyflux}\}\%$
 559 $\{\text{kg}\text{\usk}\text{s}\text{\reciprocalcubed}\}\%$
 560 $[\text{W}\text{\per}\text{m}\text{\squared}]\%$
 561 $[\text{W}\text{\per}\text{m}\text{\squared}]$
 562 $\text{\newphysicsquantity}\{\text{momentumflux}\}\%$
 563 $\{\text{\reciprocal}\text{m}\text{\usk}\text{kg}\text{\usk}\text{s}\text{\reciprocalsquare}\}\%$
 564 $[\text{N}\text{\per}\text{m}\text{\squared}]\%$

```

565 [\N\per\m\squared]
566 \newphysicsquantity{electroncurrent}%
567 {\reciprocal\s}%
568 [\ensuremath{\mathrm{e}}\per\s]%
569 [\ensuremath{\mathrm{e}}\per\s]
570 \newphysicsquantity{conventionalcurrent}%
571 {\A}%
572 [\C\per\s]%
573 [\A]
574 \newphysicsquantity{magneticdipolemoment}%
575 {\square\m\usk\A}%
576 [\J\per\T]%
577 [\A\usk\square\m]
578 \newphysicsquantity{currentdensity}%
579 {\reciprocal\square\m\usk\A}%
580 [\C\usk\s\per\square\m]%
581 [\A\per\square\m]
582 \newphysicsquantity{capacitance}%
583 {\reciprocal\square\m\usk\reciprocal\kg\usk\quartic\s\usk\square\A}%
584 [\F]%
585 [\C\per\V] % also \C\squared\per\N\usk\m, \s\per\ohm
586 \newphysicsquantity{inductance}%
587 {\square\m\usk\kg\usk\reciprocal\square\s\usk\reciprocal\square\A}%
588 [\henry]%
589 [\volt\usk\s\per\A] % also \square\m\usk\kg\per\C\squared, \Wb\per\A
590 \newphysicsquantity{conductivity}%
591 {\reciprocalcubic\m\usk\reciprocal\kg\usk\cubic\s\usk\square\A}%
592 [\siemens\per\m]%
593 [(\A\per\square\m)\per(\V\per\m)]
594 \newphysicsquantity{resistivity}%
595 {\cubic\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocal\square\A}%
596 [\ohm\usk\m]%
597 [(\V\per\m)\per(\A\per\square\m)]
598 \newphysicsquantity{resistance}%
599 {\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocal\square\A}%
600 [\V\per\A]%
601 [\ohm]
602 \newphysicsquantity{conductance}%
603 {\reciprocal\square\m\usk\reciprocal\kg\usk\cubic\s\usk\square\A}%
604 [\A\per\V]%
605 [\siemens]
606 \newphysicsquantity{magneticcharge}%
607 {\m\usk\A}%
608 [\m\usk\A]%
609 [\m\usk\A]
610 \newcommand*{\vectordisplacement}[1]{\ensuremath{\displacement{\mivector{#1}}}}
611 \newcommand*{\vectorvelocity}[1]{\ensuremath{\velocity{\mivector{#1}}}}
612 \newcommand*{\vectorvelocityc}[1]{\ensuremath{\velocityc{\mivector{#1}}}}
613 \newcommand*{\vectoracceleration}[1]{\ensuremath{\acceleration{\mivector{#1}}}}
614 \newcommand*{\vectormomentum}[1]{\ensuremath{\momentum{\mivector{#1}}}}

```

```

615 \newcommand*{\vectorforce}[1]{\ensuremath{\force{\mivector{#1}}}}
616 \newcommand*{\vectorgravitationalfield}[1]
617   {\ensuremath{\gravitationalfield{\mivector{#1}}}}
618 \newcommand*{\vectorimpulse}[1]{\ensuremath{\impulse{\mivector{#1}}}}
619 \newcommand*{\vectorangularvelocity}[1]{\ensuremath{\angularvelocity{\mivector{#1}}}}
620 \newcommand*{\vectorangularacceleration}[1]
621   {\ensuremath{\angularacceleration{\mivector{#1}}}}
622 \newcommand*{\vectorangularmomentum}[1]{\ensuremath{\angularmomentum{\mivector{#1}}}}
623 \newcommand*{\vectorangularimpulse}[1]{\ensuremath{\angularimpulse{\mivector{#1}}}}
624 \newcommand*{\vectortorque}[1]{\ensuremath{\torque{\mivector{#1}}}}
625 \newcommand*{\vectorwavenumber}[1]{\ensuremath{\wavenumber{\mivector{#1}}}}
626 \newcommand*{\vectorelectricfield}[1]{\ensuremath{\electricfield{\mivector{#1}}}}
627 \newcommand*{\vectorelectricdipolemoment}[1]
628   {\ensuremath{\electricdipolemoment{\mivector{#1}}}}
629 \newcommand*{\vectormagneticfield}[1]{\ensuremath{\magneticfield{\mivector{#1}}}}
630 \newcommand*{\vectorcmagneticfield}[1]{\ensuremath{\cmagneticfield{\mivector{#1}}}}
631 \newcommand*{\vectormagneticdipolemoment}[1]
632   {\ensuremath{\magneticdipolemoment{\mivector{#1}}}}
633 \newcommand*{\vectorcurrentdensity}[1]{\ensuremath{\currentdensity{\mivector{#1}}}}
634 \newcommand*{\lv}{\ensuremath{\left\langle}}
635 \newcommand*{\vectorenergyflux}[1]{\ensuremath{\energyflux{\mivector{#1}}}}
636 \newcommand*{\vectormomentumflux}[1]{\ensuremath{\momentumflux{\mivector{#1}}}}
637 \newcommand*{\poyntingvector}{\vectorenergyflux}
638 \newcommand*{\rv}{\ensuremath{\right\rangle}}
639 \ExplSyntaxOn % Written in LaTeX3
640 \NewDocumentCommand{\magvectncomps}{ m O{} }
641   {%
642     \sum_of_squares:nn { #1 }{ #2 }
643   }%
644 \cs_new:Npn \sum_of_squares:nn #1 #2
645   {%
646     \tl_if_empty:nTF { #2 }
647     {%
648       \clist_set:Nn \l_tmpa_clist { #1 }
649       \ensuremath{%
650         \sqrt{\left(\clist_use:Nnnn \l_tmpa_clist { \right)^2+\left( } { \right)^2+
651         \left( } { \right)^2+\left( } \right)^2 }
652       }%
653     }%
654     {%
655       \clist_set:Nn \l_tmpa_clist { #1 }
656       \ensuremath{%
657         \sqrt{\left(\clist_use:Nnnn \l_tmpa_clist {\;{ #2 }\right)^2+\left( } {\;
658         { #2 }\right)^2+\left( } {\;{ #2 }\right)^2+\left( } {\;{ #2 }\right)^2}
659       }%
660     }%
661   }%
662 \ExplSyntaxOff
663 %
664 \newcommand*{\zerovect}{\vect{0}}

```

```

665 \ifthenelse{\boolean{@optboldvectors}}
666   {\newcommand*\{\vect}[1]{\ensuremath{\boldsymbol{\mathrm{#1}}}}}
667   {\ifthenelse{\boolean{@optromanvectors}}
668     {\newcommand*\{\vect}[1]{\ensuremath{\mathrm{vv}\{\mathrm{#1}\}}}}
669     {\newcommand*\{\vect}[1]{\ensuremath{\mathrm{vv}\{#1\}}}}}
670 \ifthenelse{\boolean{@optsinglemagbars}}
671   {\newcommand*\{\magvect}[1]{\ensuremath{\mathrm{absof}\{\vect{#1}\}}}}
672   {\newcommand*\{\magvect}[1]{\ensuremath{\mathrm{magof}\{\vect{#1}\}}}}
673 \newcommand*\{\magsquaredvect}[1]{\ensuremath{\mathrm{magvect}\{#1\}\mathrm{squared}}}
674 \newcommand*\{\magvect}[2]{\ensuremath{\mathrm{magvect}\{#1\}^{\mathrm{#2}}}}
675 \newcommand*\{\dmagvect}[1]{\ensuremath{\mathrm{dx}\{\mathrm{magvect}\{#1\}\}}}
676 \newcommand*\{\Dmagvect}[1]{\ensuremath{\mathrm{Delta}\!\mathrm{magvect}\{#1\}}}
677 \ifthenelse{\boolean{@optboldvectors}}
678   {\newcommand*\{\dirvect}[1]{\ensuremath{\widehat{\boldsymbol{\mathrm{#1}}}}}}
679   {\ifthenelse{\boolean{@optromanvectors}}
680     {\newcommand*\{\dirvect}[1]{\ensuremath{\widehat{\mathrm{#1}}}}}
681     {\newcommand*\{\dirvect}[1]{\ensuremath{\widehat{#1}}}}}
682 \newcommand*\{\direction}[1]{\ensuremath{\mathrm{mivector}\{#1\}}}
683 \newcommand*\{\vectordirection}{\direction}
684 \newcommand*\{\componentalong}[2]{\ensuremath{\mathrm{comp}_{\mathrm{#1}\{#2\}}}}
685 \newcommand*\{\expcomponentalong}[2]{\ensuremath{\mathrm{frac}\{\mathrm{vectdotvect}\{#2\}\{#1\}\}}}
686 {\magof{#1}}}}
687 \newcommand*\{\ucomponentalong}[2]{\ensuremath{\mathrm{vectdotvect}\{#2\}\{#1\}}}
688 \newcommand*\{\projectiononto}[2]{\ensuremath{\mathrm{proj}_{\mathrm{#1}\{#2\}}}}
689 \newcommand*\{\expprojectiononto}[2]{\ensuremath{\mathrm{frac}\{\mathrm{vectdotvect}\{#2\}\{#1\}\}\mathrm{magof}\{#1\}}}
690 \inparens{\frac{\mathrm{vectdotvect}\{#2\}\{#1\}}{\mathrm{magof}\{#1\}}\frac{\mathrm{#1}\{\mathrm{magof}\{#1\}\}}{\mathrm{magof}\{#1\}}}
691 \newcommand*\{\uprojectiononto}[2]{\ensuremath{\mathrm{frac}\{\mathrm{vectdotvect}\{#2\}\{#1\}\}\mathrm{#1}}}
692 \inparens{\mathrm{vectdotvect}\{#2\}\{#1\}\mathrm{#1}}
693 \ifthenelse{\boolean{@optromanvectors}}
694   {\newcommand*\{\compvect}[2]{\ensuremath{\mathrm{ssub}\{\mathrm{#1}\}\{(\mathrm{#2})\}}}}
695   {\newcommand*\{\compvect}[2]{\ensuremath{\mathrm{ssub}\{#1\}\{(\mathrm{#2})\}}}}
696 \newcommand*\{\scompsvect}[1]{\ensuremath{\mathrm{lv}\mathrm{compvect}\{#1\}\{x\},\mathrm{compvect}\{#1\}\{y\},\mathrm{compvect}\{#1\}\{z\}\mathrm{rv}}}
697 \compvect{#1}{x},%
698 \compvect{#1}{y},%
699 \compvect{#1}{z}\rv}}
700 \newcommand*\{\scompsdirvect}[1]{\ensuremath{\mathrm{lv}\mathrm{compvect}\{\widehat{\mathrm{#1}}\}\{x\},\mathrm{compvect}\{\widehat{\mathrm{#1}}\}\{y\},\mathrm{compvect}\{\widehat{\mathrm{#1}}\}\{z\}\mathrm{rv}}}
701 \compvect{\widehat{\mathrm{#1}}}{x},%
702 \compvect{\widehat{\mathrm{#1}}}{y},%
703 \compvect{\widehat{\mathrm{#1}}}{z}\rv}}
704 \ifthenelse{\boolean{@optromanvectors}}
705   {\newcommand*\{\compdirvect}[2]{\ensuremath{\mathrm{ssub}\{\widehat{\mathrm{#1}}\}\{(\mathrm{#2})\}}}}
706   {\newcommand*\{\compdirvect}[2]{\ensuremath{\mathrm{ssub}\{\widehat{\mathrm{#1}}\}\{(\mathrm{#2})\}}}}
707   {\newcommand*\{\compdirvect}[2]{\ensuremath{\mathrm{ssub}\{\widehat{\mathrm{#1}}\}\{(\mathrm{#2})\}}}}
708   {\newcommand*\{\compdirvect}[2]{\ensuremath{\mathrm{ssub}\{\widehat{\mathrm{#1}}\}\{(\mathrm{#2})\}}}}
709 \newcommand*\{\magvectscomps}[1]{\ensuremath{\mathrm{sqrt}\{\mathrm{compvect}\{#1\}\{x\}\mathrm{squared} + \mathrm{compvect}\{#1\}\{y\}\mathrm{squared} + \mathrm{compvect}\{#1\}\{z\}\mathrm{squared}\}}}
710 \compvect{#1}{x}\squared +%
711 \compvect{#1}{y}\squared +%
712 \compvect{#1}{z}\squared}}
713 \newcommand*\{\dvect}[1]{\ensuremath{\mathrm{d}\mathrm{vect}\{#1\}}}
714 \newcommand*\{\Dvect}[1]{\ensuremath{\mathrm{Delta}\mathrm{vect}\{#1\}}}

```



```

715 \newcommand*{\dirvect}[1]{\ensuremath{\widehat{\dvect{#1}}}}
716 \newcommand*{\dirDvect}[1]{\ensuremath{\widehat{\Dvect{#1}}}}
717 \newcommand*{\ddirvect}[1]{\ensuremath{\mathrm{d}\dirvect{#1}}}
718 \newcommand*{\ddirection}{\ddirvect}
719 \newcommand*{\Ddirvect}[1]{\ensuremath{\Delta\dirvect{#1}}}
720 \newcommand*{\Ddirection}{\Ddirvect}
721 \ifthenelse{\boolean{@optsinglemagbars}}
722   {\newcommand*{\magdvect}[1]{\ensuremath{\absof{\dvect{#1}}}}}
723   {\newcommand*{\magDvect}[1]{\ensuremath{\absof{\Dvect{#1}}}}}
724   {\newcommand*{\magdvect}[1]{\ensuremath{\magof{\dvect{#1}}}}}
725   {\newcommand*{\magDvect}[1]{\ensuremath{\magof{\Dvect{#1}}}}}
726 \newcommand*{\compdvect}[2]{\ensuremath{\mathrm{d}\compvect{#1}{#2}}}
727 \newcommand*{\compDvect}[2]{\ensuremath{\Delta\compvect{#1}{#2}}}
728 \newcommand*{\scompsdvect}[1]{\ensuremath{\lv%
729   \compdvect{#1}{x},%
730   \compdvect{#1}{y},%
731   \compdvect{#1}{z}\rv}}
732 \newcommand*{\scompsDvect}[1]{\ensuremath{\lv%
733   \compDvect{#1}{x},%
734   \compDvect{#1}{y},%
735   \compDvect{#1}{z}\rv}}
736 \newcommand*{\dervect}[2]{\ensuremath{\frac{\dvect{#1}}{\mathrm{d}{#2}}}}
737 \newcommand*{\Dervect}[2]{\ensuremath{\frac{\Dvect{#1}}{\Delta{#2}}}}
738 \newcommand*{\compdervect}[3]{\ensuremath{\dbyd{\compvect{#1}{#2}}{#3}}}
739 \newcommand*{\compDervect}[3]{\ensuremath{\DbyD{\compvect{#1}{#2}}{#3}}}
740 \newcommand*{\scompsdervect}[2]{\ensuremath{\lv%
741   \compdervect{#1}{x}{#2},%
742   \compdervect{#1}{y}{#2},%
743   \compdervect{#1}{z}{#2}\rv}}
744 \newcommand*{\scompsDervect}[2]{\ensuremath{\lv%
745   \compDervect{#1}{x}{#2},%
746   \compDervect{#1}{y}{#2},%
747   \compDervect{#1}{z}{#2}\rv}}
748 \ifthenelse{\boolean{@optsinglemagbars}}
749   {\newcommand*{\magdervect}[2]{\ensuremath{\absof{\dervect{#1}{#2}}}}}
750   {\newcommand*{\magDervect}[2]{\ensuremath{\absof{\Dervect{#1}{#2}}}}}
751   {\newcommand*{\magdervect}[2]{\ensuremath{\magof{\dervect{#1}{#2}}}}}
752   {\newcommand*{\magDervect}[2]{\ensuremath{\magof{\Dervect{#1}{#2}}}}}
753 \newcommand*{\dermagvect}[2]{\ensuremath{\dbyd{\magvect{#1}}{#2}}}
754 \newcommand*{\Dermagvect}[2]{\ensuremath{\DbyD{\magvect{#1}}{#2}}}
755 \newcommand*{\derdirvect}[2]{\ensuremath{\dbyd{\dirvect{#1}}{#2}}}
756 \newcommand*{\derdirection}{\derdirvect}
757 \newcommand*{\Derdirvect}[2]{\ensuremath{\DbyD{\dirvect{#1}}{#2}}}
758 \newcommand*{\Derdirection}{\Derdirvect}
759 \ifthenelse{\boolean{@optboldvectors}}
760   {\newcommand*{\vectsub}[2]{\ensuremath{\boldsymbol{#1}_{\text{\tiny{#2}}}}}}
761   {\ifthenelse{\boolean{@optromanvectors}}
762     {\newcommand*{\vectsub}[2]{\ensuremath{\vv{\mathrm{#1}}_{\text{\tiny{#2}}}}}}
763     {\newcommand*{\vectsub}[2]{\ensuremath{\vv{#1}_{\text{\tiny{#2}}}}}}}
764 \ifthenelse{\boolean{@optromanvectors}}

```

```

765 {\newcommand*\compvectsub}[3]{\ensuremath{\ssub{\mathrm{#1}}{#2},\,(#3\)}}}
766 {\newcommand*\compvectsub}[3]{\ensuremath{\ssub{#1}{#2},\,(#3\)}}}
767 \newcommand*\scompsvectsub[2]{\ensuremath{\lv%
768 \compvectsub{#1}{#2}{x},%
769 \compvectsub{#1}{#2}{y},%
770 \compvectsub{#1}{#2}{z}\rv}}
771 \ifthenelse{\boolean{@optsinglemagbars}}{
772 {\newcommand*\magvectsub}[2]{\ensuremath{\absof{\vectsub{#1}{#2}}}}
773 {\newcommand*\magvectsub}[2]{\ensuremath{\magof{\vectsub{#1}{#2}}}}
774 \newcommand*\magsquaredvectsub[2]{\ensuremath{\magvectsub{#1}{#2}\squared}}
775 \newcommand*\magnvectsub[3]{\ensuremath{\magvectsub{#1}{#2}^{\#3}}}
776 \newcommand*\magvectsubcomps[2]{\ensuremath{\sqrt{%
777 \compvectsub{#1}{#2}{x}\squared +%
778 \compvectsub{#1}{#2}{y}\squared +%
779 \compvectsub{#1}{#2}{z}\squared}}}
780 \ifthenelse{\boolean{@optromanvectors}}{
781 {\newcommand*\dirvectsub}[2]{\ensuremath{\ssub{\widehat{\mathrm{#1}}}{#2}}}}
782 {\newcommand*\dirvectsub}[2]{\ensuremath{\ssub{\widehat{#1}}{#2}}}}
783 \newcommand*\directionsub{\dirvectsub}
784 \newcommand*\dvectsub[2]{\ensuremath{\mathrm{d}\vectsub{#1}{#2}}}
785 \newcommand*\Dvectsub[2]{\ensuremath{\Delta\vectsub{#1}{#2}}}
786 \newcommand*\compdvectsub[3]{\ensuremath{\mathrm{d}\compvectsub{#1}{#2}{#3}}}
787 \newcommand*\compDvectsub[3]{\ensuremath{\Delta\compvectsub{#1}{#2}{#3}}}
788 \newcommand*\scompsdvectsub[2]{\ensuremath{\lv%
789 \compdvectsub{#1}{#2}{x},%
790 \compdvectsub{#1}{#2}{y},%
791 \compdvectsub{#1}{#2}{z}\rv}}
792 \newcommand*\scompsDvectsub[2]{\ensuremath{\lv%
793 \compDvectsub{#1}{#2}{x},%
794 \compDvectsub{#1}{#2}{y},%
795 \compDvectsub{#1}{#2}{z}\rv}}
796 \newcommand*\dermagvectsub[3]{\ensuremath{\dbyd{\magvectsub{#1}{#2}}{#3}}}
797 \newcommand*\Dermagvectsub[3]{\ensuremath{\DbyD{\magvectsub{#1}{#2}}{#3}}}
798 \newcommand*\derdvectsub[3]{\ensuremath{\dbyd{\vectsub{#1}{#2}}{#3}}}
799 \newcommand*\Derdvectsub[3]{\ensuremath{\DbyD{\vectsub{#1}{#2}}{#3}}}
800 \ifthenelse{\boolean{@optsinglemagbars}}{
801 {\newcommand*\magderdvectsub[3]{\ensuremath{\absof{\derdvectsub{#1}{#2}{#3}}}}
802 \newcommand*\magDerdvectsub[3]{\ensuremath{\absof{\Derdvectsub{#1}{#2}{#3}}}}
803 {\newcommand*\magderdvectsub[3]{\ensuremath{\magof{\derdvectsub{#1}{#2}{#3}}}}
804 \newcommand*\magDerdvectsub[3]{\ensuremath{\magof{\Derdvectsub{#1}{#2}{#3}}}}
805 \newcommand*\compderdvectsub[4]{\ensuremath{\dbyd{\compvectsub{#1}{#2}{#3}}{#4}}}
806 \newcommand*\compDerdvectsub[4]{\ensuremath{\DbyD{\compvectsub{#1}{#2}{#3}}{#4}}}
807 \newcommand*\scompsderdvectsub[3]{\ensuremath{\lv%
808 \compderdvectsub{#1}{#2}{x}{#3},%
809 \compderdvectsub{#1}{#2}{y}{#3},%
810 \compderdvectsub{#1}{#2}{z}{#3}\rv}}
811 \newcommand*\scompsDerdvectsub[3]{\ensuremath{\lv%
812 \compDerdvectsub{#1}{#2}{x}{#3},%
813 \compDerdvectsub{#1}{#2}{y}{#3},%
814 \compDerdvectsub{#1}{#2}{z}{#3}\rv}}

```

```

815 \newcommand*\vectdotvect}[2]{\ensuremath{\#1\bullet\#2}}
816 \newcommand*\vectdotsvect}[2]{\ensuremath{\scompsvect{\#1}\bullet\scompsvect{\#2}}}
817 \newcommand*\vectdotevect}[2]{\ensuremath{%
818   \compvect{\#1}{x}\compvect{\#2}{x}+%
819   \compvect{\#1}{y}\compvect{\#2}{y}+%
820   \compvect{\#1}{z}\compvect{\#2}{z}}}
821 \newcommand*\vectdotsdvect}[2]{\ensuremath{\scompsvect{\#1}\bullet\scompsdvect{\#2}}}
822 \newcommand*\vectdotsDvect}[2]{\ensuremath{\scompsvect{\#1}\bullet\scompsDvect{\#2}}}
823 \newcommand*\vectdotedvect}[2]{\ensuremath{%
824   \compvect{\#1}{x}\compdvect{\#2}{x}+%
825   \compvect{\#1}{y}\compdvect{\#2}{y}+%
826   \compvect{\#1}{z}\compdvect{\#2}{z}}}
827 \newcommand*\vectdoteDvect}[2]{\ensuremath{%
828   \compvect{\#1}{x}\compDvect{\#2}{x}+%
829   \compvect{\#1}{y}\compDvect{\#2}{y}+%
830   \compvect{\#1}{z}\compDvect{\#2}{z}}}
831 \newcommand*\vectsubdotsvectsub}[4]{\ensuremath{%
832   \scompsvectsub{\#1}{\#2}\bullet\scompsvectsub{\#3}{\#4}}}
833 \newcommand*\vectsubdotevectsub}[4]{\ensuremath{%
834   \compvectsub{\#1}{\#2}{x}\compvectsub{\#3}{\#4}{x}+%
835   \compvectsub{\#1}{\#2}{y}\compvectsub{\#3}{\#4}{y}+%
836   \compvectsub{\#1}{\#2}{z}\compvectsub{\#3}{\#4}{z}}}
837 \newcommand*\vectsubdotsdvectsub}[4]{\ensuremath{%
838   \scompsvectsub{\#1}{\#2}\bullet\scompsdvectsub{\#3}{\#4}}}
839 \newcommand*\vectsubdotsDvectsub}[4]{\ensuremath{%
840   \scompsvectsub{\#1}{\#2}\bullet\scompsDvectsub{\#3}{\#4}}}
841 \newcommand*\vectsubdotedvectsub}[4]{\ensuremath{%
842   \compvectsub{\#1}{\#2}{x}\compdvectsub{\#3}{\#4}{x}+%
843   \compvectsub{\#1}{\#2}{y}\compdvectsub{\#3}{\#4}{y}+%
844   \compvectsub{\#1}{\#2}{z}\compdvectsub{\#3}{\#4}{z}}}
845 \newcommand*\vectsubdoteDvectsub}[4]{\ensuremath{%
846   \compvectsub{\#1}{\#2}{x}\compDvectsub{\#3}{\#4}{x}+%
847   \compvectsub{\#1}{\#2}{y}\compDvectsub{\#3}{\#4}{y}+%
848   \compvectsub{\#1}{\#2}{z}\compDvectsub{\#3}{\#4}{z}}}
849 \newcommand*\vectsubdotsdvect}[3]{\ensuremath{%
850   \scompsvectsub{\#1}{\#2}\bullet\scompsdvect{\#3}}}
851 \newcommand*\vectsubdotsDvect}[3]{\ensuremath{%
852   \scompsvectsub{\#1}{\#2}\bullet\scompsDvect{\#3}}}
853 \newcommand*\vectsubdotedvect}[3]{\ensuremath{%
854   \compvectsub{\#1}{\#2}{x}\compdvect{\#3}{x}+%
855   \compvectsub{\#1}{\#2}{y}\compdvect{\#3}{y}+%
856   \compvectsub{\#1}{\#2}{z}\compdvect{\#3}{z}}}
857 \newcommand*\vectsubdoteDvect}[3]{\ensuremath{%
858   \compvectsub{\#1}{\#2}{x}\compDvect{\#3}{x}+%
859   \compvectsub{\#1}{\#2}{y}\compDvect{\#3}{y}+%
860   \compvectsub{\#1}{\#2}{z}\compDvect{\#3}{z}}}
861 \newcommand*\dervectdotsvect}[3]{\ensuremath{%
862   \scompsdervect{\#1}{\#2}\bullet\scompsvect{\#3}}}
863 \newcommand*\Dervectdotsvect}[3]{\ensuremath{%
864   \scompsDervect{\#1}{\#2}\bullet\scompsvect{\#3}}}

```

```

865 \newcommand*\dervectdotevect}[3]{\ensuremath{%
866   \compdervect{#1}{x}{#2}\compvect{#3}{x}+%
867   \compdervect{#1}{y}{#2}\compvect{#3}{y}+%
868   \compdervect{#1}{z}{#2}\compvect{#3}{z}}}
869 \newcommand*\Dervectdotevect}[3]{\ensuremath{%
870   \compDervect{#1}{x}{#2}\compvect{#3}{x}+%
871   \compDervect{#1}{y}{#2}\compvect{#3}{y}+%
872   \compDervect{#1}{z}{#2}\compvect{#3}{z}}}
873 \newcommand*\vectdotsdervect}[3]{\ensuremath{%
874   \scompsvect{#1}\bullet\scompsdervect{#2}{#3}}}
875 \newcommand*\vectdotsDervect}[3]{\ensuremath{%
876   \scompsvect{#1}\bullet\scompsDervect{#2}{#3}}}
877 \newcommand*\vectdotedervect}[3]{\ensuremath{%
878   \compvect{#1}{x}\compdervect{#2}{x}{#3}+%
879   \compvect{#1}{y}\compdervect{#2}{y}{#3}+%
880   \compvect{#1}{z}\compdervect{#2}{z}{#3}}}
881 \newcommand*\vectdoteDervect}[3]{\ensuremath{%
882   \compvect{#1}{x}\compDervect{#2}{x}{#3}+%
883   \compvect{#1}{y}\compDervect{#2}{y}{#3}+%
884   \compvect{#1}{z}\compDervect{#2}{z}{#3}}}
885 \newcommand*\dervectdotsdvect}[3]{\ensuremath{%
886   \scompsdervect{#1}{#2}\bullet\scompsdvect{#3}}}
887 \newcommand*\DervectdotsDvect}[3]{\ensuremath{%
888   \scompsDervect{#1}{#2}\bullet\scompsDvect{#3}}}
889 \newcommand*\dervectdotedvect}[3]{\ensuremath{%
890   \compdervect{#1}{x}{#2}\compdvect{#3}{x}+%
891   \compdervect{#1}{y}{#2}\compdvect{#3}{y}+%
892   \compdervect{#1}{z}{#2}\compdvect{#3}{z}}}
893 \newcommand*\DervectdoteDvect}[3]{\ensuremath{%
894   \compDervect{#1}{x}{#2}\compDvect{#3}{x}+%
895   \compDervect{#1}{y}{#2}\compDvect{#3}{y}+%
896   \compDervect{#1}{z}{#2}\compDvect{#3}{z}}}
897 \newcommand*\vectcrossvect}[2]{\ensuremath{%
898   {#1}\boldsymbol{\times}{#2}}}
899 \newcommand*\ltriplecross}[3]{\ensuremath{%
900   \inparens{#1}\boldsymbol{\times}{#2}\boldsymbol{\times}{#3}}}
901 \newcommand*\rtriplecross}[3]{\ensuremath{\inparens{#1}\boldsymbol{\times}%
902   \inparens{#2}\boldsymbol{\times}{#3}}}
903 \newcommand*\ltriplescalar}[3]{\ensuremath{%
904   {#1}\boldsymbol{\times}{#2}\bullet{#3}}}
905 \newcommand*\rtriplescalar}[3]{\ensuremath{%
906   {#1}\bullet{#2}\boldsymbol{\times}{#3}}}
907 \newcommand*\ezero{\ensuremath{\boldsymbol{e}_0}}
908 \newcommand*\eone{\ensuremath{\boldsymbol{e}_1}}
909 \newcommand*\etwo{\ensuremath{\boldsymbol{e}_2}}
910 \newcommand*\ethree{\ensuremath{\boldsymbol{e}_3}}
911 \newcommand*\efour{\ensuremath{\boldsymbol{e}_4}}
912 \newcommand*\ek[1]{\ensuremath{\boldsymbol{e}_{#1}}}
913 \newcommand*\e{\ek}
914 \newcommand*\uezero{\ensuremath{\widehat{\boldsymbol{e}}_0}}

```

```

915 \newcommand*\ueone{\ensuremath{\widehat{\boldsymbol{e}}_1}}
916 \newcommand*\uetwo{\ensuremath{\widehat{\boldsymbol{e}}_2}}
917 \newcommand*\uthree{\ensuremath{\widehat{\boldsymbol{e}}_3}}
918 \newcommand*\uefour{\ensuremath{\widehat{\boldsymbol{e}}_4}}
919 \newcommand*\uek[1]{\ensuremath{\widehat{\boldsymbol{e}}_{\#1}}}
920 \newcommand*\ue{\uek}
921 \newcommand*\ezerozero{\ek{00}}
922 \newcommand*\ezeroone{\ek{01}}
923 \newcommand*\ezerotwo{\ek{02}}
924 \newcommand*\ezerothree{\ek{03}}
925 \newcommand*\ezerofour{\ek{04}}
926 \newcommand*\eoneone{\ek{11}}
927 \newcommand*\eonetwo{\ek{12}}
928 \newcommand*\eonethree{\ek{13}}
929 \newcommand*\eonefour{\ek{14}}
930 \newcommand*\etwoone{\ek{21}}
931 \newcommand*\etwotwo{\ek{22}}
932 \newcommand*\etwothree{\ek{23}}
933 \newcommand*\etwofour{\ek{24}}
934 \newcommand*\ethreeone{\ek{31}}
935 \newcommand*\ethreetwo{\ek{32}}
936 \newcommand*\ethreethree{\ek{33}}
937 \newcommand*\ethreefour{\ek{34}}
938 \newcommand*\efourone{\ek{41}}
939 \newcommand*\efourtwo{\ek{42}}
940 \newcommand*\efourthree{\ek{43}}
941 \newcommand*\efourfour{\ek{44}}
942 \newcommand*\euzero{\ensuremath{\boldsymbol{e}^0}}
943 \newcommand*\euone{\ensuremath{\boldsymbol{e}^1}}
944 \newcommand*\eutwo{\ensuremath{\boldsymbol{e}^2}}
945 \newcommand*\euthree{\ensuremath{\boldsymbol{e}^3}}
946 \newcommand*\eufour{\ensuremath{\boldsymbol{e}^4}}
947 \newcommand*\euk[1]{\ensuremath{\boldsymbol{e}^{\#1}}}
948 \newcommand*\eu{\euk}
949 \newcommand*\uezero{\ensuremath{\widehat{\boldsymbol{e}}^0}}
950 \newcommand*\ueuone{\ensuremath{\widehat{\boldsymbol{e}}^1}}
951 \newcommand*\uetwo{\ensuremath{\widehat{\boldsymbol{e}}^2}}
952 \newcommand*\ueuthree{\ensuremath{\widehat{\boldsymbol{e}}^3}}
953 \newcommand*\ueufour{\ensuremath{\widehat{\boldsymbol{e}}^4}}
954 \newcommand*\uek[1]{\ensuremath{\widehat{\boldsymbol{e}}^{\#1}}}
955 \newcommand*\ueu{\uek}
956 \newcommand*\euzerozero{\euk{00}}
957 \newcommand*\euzeroone{\euk{01}}
958 \newcommand*\euzerotwo{\euk{02}}
959 \newcommand*\euzerothree{\euk{03}}
960 \newcommand*\euzerofour{\euk{04}}
961 \newcommand*\euoneone{\euk{11}}
962 \newcommand*\euonetwo{\euk{12}}
963 \newcommand*\euonethree{\euk{13}}
964 \newcommand*\euonefour{\euk{14}}

```

```

965 \newcommand*\eutwoone{\euk{21}}
966 \newcommand*\eutwotwo{\euk{22}}
967 \newcommand*\eutwothree{\euk{23}}
968 \newcommand*\eutwofour{\euk{24}}
969 \newcommand*\euthreeone{\euk{31}}
970 \newcommand*\euthreetwo{\euk{32}}
971 \newcommand*\euthreethree{\euk{33}}
972 \newcommand*\euthreefour{\euk{34}}
973 \newcommand*\eufourone{\euk{41}}
974 \newcommand*\eufourtwo{\euk{42}}
975 \newcommand*\eufourthree{\euk{43}}
976 \newcommand*\eufourfour{\euk{44}}
977 \newcommand*\gzero{\ensuremath{\boldsymbol{\gamma}_0}}
978 \newcommand*\gone{\ensuremath{\boldsymbol{\gamma}_1}}
979 \newcommand*\gtwo{\ensuremath{\boldsymbol{\gamma}_2}}
980 \newcommand*\gthree{\ensuremath{\boldsymbol{\gamma}_3}}
981 \newcommand*\gfour{\ensuremath{\boldsymbol{\gamma}_4}}
982 \newcommand*\gk[1]{\ensuremath{\boldsymbol{\gamma}_{\#1}}}
983 \newcommand*\g{\gk}
984 \newcommand*\gzerozero{\gk{00}}
985 \newcommand*\gzeroone{\gk{01}}
986 \newcommand*\gzerotwo{\gk{02}}
987 \newcommand*\gzerothree{\gk{03}}
988 \newcommand*\gzerofour{\gk{04}}
989 \newcommand*\goneone{\gk{11}}
990 \newcommand*\gonetwo{\gk{12}}
991 \newcommand*\gonethree{\gk{13}}
992 \newcommand*\gonefour{\gk{14}}
993 \newcommand*\gtwoone{\gk{21}}
994 \newcommand*\gtwotwo{\gk{22}}
995 \newcommand*\gtwothree{\gk{23}}
996 \newcommand*\gtwofour{\gk{24}}
997 \newcommand*\gthreeone{\gk{31}}
998 \newcommand*\gthreetwo{\gk{32}}
999 \newcommand*\gthreethree{\gk{33}}
1000 \newcommand*\gthreefour{\gk{34}}
1001 \newcommand*\gfourone{\gk{41}}
1002 \newcommand*\gfourtwo{\gk{42}}
1003 \newcommand*\gfourthree{\gk{43}}
1004 \newcommand*\gfourfour{\gk{44}}
1005 \newcommand*\guzero{\ensuremath{\boldsymbol{\gamma}^0}}
1006 \newcommand*\guone{\ensuremath{\boldsymbol{\gamma}^1}}
1007 \newcommand*\gutwo{\ensuremath{\boldsymbol{\gamma}^2}}
1008 \newcommand*\guthree{\ensuremath{\boldsymbol{\gamma}^3}}
1009 \newcommand*\gufour{\ensuremath{\boldsymbol{\gamma}^4}}
1010 \newcommand*\guk[1]{\ensuremath{\boldsymbol{\gamma}^{\#1}}}
1011 \newcommand*\gu{\guk}
1012 \newcommand*\guzerozero{\guk{00}}
1013 \newcommand*\guzeroone{\guk{01}}
1014 \newcommand*\guzerotwo{\guk{02}}

```

```

1015 \newcommand*\guzerothree{\guk{03}}
1016 \newcommand*\guzerofour{\guk{04}}
1017 \newcommand*\guoneone{\guk{11}}
1018 \newcommand*\guonetwo{\guk{12}}
1019 \newcommand*\guonethree{\guk{13}}
1020 \newcommand*\guonefour{\guk{14}}
1021 \newcommand*\gutwoone{\guk{21}}
1022 \newcommand*\gutwotwo{\guk{22}}
1023 \newcommand*\gutwothree{\guk{23}}
1024 \newcommand*\gutwofour{\guk{24}}
1025 \newcommand*\guthreeone{\guk{31}}
1026 \newcommand*\guthreetwo{\guk{32}}
1027 \newcommand*\guthreethree{\guk{33}}
1028 \newcommand*\guthreefour{\guk{34}}
1029 \newcommand*\gufourone{\guk{41}}
1030 \newcommand*\gufourtwo{\guk{42}}
1031 \newcommand*\gufourthree{\guk{43}}
1032 \newcommand*\gufourfour{\guk{44}}
1033 \ExplSyntaxOn % Vectors formatted as in M&I, written in LaTeX3
1034 \NewDocumentCommand{\mivector}{ 0{,} m o }{%
1035   {%
1036     \mi_vector:nn { #1 } { #2 }
1037     \IfValueT{#3}{\,;{#3}}
1038   }%
1039 \seq_new:N \l__mi_list_seq
1040 \cs_new_protected:Npn \mi_vector:nn #1 #2
1041 {%
1042   \ensuremath{%
1043     \seq_set_split:Nnn \l__mi_list_seq { , } { #2 }
1044     \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \left\langle }
1045     \seq_use:Nnnn \l__mi_list_seq { #1 } { #1 } { #1 }
1046     \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \right\rangle }
1047   }%
1048 }%
1049 \ExplSyntaxOff
1050 \ExplSyntaxOn % Column and row vectors, written in LaTeX3
1051 \seq_new:N \l__vector_arg_seq
1052 \cs_new_protected:Npn \vector_main:nnnn #1 #2 #3 #4
1053 {%
1054   \seq_set_split:Nnn \l__vector_arg_seq { #3 } { #4 }
1055   \begin{#1matrix}
1056     \seq_use:Nnnn \l__vector_arg_seq { #2 } { #2 } { #2 }
1057   \end{#1matrix}
1058 }%
1059 \NewDocumentCommand{\rowvector}{ 0{,} m }
1060 {%
1061   \ensuremath{
1062     \vector_main:nnnn { p } { \, , \, } { #1 } { #2 }
1063   }%
1064 }%

```

```

1065 \NewDocumentCommand{\colvector}{ 0{,} m }
1066 {%
1067   \ensuremath{
1068     \vector_main:nnnn { p } { \ } { #1 } { #2 }
1069   }%
1070 }%
1071 \ExplSyntaxOff
1072 \newcommandx{\scompscvect}[2][1,usedefault]{%
1073   \ifthenelse{\equal{#1}{}}{%
1074     {%
1075       \colvector{\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
1076     }%
1077     {%
1078       \colvector{\msub{#2}{0},\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
1079     }%
1080 }%
1081 \newcommandx{\scompscvect}[2][1,usedefault]{%
1082   \ifthenelse{\equal{#1}{}}{%
1083     {%
1084       \colvector{\msup{#2}{1},\msup{#2}{2},\msup{#2}{3}}%
1085     }%
1086     {%
1087       \colvector{\msup{#2}{0},\msup{#2}{1},\msup{#2}{2},\msup{#2}{3}}%
1088     }%
1089 }%
1090 \newcommandx{\scompsrvect}[2][1,usedefault]{%
1091   \ifthenelse{\equal{#1}{}}{%
1092     {%
1093       \rowvector[,]{\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
1094     }%
1095     {%
1096       \rowvector[,]{\msub{#2}{0},\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
1097     }%
1098 }%
1099 \newcommandx{\scompsRvect}[2][1,usedefault]{%
1100   \ifthenelse{\equal{#1}{}}{%
1101     {%
1102       \rowvector[,]{\msup{#2}{1},\msup{#2}{2},\msup{#2}{3}}%
1103     }%
1104     {%
1105       \rowvector[,]{\msup{#2}{0},\msup{#2}{1},\msup{#2}{2},\msup{#2}{3}}%
1106     }%
1107 }%
1108 \newcommand*{\bra}[1]{\ensuremath{\left\langle\!#1\right|\!}}
1109 \newcommand*{\ket}[1]{\ensuremath{\left|\!#1\right\rangle}}
1110 \newcommand*{\bracket}[2]{\ensuremath{\left\langle\!#1\right|\!#2\right\rangle}}
1111 \left|\!#2\right\rangle}
1112 \newphysicsconstant{oofpez}%
1113 {\ensuremath{\frac{1}{\phantom{o}4\pi\epsilon_0}}}%
1114 {\mi@p{9}{8.9876}\timestento{9}}%

```


1115 $\{\text{m}^3\text{kg}\text{us}\text{reciprocalquartic}\text{s}\text{us}\text{A}\text{reciprocalssquared}\}$ %
1116 $[\text{m}\text{per}\text{farad}]$ %
1117 $[\text{newton}\text{us}\text{m}\text{squared}\text{per}\text{coulomb}\text{squared}]$ %
1118 $\text{newphysicsconstant}\{\text{ofpezc}\}$ %
1119 $\{\text{ensuremath}\{\frac{1}{\text{phantom}\{0\}^4\pi\epsilon_0 c^2\text{phantom}\{0\}}\}\}$ %
1120 $\{\text{tento}\{-7\}\}$ %
1121 $\{\text{m}\text{us}\text{kg}\text{us}\text{s}\text{reciprocalssquared}\text{us}\text{A}\text{reciprocalssquared}\}$ %
1122 $[\text{T}\text{us}\text{m}\text{squared}]$ %
1123 $[\text{N}\text{us}\text{s}\text{squared}\text{per}\text{C}\text{squared}]$ %
1124 $\text{newphysicsconstant}\{\text{vacuumpermittivity}\}$ %
1125 $\{\text{ensuremath}\{\epsilon_0\}\}$ %
1126 $\{\text{mi}\text{p}\{9.0\}\{8.8542\}\text{timestento}\{-12\}\}$ %
1127 $\{\text{m}\text{reciprocalcubed}\text{us}\text{reciprocal}\text{kg}\text{us}\text{s}\text{quarted}\text{us}\text{A}\text{squared}\}$ %
1128 $[\text{F}\text{per}\text{m}]$ %
1129 $[\text{C}\text{squared}\text{per}\text{N}\text{us}\text{m}\text{squared}]$ %
1130 $\text{newphysicsconstant}\{\text{mzofp}\}$ %
1131 $\{\text{ensuremath}\{\frac{\text{phantom}\{0\}\mu_0\text{phantom}\{0\}}{4\pi}\}\}$ %
1132 $\{\text{tento}\{-7\}\}$ %
1133 $\{\text{m}\text{us}\text{kg}\text{us}\text{s}\text{reciprocalssquared}\text{us}\text{A}\text{reciprocalssquared}\}$ %
1134 $[\text{henry}\text{per}\text{m}]$ %
1135 $[\text{tesla}\text{us}\text{m}\text{per}\text{A}]$ %
1136 $\text{newphysicsconstant}\{\text{vacuumpermeability}\}$ %
1137 $\{\text{ensuremath}\{\mu_0\}\}$ %
1138 $\{4\pi\text{timestento}\{-7\}\}$ %
1139 $\{\text{m}\text{us}\text{kg}\text{us}\text{s}\text{reciprocalssquared}\text{us}\text{A}\text{reciprocalssquared}\}$ %
1140 $[\text{henry}\text{per}\text{m}]$ %
1141 $[\text{T}\text{us}\text{m}\text{per}\text{A}]$ %
1142 $\text{newphysicsconstant}\{\text{boltzmann}\}$ %
1143 $\{\text{ensuremath}\{k_B\}\}$ %
1144 $\{\text{mi}\text{p}\{1.4\}\{1.3806\}\text{timestento}\{-23\}\}$ %
1145 $\{\text{m}\text{squared}\text{us}\text{kg}\text{us}\text{reciprocalsquare}\text{s}\text{us}\text{reciprocal}\text{K}\}$ %
1146 $[\text{joule}\text{per}\text{K}]$ %
1147 $[\text{J}\text{per}\text{K}]$ %
1148 $\text{newphysicsconstant}\{\text{boltzmannineV}\}$ %
1149 $\{\text{ensuremath}\{k_B\}\}$ %
1150 $\{\text{mi}\text{p}\{8.6\}\{8.6173\}\text{timestento}\{-5\}\}$ %
1151 $\{\text{eV}\text{us}\text{reciprocal}\text{K}\}$ %
1152 $[\text{eV}\text{per}\text{K}]$ %
1153 $[\text{eV}\text{per}\text{K}]$ %
1154 $\text{newphysicsconstant}\{\text{stefanboltzmann}\}$ %
1155 $\{\text{ensuremath}\{\sigma\}\}$ %
1156 $\{\text{mi}\text{p}\{5.7\}\{5.6704\}\text{timestento}\{-8\}\}$ %
1157 $\{\text{kg}\text{us}\text{s}\text{reciprocalcubed}\text{us}\text{K}\text{reciprocalquarted}\}$ %
1158 $[\text{W}\text{per}\text{m}\text{squared}\text{us}\text{K}^4]$ %
1159 $[\text{W}\text{per}\text{m}\text{squared}\text{us}\text{K}\text{quarted}]$ %
1160 $\text{newphysicsconstant}\{\text{planck}\}$ %
1161 $\{\text{ensuremath}\{h\}\}$ %
1162 $\{\text{mi}\text{p}\{6.6\}\{6.6261\}\text{timestento}\{-34\}\}$ %
1163 $\{\text{m}\text{squared}\text{us}\text{kg}\text{us}\text{reciprocal}\text{s}\}$ %
1164 $[\text{J}\text{us}\text{s}]$ %

```

1165 [\J\usk\s]
1166 \newphysicsconstant{planckineV}%
1167 {\ensuremath{h}}%
1168 {\mi@p{4.1}{4.1357}\timestento{-15}}%
1169 {\eV\usk\s}%
1170 [\eV\usk\s]%
1171 [\eV\usk\s]
1172 \newphysicsconstant{planckbar}%
1173 {\ensuremath{\hslash}}%
1174 {\mi@p{1.1}{1.0546}\timestento{-34}}%
1175 {\m\squared\usk\kg\usk\reciprocal\s}%
1176 [\J\usk\s]%
1177 [\J\usk\s]
1178 \newphysicsconstant{planckbarineV}%
1179 {\ensuremath{\hslash}}%
1180 {\mi@p{6.6}{6.5821}\timestento{-16}}%
1181 {\eV\usk\s}%
1182 [\eV\usk\s]%
1183 [\eV\usk\s]
1184 \newphysicsconstant{planckc}%
1185 {\ensuremath{hc}}%
1186 {\mi@p{2.0}{1.9864}\timestento{-25}}%
1187 {\m\cubed\usk\kg\usk\reciprocalsquare\s}%
1188 [\J\usk\m]%
1189 [\J\usk\m]
1190 \newphysicsconstant{planckcineV}%
1191 {\ensuremath{hc}}%
1192 {\mi@p{2.0}{1.9864}\timestento{-25}}%
1193 {\eV\usk\text{n}\m}%
1194 [\eV\usk\text{n}\m]%
1195 [\eV\usk\text{n}\m]
1196 \newphysicsconstant{rydberg}%
1197 {\ensuremath{\msub{R}{\infty}}}%
1198 {\mi@p{1.1}{1.0974}\timestento{7}}%
1199 {\reciprocal\m}%
1200 [\reciprocal\m]%
1201 [\reciprocal\m]
1202 \newphysicsconstant{bohrradius}%
1203 {\ensuremath{a_0}}%
1204 {\mi@p{5.3}{5.2918}\timestento{-11}}%
1205 {\m}%
1206 [\m]%
1207 [\m]
1208 \newphysicsconstant{finestructure}%
1209 {\ensuremath{\alpha}}%
1210 {\mi@p{\frac{1}{137}}{7.2974}\timestento{-3}}%
1211 {}%
1212 []%
1213 []
1214 \newphysicsconstant{avogadro}%

```

```

1215 {\ensuremath{N_A}}%
1216 {\mi@p{6.0}{6.0221}\timestento{23}}%
1217 {\reciprocal\mol}%
1218 [\reciprocal\mol]%
1219 [\reciprocal\mol]
1220 \newphysicsconstant{universalgrav}%
1221 {\ensuremath{G}}%
1222 {\mi@p{6.7}{6.6738}\timestento{-11}}%
1223 {\m\cubed\usk\reciprocal\kg\usk\s\reciprocalssquared}%
1224 [\J\usk\m\per\kg\squared]%
1225 [\N\usk\m\squared\per\kg\squared]
1226 \newphysicsconstant{surfacegravfield}%
1227 {\ensuremath{g}}%
1228 {\mi@p{9.8}{9.80}}%
1229 {\m\usk\s\reciprocalssquared}%
1230 [\N\per\kg]%
1231 [\N\per\kg]
1232 \newphysicsconstant{clight}%
1233 {\ensuremath{c}}%
1234 {\mi@p{3}{2.9979}\timestento{8}}%
1235 {\m\usk\reciprocal\s}%
1236 [\m\per\s]%
1237 [\m\per\s]
1238 \newphysicsconstant{clightinfeet}%
1239 {\ensuremath{c}}%
1240 {\mi@p{1}{0.9836}}%
1241 {\text{ft}\usk\reciprocal{\text{n}\s}}%
1242 [\text{ft}\per\text{n}\s]%
1243 [\text{ft}\per\mathrm{n}\s]
1244 \newphysicsconstant{Ratom}%
1245 {\ensuremath{r_{\text{atom}}}}%
1246 {\tento{-10}}%
1247 {\m}%
1248 [\m]%
1249 [\m]
1250 \newphysicsconstant{Mproton}%
1251 {\ensuremath{m_p}}%
1252 {\mi@p{1.7}{1.6726}\timestento{-27}}%
1253 {\kg}%
1254 [\kg]%
1255 [\kg]
1256 \newphysicsconstant{Mneutron}%
1257 {\ensuremath{m_n}}%
1258 {\mi@p{1.7}{1.6749}\timestento{-27}}%
1259 {\kg}%
1260 [\kg]%
1261 [\kg]
1262 \newphysicsconstant{Mhydrogen}%
1263 {\ensuremath{m_H}}%
1264 {\mi@p{1.7}{1.6737}\timestento{-27}}%

```

```

1265 {\kg}%
1266 [\kg]%
1267 [\kg]
1268 \newphysicsconstant{Melectron}%
1269 {\ensuremath{m_e}}%
1270 {\mi@p{9.1}{9.1094}\timestento{-31}}%
1271 {\kg}%
1272 [\kg]%
1273 [\kg]
1274 \newphysicsconstant{echarge}%
1275 {\ensuremath{e}}%
1276 {\mi@p{1.6}{1.6022}\timestento{-19}}%
1277 {\A\usk\s}%
1278 [\C]%
1279 [\C]
1280 \newphysicsconstant{Qelectron}%
1281 {\ensuremath{Q_e}}%
1282 {-\echargevalue}%
1283 {\A\usk\s}%
1284 [\C]%
1285 [\C]
1286 \newphysicsconstant{qelectron}%
1287 {\ensuremath{q_e}}%
1288 {-\echargevalue}%
1289 {\A\usk\s}%
1290 [\C]%
1291 [\C]
1292 \newphysicsconstant{Qproton}%
1293 {\ensuremath{Q_p}}%
1294 {+\echargevalue}%
1295 {\A\usk\s}%
1296 [\C]%
1297 [\C]
1298 \newphysicsconstant{qproton}%
1299 {\ensuremath{q_p}}%
1300 {+\echargevalue}%
1301 {\A\usk\s}%
1302 [\C]%
1303 [\C]
1304 \newphysicsconstant{MEarth}%
1305 {\ensuremath{M_{\text{Earth}}}}%
1306 {\mi@p{6.0}{5.9736}\timestento{24}}%
1307 {\kg}%
1308 [\kg]%
1309 [\kg]
1310 \newphysicsconstant{MMoon}%
1311 {\ensuremath{M_{\text{Moon}}}}%
1312 {\mi@p{7.3}{7.3459}\timestento{22}}%
1313 {\kg}%
1314 [\kg]%

```

```

1315  [\kg]
1316 \newphysicsconstant{MSun}%
1317  {\ensuremath{M_{\text{Sun}}}}%
1318  {\mi@p{2.0}{1.9891}\timestento{30}}%
1319  {\kg}%
1320  [\kg]%
1321  [\kg]
1322 \newphysicsconstant{REarth}%
1323  {\ensuremath{R_{\text{Earth}}}}%
1324  {\mi@p{6.4}{6.3675}\timestento{6}}%
1325  {\m}%
1326  [\m]%
1327  [\m]
1328 \newphysicsconstant{RMoon}%
1329  {\ensuremath{R_{\text{Moon}}}}%
1330  {\mi@p{1.7}{1.7375}\timestento{6}}%
1331  {\m}%
1332  [\m]%
1333  [\m]
1334 \newphysicsconstant{RSun}%
1335  {\ensuremath{R_{\text{Sun}}}}%
1336  {\mi@p{7.0}{6.9634}\timestento{8}}%
1337  {\m}%
1338  [\m]%
1339  [\m]
1340 \newphysicsconstant{ESdist}%
1341  {\magvectsub{r}{ES}}%
1342  {\mi@p{1.5}{1.4960}\timestento{11}}%
1343  {\m}%
1344  [\m]%
1345  [\m]
1346 \newphysicsconstant{SEdist}%
1347  {\magvectsub{r}{SE}}%
1348  {\mi@p{1.5}{1.4960}\timestento{11}}%
1349  {\m}%
1350  [\m]%
1351  [\m]
1352 \newphysicsconstant{EMdist}%
1353  {\magvectsub{r}{EM}}%
1354  {\mi@p{3.8}{3.8440}\timestento{8}}%
1355  {\m}%
1356  [\m]%
1357  [\m]
1358 \newphysicsconstant{MEDist}%
1359  {\magvectsub{r}{ME}}%
1360  {\mi@p{3.8}{3.8440}\timestento{8}}%
1361  {\m}%
1362  [\m]%
1363  [\m]
1364 \newphysicsconstant{LSun}%

```

```

1365 {\ensuremath{L_{\text{Sun}}}}%
1366 {\mi@p{3.8}{3.8460}\timestento{26}}%
1367 {\m\squared\usk\kg\usk\s\reciprocalcubed}%
1368 [\W]
1369 [\J\per\s]
1370 \newphysicsconstant{TSun}%
1371 {\ensuremath{T_{\text{Sun}}}}%
1372 {\mi@p{5800}{5778}}%
1373 {\K}%
1374 [\K]%
1375 [\K]
1376 \newphysicsconstant{MagSun}%
1377 {\ensuremath{M_{\text{Sun}}}}%
1378 {+4.83}%
1379 {}%
1380 []%
1381 []
1382 \newphysicsconstant{magSun}%
1383 {\ensuremath{m_{\text{Sun}}}}%
1384 {-26.74}%
1385 {}%
1386 []%
1387 []
1388 \newcommand*{\coulombconstant}{\oofpez}
1389 \newcommand*{\altcoulombconstant}{\oofpezcs}
1390 \newcommand*{\biotsavartconstant}{\mzofp}
1391 \newcommand*{\boltzmannconstant}{\boltzmann}
1392 \newcommand*{\stefanboltzmannconstant}{\stefanboltzmann}
1393 \newcommand*{\planckconstant}{\planck}
1394 \newcommand*{\reducedplanckconstant}{\planckbar}
1395 \newcommand*{\planckconstanttimesc}{\planckc}
1396 \newcommand*{\rydbergconstant}{\rydberg}
1397 \newcommand*{\finestructureconstant}{\finestructure}
1398 \newcommand*{\avogadroconstant}{\avogadro}
1399 \newcommand*{\universalgravitationalconstant}{\universalgrav}
1400 \newcommand*{\earthssurfacegravitationalfield}{\surfacegravfield}
1401 \newcommand*{\photonconstant}{\clight}
1402 \newcommand*{\elementarycharge}{\echarge}
1403 \newcommand*{\EarthSundistance}{\ESdist}
1404 \newcommand*{\SunEarthdistance}{\SEdist}
1405 \newcommand*{\EarthMoondistance}{\ESdist}
1406 \newcommand*{\MoonEarthdistance}{\SEdist}
1407 \newcommand*{\Lstar}[1][\(\star\)]{\ensuremath{L_{\text{\scriptsize #1}}}\xspace}
1408 \newcommand*{\Lsolar}{\ensuremath{L_{\text{\scriptsize solar}}}\xspace}
1409 \newcommand*{\Tstar}[1][\(\star\)]{\ensuremath{T_{\text{\scriptsize #1}}}\xspace}
1410 \newcommand*{\Tsolar}{\ensuremath{T_{\text{\scriptsize solar}}}\xspace}
1411 \newcommand*{\Rstar}[1][\(\star\)]{\ensuremath{R_{\text{\scriptsize #1}}}\xspace}
1412 \newcommand*{\Rsolar}{\ensuremath{R_{\text{\scriptsize solar}}}\xspace}
1413 \newcommand*{\Mstar}[1][\(\star\)]{\ensuremath{M_{\text{\scriptsize #1}}}\xspace}
1414 \newcommand*{\Msolar}{\ensuremath{M_{\text{\scriptsize solar}}}\xspace}

```



```

1465 \newcommand*{\fourtenths}{\ensuremath{\frac{4}{10}}\xspace}
1466 \newcommand*{\sumoverall}[1]{\ensuremath{\displaystyle
1467 \sum_{\substack{\text{\tiny{all }}\text{\tiny{#1}}}}}}
1468 \newcommand*{\dx}[1]{\ensuremath{\,\mathrm{d}\{#1\}}}
1469 \newcommandx{\evaluatedfromto}[2][2,usedefault]{\ensuremath{%
1470 \Bigg.\Bigg\rvert_{#1}^{#2}}}
1471 \newcommand*{\evaluatedat}{\evaluatedfromto}
1472 \newcommandx{\integral}[4][1,2,usedefault]{\ensuremath{%
1473 \int_{\ifthenelse{\equal{#1}{}}{\ifthenelse{%
1474 \equal{#2}{}}{\ifthenelse{\equal{#4}{#1}}{\ifthenelse{%
1475 \newcommand*{\opensurfaceintegral}[2]{\ensuremath{%
1476 \iint\limits_{#1}\vectdotvect{#2}{\dirvect{n}}\dx{A}}}
1477 \newcommand*{\closedsurfaceintegral}[2]{\ensuremath{%
1478 \varoiint\limits_{#1}\vectdotvect{#2}{\dirvect{n}}\dx{A}}}
1479 \newcommand*{\openlineintegral}[2]{\ensuremath{%
1480 \int\limits_{#1}\vectdotvect{#2}{\dirvect{t}}\dx{\ell}}}
1481 \newcommand*{\closedlineintegral}[2]{\ensuremath{%
1482 \oint\limits_{#1}\vectdotvect{#2}{\dirvect{t}}\dx{\ell}}}
1483 \newcommand*{\volumeintegral}[2]{\ensuremath{%
1484 \iiint\limits_{#1}{#2}\dx{V}}}
1485 \newcommandx{\dbydt}[1][1]{\ensuremath{%
1486 \frac{\mathrm{d}\{#1\}}{\mathrm{d}t}}}
1487 \newcommandx{\DbyDt}[1][1]{\ensuremath{%
1488 \frac{\Delta\{#1\}}{\Delta t}}}
1489 \newcommandx{\ddbydt}[1][1]{\ensuremath{%
1490 \frac{\mathrm{d}^2\{#1\}}{\mathrm{d}t^2}}}
1491 \newcommandx{\DDbyDt}[1][1]{\ensuremath{%
1492 \frac{\Delta^2\{#1\}}{\Delta t^2}}}
1493 \newcommandx{\pbypt}[1][1]{\ensuremath{%
1494 \frac{\partial\{#1\}}{\partial t}}}
1495 \newcommandx{\ppbypt}[1][1]{\ensuremath{%
1496 \frac{\partial^2\{#1\}}{\partial t^2}}}
1497 \newcommand*{\dbyd}[2]{\ensuremath{\frac{%
1498 \mathrm{d}\{#1\}}{\mathrm{d}\{#2\}}}}
1499 \newcommand*{\DbyD}[2]{\ensuremath{\frac{%
1500 \Delta\{#1\}}{\Delta\{#2\}}}}
1501 \newcommand*{\ddbyd}[2]{\ensuremath{%
1502 \frac{\mathrm{d}^2\{#1\}}{\mathrm{d}\{#2\}^2}}}
1503 \newcommand*{\DDbyD}[2]{\ensuremath{%
1504 \frac{\Delta^2\{#1\}}{\Delta\{#2\}^2}}}
1505 \newcommand*{\pbyp}[2]{\ensuremath{%
1506 \frac{\partial\{#1\}}{\partial\{#2\}}}}
1507 \newcommand*{\ppbyp}[2]{\ensuremath{%
1508 \frac{\partial^2\{#1\}}{\partial\{#2\}^2}}}
1509 \newcommand*{\seriesfofx}{\ensuremath{%
1510 f(x) \approx f(a) + \frac{f'\prime(a)}{1!}(x-a) + \frac{f''\prime\prime(a)}{2!}
1511 (x-a)^2 + \frac{f'''\prime\prime\prime(a)}{3!}(x-a)^3 + \ldots\xspace}
1512 \newcommand*{\seriesexp}{\ensuremath{%
1513 e^x \approx 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots\xspace}
1514 \newcommand*{\seriesinx}{\ensuremath{%

```



```

1515 \sin x \approx x - \frac{x^3}{3!} + \frac{x^5}{5!} - \ldots \xspace}
1516 \newcommand*{\seriescosx}{\ensuremath{%
1517 \cos x \approx 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \ldots \xspace}
1518 \newcommand*{\seriesstanx}{\ensuremath{%
1519 \tan x \approx x + \frac{x^3}{3} + \frac{2x^5}{15} + \ldots \xspace}
1520 \newcommand*{\seriesatox}{\ensuremath{%
1521 a^x \approx 1 + x \ln a + \frac{(x \ln a)^2}{2!} + \frac{(x \ln a)^3}{3!} + %
1522 \ldots \xspace}
1523 \newcommand*{\serieslnoneplusx}{\ensuremath{%
1524 \ln(1 \pm x) \approx \pm x - \frac{x^2}{2} \pm \frac{x^3}{3} - %
1525 \frac{x^4}{4} \pm \ldots \xspace}
1526 \newcommand*{\binomialseries}{\ensuremath{%
1527 (1 + x)^n \approx 1 + nx + \frac{n(n-1)}{2!}x^2 + \ldots \xspace}
1528 \newcommand*{\gradient}{\ensuremath{\boldsymbol{\nabla}}}
1529 \newcommand*{\divergence}{\ensuremath{\boldsymbol{\nabla}\bullet}}
1530 \newcommand*{\curl}{\ensuremath{\boldsymbol{\nabla}\times}}
1531 \newcommand{\taigrad}{\ensuremath{\nabla}}
1532 \newcommand{\taisvec}{\ensuremath{\nabla}}
1533 \stackinset{c}{0.07ex}{c}{0.1ex}{\tiny$-$}{\nabla$}
1534 }%
1535 \newcommand{\taidivg}{\ensuremath{\nabla}}
1536 \stackinset{c}{0.07ex}{c}{0.1ex}{\tiny$\cdot$}{\nabla$}
1537 }%
1538 \newcommand{\taicurl}{\ensuremath{\nabla}}
1539 \stackinset{c}{0.04ex}{c}{0.32ex}{\tiny$\times$}{\nabla$}
1540 }%
1541 \newcommand*{\laplacian}{\ensuremath{\boldsymbol{\nabla}^2}}
1542 \newcommand*{\dalembertian}{\ensuremath{\boldsymbol{\Box}}}
1543 \newcommand*{\diracdelta}[1]{\ensuremath{\delta}(#1)}
1544 \newcommand*{\orderof}[1]{\ensuremath{\mathcal{O}(#1)}}
1545 \DeclareMathOperator{\asin}{\sin^{-1}}
1546 \DeclareMathOperator{\acos}{\cos^{-1}}
1547 \DeclareMathOperator{\atan}{\tan^{-1}}
1548 \DeclareMathOperator{\asec}{\sec^{-1}}
1549 \DeclareMathOperator{\acsc}{\csc^{-1}}
1550 \DeclareMathOperator{\acot}{\cot^{-1}}
1551 \DeclareMathOperator{\sech}{\sech}
1552 \DeclareMathOperator{\csch}{\csch}
1553 \DeclareMathOperator{\asinh}{\sinh^{-1}}
1554 \DeclareMathOperator{\acosh}{\cosh^{-1}}
1555 \DeclareMathOperator{\atanh}{\tanh^{-1}}
1556 \DeclareMathOperator{\asech}{\sech^{-1}}
1557 \DeclareMathOperator{\acsch}{\csch^{-1}}
1558 \DeclareMathOperator{\acoth}{\coth^{-1}}
1559 \DeclareMathOperator{\sgn}{sgn}
1560 \DeclareMathOperator{\dex}{dex}
1561 \newcommand*{\logb}[1][\relax]{\ensuremath{\log_{#1}}}
1562 \ifthenelse{\boolean{@optboldvectors}}
1563 {\newcommand*{\cB}{\ensuremath{\boldsymbol{c\mskip -3.00mu B}}}}
1564 {\ifthenelse{\boolean{@optromanvectors}}

```

```

1565 {\newcommand*\cB{\ensuremath{\textsf{c}\mskip -3.00mu\mathrm{B}}}}
1566 {\newcommand*\cB{\ensuremath{c\mskip -3.00mu B}}}}
1567 \newcommand*\newpi{\ensuremath{\pi\mskip -7.8mu\pi}}
1568 \newcommand*\scripty[1]{\ensuremath{\mathcalligra{#1}}}
1569 \newcommand*\Lagr{\ensuremath{\mathcal{L}}}
1570 \newcommandx{\flux}[1][1]{\ensuremath{\ssub{\Phi}{#1}}}
1571 \newcommand*\absof[1]{\ensuremath{%
1572 \left\lvert\ifblank{#1}{\:\_:\:}{#1}\right\rvert}}
1573 \newcommand*\inparens[1]{\ensuremath{%
1574 \left(\ifblank{#1}{\:\_:\:}{#1}\right)}}
1575 \newcommand*\magof[1]{\ensuremath{%
1576 \left\lVert\ifblank{#1}{\:\_:\:}{#1}\right\rVert}}
1577 \newcommand*\dimsof[1]{\ensuremath{%
1578 \left[\ifblank{#1}{\:\_:\:}{#1}\right]}}
1579 \newcommand*\unitsof[1]{\ensuremath{%
1580 \left[\ifblank{#1}{\:\_:\:}{#1}\right]_u}}
1581 \newcommand*\changein[1]{\ensuremath{\delta{#1}}}
1582 \newcommand*\Changein[1]{\ensuremath{\Delta{#1}}}
1583 \newcommandx{\timestento}[2][2=\\!,usedefault]{\ensuremath{%
1584 \ifthenelse{equal{#2}}{
1585 {\unit{;}\times;10^{#1}}{
1586 {\unit{;}\times;10^{#1}}{#2}}}}
1587 \newcommand*\xtento{\timestento}
1588 \newcommandx{\tento}[2][2=\\!,usedefault]{\ensuremath{%
1589 \ifthenelse{equal{#2}}{
1590 {\unit{10^{#1}}}{
1591 {\unit{10^{#1}}{#2}}}}
1592 \newcommand*\ee[2]{\texttt{#1}e{#2}}
1593 \newcommand*\EE[2]{\texttt{#1}E{#2}}
1594 \newcommand*\dms[3]{\ensuremath{%
1595 \indegrees{#1}\inarcminutes{#2}\inarcseconds{#3}}}
1596 \newcommand*\hms[3]{\ensuremath{%
1597 {#1}^{\mathrm{h}}{#2}^{\mathrm{m}}{#3}^{\mathrm{s}}}
1598 \newcommand*\clockreading{\hms}
1599 \newcommand*\latitude[1]{\unit{#1}{\degree}}
1600 \newcommand*\latitudeN[1]{\unit{#1}{\degree;\mathrm{N}}}
1601 \newcommand*\latitudeS[1]{\unit{#1}{\degree;\mathrm{S}}}
1602 \newcommand*\longitude[1]{\unit{#1}{\degree}}
1603 \newcommand*\longitudeE[1]{\unit{#1}{\degree;\mathrm{E}}}
1604 \newcommand*\longitudeW[1]{\unit{#1}{\degree;\mathrm{W}}}
1605 \newcommand*\ssub[2]{\ensuremath{#1_{\text{#2}}}}
1606 \newcommand*\ssup[2]{\ensuremath{#1^{\text{#2}}}}
1607 \newcommand*\ssud[3]{\ensuremath{#1^{\text{#2}}_{\text{#3}}}}
1608 \newcommand*\msub[2]{\ensuremath{#1_{#2}}}
1609 \newcommand*\msup[2]{\ensuremath{#1^{#2}}}
1610 \newcommand*\msud[3]{\ensuremath{#1^{#2}_{#3}}}
1611 \newcommand*\levicivita[1]{\ensuremath{%
1612 \varepsilon_{\scriptscriptstyle{#1}}}}
1613 \newcommand*\kronecker[1]{\ensuremath{%
1614 \delta_{\scriptscriptstyle{#1}}}}

```

```

1615 \newcommand*\xaxis{\ensuremath{x\text{-axis}}\xspace}
1616 \newcommand*\yaxis{\ensuremath{y\text{-axis}}\xspace}
1617 \newcommand*\zaxis{\ensuremath{z\text{-axis}}\xspace}
1618 \newcommand*\naxis[1]{\ensuremath{\{#1\}\text{-axis}}\xspace}
1619 \newcommand*\axis{\ensuremath{\text{-axis}}\xspace}
1620 \newcommand*\xyplane{\ensuremath{xy\text{-plane}}\xspace}
1621 \newcommand*\yzplane{\ensuremath{yz\text{-plane}}\xspace}
1622 \newcommand*\zxplane{\ensuremath{zx\text{-plane}}\xspace}
1623 \newcommand*\yxplane{\ensuremath{yx\text{-plane}}\xspace}
1624 \newcommand*\zyplane{\ensuremath{zy\text{-plane}}\xspace}
1625 \newcommand*\xzplane{\ensuremath{xz\text{-plane}}\xspace}
1626 \newcommand*\plane{\ensuremath{\text{-plane}}\xspace}
1627 % Frequently used roots. Prepend |f| for fractional exponents.
1628 \newcommand*\cuberoot[1]{\ensuremath{\sqrt[3]{#1}}}
1629 \newcommand*\fourthroot[1]{\ensuremath{\sqrt[4]{#1}}}
1630 \newcommand*\fifthroot[1]{\ensuremath{\sqrt[5]{#1}}}
1631 \newcommand*\fsqrt[1]{\ensuremath{\{#1\}^{\text{onehalf}}}}
1632 \newcommand*\fcuberoot[1]{\ensuremath{\{#1\}^{\text{onethird}}}}
1633 \newcommand*\ffourthroot[1]{\ensuremath{\{#1\}^{\text{onefourth}}}}
1634 \newcommand*\ffifthroot[1]{\ensuremath{\{#1\}^{\text{onefifth}}}}
1635 \newcommand*\relgamma[1]{\ensuremath{\%
1636   \frac{1}{\sqrt{1-\text{inparens}\frac{#1}{c}\text{squared}}}}}
1637 \newcommand*\frelgamma[1]{\ensuremath{\%
1638   \text{inparens}\{1-\frac{#1}{\text{squared}}\}^{\text{-onehalf}}}}
1639 \newcommand*\oosqrtomxs[1]{\ensuremath{\frac{1}{\sqrt{1-#1\text{squared}}}}}
1640 \newcommand*\oosqrtomx[1]{\ensuremath{\frac{1}{\sqrt{1-#1}}}}
1641 \newcommand*\oomx[1]{\ensuremath{\frac{1}{1-#1}}}
1642 \newcommand*\oopx[1]{\ensuremath{\frac{1}{1+#1}}}
1643 \newcommand*\isequals{\wordoperator{=}\xspace}
1644 \newcommand*\wordoperator[2]{\ensuremath{\%
1645   \mathrel{\vcenter{\offinterlineskip
1646     \halign{\hfil\tiny\upshape##\hfil\cr\noalign{\vskip-.5ex}
1647       {#1}\cr\noalign{\vskip.5ex}{#2}\cr}}}\right)}}}
1648 \newcommand*\definedas{\wordoperator{defined}{as}\xspace}
1649 \newcommand*\associated{\wordoperator{associated}{with}\xspace}
1650 \newcommand*\adjustedby{\wordoperator{adjusted}{by}\xspace}
1651 \newcommand*\earlierthan{\wordoperator{earlier}{than}\xspace}
1652 \newcommand*\laterthan{\wordoperator{later}{than}\xspace}
1653 \newcommand*\forevery{\wordoperator{for}{every}\xspace}
1654 \newcommand*\pwordoperator[2]{\ensuremath{\left(\%
1655   \mathrel{\vcenter{\offinterlineskip\%
1656     \halign{\hfil\tiny\upshape##\hfil\cr\noalign{\vskip-.5ex}\%
1657       {#1}\cr\noalign{\vskip.5ex}{#2}\cr}}}\right)}}}
1658 \newcommand*\pdefinedas{\pwordoperator{defined}{as}\xspace}
1659 \newcommand*\passociated{\pwordoperator{associated}{with}\xspace}
1660 \newcommand*\padjustedby{\pwordoperator{adjusted}{by}\xspace}
1661 \newcommand*\pearlierthan{\pwordoperator{earlier}{than}\xspace}
1662 \newcommand*\platerthan{\pwordoperator{later}{than}\xspace}
1663 \newcommand*\pforevery{\pwordoperator{for}{every}\xspace}
1664 \newcommand*\defines{\ensuremath{\stackrel{\text{tiny}{def}}{=}}\xspace}

```

```

1665 \newcommand*{\inframe}[1][\relax]{\ensuremath{%
1666   \xrightarrow[\text{\tiny{\mathcal #1}}{}]{\hspace{
1667   \newcommand*{\associates}{\ensuremath{%
1668     \xrightarrow[\text{\tiny{assoc}}{}]{\hspace{
1669   \newcommand*{\becomes}{\ensuremath{%
1670     \xrightarrow[\text{\tiny{becomes}}{}]{\hspace{
1671   \newcommand*{\rrelatedto}[1]{\ensuremath{%
1672     \xLongrightarrow[\text{\tiny{#1}}{}]{
1673   \newcommand*{\lrelatedto}[1]{\ensuremath{%
1674     \xLongleftarrow[\text{\tiny{#1}}{}]{
1675   \newcommand*{\brelatedto}[2]{\ensuremath{%
1676     \xLongleftarrow[\text{\tiny{#1}}]{\text{\tiny{#2}}}}
1677   \newcommand*{\genericinteractionplaces}[5]{\ensuremath{\inparen{#1}
1678     \frac{\inparen{#2}\inparen{#3}}{\inparen{#4}^2}{\ifblank{#5}{%
1679     \mivector{\_ , \_ , \_}{#5}}}}
1680   \newcommand*{\genericfieldofparticleplaces}[4]{\ensuremath{\inparen{#1}
1681     \frac{\inparen{#2}}{\inparen{#3}^2}{\ifblank{#4}{\mivector{\_ , \_ , \_}{#4}}}}
1682   \newcommand*{\genericpotentialenergyplaces}[4]{\ensuremath{%
1683     \inparen{#1}\frac{\inparen{#2}\inparen{#3}}{\inparen{#4}}
1684   \newcommand*{\genericelectricdipoleplaces}[5]{%
1685     \ensuremath{\inparen{#1}\frac{\inparen{#2}\inparen{#3}}{\inparen{#4}^3}%
1686     {\ifblank{#5}{\mivector{\_ , \_ , \_}{#5}}}}
1687   \newcommand*{\genericelectricdipoleonaxisplaces}[5]{%
1688     \ensuremath{\inparen{#1}\frac{2\inparen{#2}\inparen{#3}}{\inparen{#4}^3}%
1689     {\ifblank{#5}{\mivector{\_ , \_ , \_}{#5}}}}
1690   \newcommand*{\gfieldofparticle}{\ensuremath{\universalgravmathsymbol\frac{M}{%
1691     {\magsquaredvect{r}}\inparen{-\direct{r}}}}
1692   \newcommand*{\gravitationalinteractionplaces}[4]{%
1693     \genericinteractionplaces{\universalgrav}{#1}{#2}{#3}{#4}}
1694   \newcommand*{\gfieldofparticleplaces}[3]{%
1695     \genericfieldofparticleplaces{\universalgrav}{#1}{#2}{#3}}
1696   \newcommand*{\electricinteractionplaces}[4]{%
1697     \genericinteractionplaces{oofpez}{#1}{#2}{#3}{#4}}
1698   \newcommand*{\Efieldofparticleplaces}[3]{%
1699     \genericfieldofparticleplaces{oofpez}{#1}{#2}{#3}}
1700   \newcommand*{\Bfieldofparticleplaces}[5]{\ensuremath{\inparen{\mzofp}%
1701     \frac{\inparen{#1}\inparen{#2}}{\inparen{#3}^2}{\ifblank{#4}{%
1702     \mivector{\_ , \_ , \_}{#4}}}\times{\ifblank{#5}{\mivector{\_ , \_ , \_}{#5}}}}
1703   \newcommand*{\springinteractionplaces}[3]{\ensuremath{\inparen{#1}
1704     \inparen{#2}{\ifblank{#3}{\mivector{\_ , \_ , \_}{#3}}}}
1705   \newcommand*{\gravitationalpotentialenergyplaces}[3]{%
1706     -\genericpotentialenergyplaces{\universalgrav}{#1}{#2}{#3}}
1707   \newcommand*{\electricpotentialenergyplaces}[3]{%
1708     \genericpotentialenergyplaces{oofpez}{#1}{#2}{#3}}
1709   \newcommand*{\springpotentialenergyplaces}[2]{\ensuremath{%
1710     \onehalf\inparen{#1}\inparen{#2}^2}}
1711   \newcommand*{\electricdipoleonaxisplaces}[4]{%
1712     \genericelectricdipoleonaxisplaces{oofpez}{\absof{#1}}{#2}{#3}{\ifblank{#4}{%
1713     \mivector{\_ , \_ , \_}{#4}}}}
1714   \newcommand*{\electricdipoleonbisectorplaces}[4]{%

```

```

1715 \genericelectricdipoleplaces{\oofpez}{\absof{#1}}{#2}{#3}{\ifblank{#4}{%
1716 \mivector{\_ , \_ , \_}}{#4}}}}
1717 \newcommand{\define}[2]{\newcommand{#1}{#2}}
1718 \newcommand*\momentumprinciple{\ensuremath{%
1719 \vectsub{p}{sys,final}=\vectsub{p}{sys,initial}+\Fnetsys\Delta t}}
1720 \newcommand*\LHSmomentumprinciple{\ensuremath{\vectsub{p}{sys,final}}}
1721 \newcommand*\RHSmomentumprinciple{\ensuremath{%
1722 \vectsub{p}{sys,initial}+\Fnetsys\Delta t}}
1723 \newcommand*\momentumprinciplediff{\ensuremath{%
1724 \Dvectsub{p}{sys}=\Fnetsys\Delta t}}
1725 \newcommand*\energyprinciple{\ensuremath{%
1726 \ssub{E}{sys,final}=\ssub{E}{sys,initial}+W+Q}}
1727 \newcommand*\LHSEnergyprinciple{\ensuremath{\ssub{E}{sys,final}}}
1728 \newcommand*\RHSenergyprinciple{\ensuremath{\ssub{E}{sys,initial}+W+Q}}
1729 \newcommand*\energyprinciplediff{\ensuremath{\Delta\ssub{E}{sys}=W+Q}}
1730 \newcommand*\angularmomentumprinciple{\ensuremath{%
1731 \vectsub{L}{\langle A \rangle,sys,final}=\vectsub{L}{\langle A \rangle,sys,initial}+\Tsub{net}\Delta t}}
1732 \newcommand*\LHSangularmomentumprinciple{\ensuremath{%
1733 \vectsub{L}{\langle A \rangle,sys,final}}}
1734 \newcommand*\RHSangularmomentumprinciple{\ensuremath{%
1735 \vectsub{L}{\langle A \rangle,sys,initial}+\Tsub{net}\Delta t}}
1736 \newcommand*\angularmomentumprinciplediff{\ensuremath{%
1737 \Dvectsub{L}{\langle A \rangle,sys}=\Tsub{net}\Delta t}}
1738 \newcommand*\gravitationalinteraction{\ensuremath{%
1739 \universalgravmathsymbol\frac{m_{\text{sub}}{M}^2}{m_{\text{sub}}{M}}}}
1740 \magvectsub{r}{12}\squared{-\dirvectsub{r}{12}}}}
1741 \newcommand*\electricinteraction{\ensuremath{%
1742 \oofpezmathsymbol\frac{q_{\text{sub}}{Q}^2}{q_{\text{sub}}{Q}}\magvectsub{r}{12}\squared}
1743 \dirvectsub{r}{12}}}
1744 \newcommand*\springinteraction{\ensuremath{\k_s\magvect{s}-\dirvect{s}}}}
1745 \newcommand*\Bfieldofparticle{\ensuremath{%
1746 \mzofpmathsymbol\frac{Q\magvect{v}}{Q\magsquaredvect{r}}\dirvect{v}\times
1747 \dirvect{r}}}
1748 \newcommand*\Efieldofparticle{\ensuremath{%
1749 \oofpezmathsymbol\frac{Q}{Q\magsquaredvect{r}}\dirvect{r}}}
1750 \newcommandx{Esys}[1][1]{\ifthenelse{%
1751 \equal{#1}{}}{\ssub{E}{sys}}{\ssub{E}{sys,#1}}}
1752 \newcommandx{Us}[1][1]{\ifthenelse{%
1753 \equal{#1}{}}{\ssub{U}{\langle s \rangle}}{\ssub{U}{\langle s \rangle,#1}}}
1754 \newcommandx{Ug}[1][1]{\ifthenelse{%
1755 \equal{#1}{}}{\ssub{U}{\langle g \rangle}}{\ssub{U}{\langle g \rangle,#1}}}
1756 \newcommandx{Ue}[1][1]{\ifthenelse{%
1757 \equal{#1}{}}{\ssub{U}{\langle e \rangle}}{\ssub{U}{\langle e \rangle,#1}}}
1758 \newcommandx{Ktrans}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{K}{trans}}
1759 {\ssub{K}{trans,#1}}}
1760 \newcommandx{Krot}[1][1]{\ifthenelse{%
1761 \equal{#1}{}}{\ssub{K}{rot}}{\ssub{K}{rot,#1}}}
1762 \newcommandx{Kvib}[1][1]{\ifthenelse{%
1763 \equal{#1}{}}{\ssub{K}{vib}}{\ssub{K}{vib,#1}}}
1764 \newcommandx{Eparticle}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{particle}}

```

```

1765 {\ssub{E}{particle,#1}}
1766 \newcommandx{\Einternal}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{internal}}
1767 {\ssub{E}{internal,#1}}}
1768 \newcommandx{\Erest}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{rest}}{\ssub{E}
1769 {rest,#1}}}
1770 \newcommandx{\Echem}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{chem}}{\ssub{E}
1771 {chem,#1}}}
1772 \newcommandx{\Etherm}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{therm}}
1773 {\ssub{E}{therm,#1}}}
1774 \newcommandx{\Evib}[1][1]{\ifthenelse{
1775 \equal{#1}{}}{\ssub{E}{vib}}{\ssub{E}{vib,#1}}}
1776 \newcommandx{\Ephoton}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{photon}}
1777 {\ssub{E}{photon,#1}}}
1778 \newcommand*{\DEsys}{\Changein\Esys}
1779 \newcommand*{\DUs}{\Changein\Us}
1780 \newcommand*{\DUg}{\Changein\Ug}
1781 \newcommand*{\DUe}{\Changein\Ue}
1782 \newcommand*{\DKtrans}{\Changein\Ktrans}
1783 \newcommand*{\DKrot}{\Changein\Krot}
1784 \newcommand*{\DKvib}{\Changein\Kvib}
1785 \newcommand*{\DEparticle}{\Changein\Eparticle}
1786 \newcommand*{\DEinternal}{\Changein\Einternal}
1787 \newcommand*{\DERest}{\Changein\Erest}
1788 \newcommand*{\DEchem}{\Changein\Echem}
1789 \newcommand*{\DEtherm}{\Changein\Etherm}
1790 \newcommand*{\DEvib}{\Changein\Evib}
1791 \newcommand*{\DEphoton}{\Changein\Ephoton}
1792 \newcommand*{\springpotentialenergy}{\onehalf\ks\magsquaredvect{s}}
1793 \newcommand*{\finalspringpotentialenergy}
1794 {\ssub{\left(\springpotentialenergy\right)}{\!\!\!final}}
1795 \newcommand*{\initialspringpotentialenergy}
1796 {\ssub{\left(\springpotentialenergy\right)}{\!\!\!initial}}
1797 \newcommand*{\gravitationalpotentialenergy}{\ensuremath{
1798 -G\frac{\msub{M}{1}\msub{M}{2}}{\magvectsub{r}{12}}}}
1799 \newcommand*{\finalgravitationalpotentialenergy}
1800 {\ssub{\left(\gravitationalpotentialenergy\right)}{\!\!\!final}}
1801 \newcommand*{\initialgravitationalpotentialenergy}
1802 {\ssub{\left(\gravitationalpotentialenergy\right)}{\!\!\!initial}}
1803 \newcommand*{\electricpotentialenergy}{\ensuremath{
1804 \oofpezmathsymbolfrac{\ssub{Q}{1}\ssub{Q}{2}}{\magvectsub{r}{12}}}}
1805 \newcommand*{\finalelectricpotentialenergy}
1806 {\ssub{\left(\electricpotentialenergy\right)}{\!\!\!final}}
1807 \newcommand*{\initialelectricpotentialenergy}
1808 {\ssub{\left(\electricpotentialenergy\right)}{\!\!\!initial}}
1809 \newcommand*{\ks}{\msub{k}{s}}
1810 \newcommand*{\Fnet}{\ensuremath{\vectsub{F}{net}}}
1811 \newcommand*{\Fnetext}{\ensuremath{\vectsub{F}{net,ext}}}
1812 \newcommand*{\Fnetsys}{\ensuremath{\vectsub{F}{net,sys}}}
1813 \newcommand*{\Fsub}[1]{\ensuremath{\vectsub{F}{#1}}}
1814 \newcommand*{\Ltotal}{\ensuremath{\vectsub{L}{(A),total}}}

```

```

1815 \newcommand*{\Lsys}{\ensuremath{\vectsub{L}{\langle A \rangle}, sys}}
1816 \newcommand*{\Lsub}[1]{\ensuremath{\vectsub{L}{\langle A \rangle}, \{#1\}}}
1817 \newcommand*{\Tnet}{\ensuremath{\vectsub{\tau}{\langle A \rangle}, net}}
1818 \newcommand*{\Tnetext}{\ensuremath{\vectsub{\tau}{\langle A \rangle}, net, ext}}
1819 \newcommand*{\Tnetsys}{\ensuremath{\vectsub{\tau}{\langle A \rangle}, net, sys}}
1820 \newcommand*{\Tsub}[1]{\ensuremath{\vectsub{\tau}{\langle A \rangle}, \{#1\}}}
1821 \newcommand*{\LHSmaxwelliint}[1][\partial V]{\ensuremath{\%
1822 \quad \closedsurfaceintegral\{#1\}{\vect{E}}}}
1823 \newcommand*{\RHSmaxwelliint}{\ensuremath{\frac{\ssub{Q}{\langle e \rangle}, net}}{\%
1824 \quad \vacuumpermittivitymathsymbol}}}
1825 \newcommand*{\RHSmaxwelliinta}[1][V]{\ensuremath{\%
1826 \quad \frac{1}{\vacuumpermittivitymathsymbol}\volumeintegral\{#1\}{\msub{\rho}{e}}}}
1827 \newcommand*{\RHSmaxwelliintfree}{\ensuremath{0}}
1828 \newcommand*{\maxwelliint}[1][\partial V]{\ensuremath{\%
1829 \quad \LHSmaxwelliint\{#1\}=\RHSmaxwelliint}}
1830 \newcommandx*{\maxwelliinta}[2][1={\partial V}, 2={V}, usedefault]{\ensuremath{\%
1831 \quad \LHSmaxwelliint\{#1\}=\RHSmaxwelliinta\{#2\}}}
1832 \newcommand*{\maxwelliintfree}[1][\partial V]{\ensuremath{\%
1833 \quad \LHSmaxwelliint\{#1\}=\RHSmaxwelliintfree}}
1834 \newcommand*{\LHSmaxwelliint}[1][\partial V]{\ensuremath{\%
1835 \quad \closedsurfaceintegral\{#1\}{\vect{B}}}}
1836 \newcommand*{\RHSmaxwelliint}{\ensuremath{0}}
1837 \newcommand*{\RHSmaxwelliintm}{\ensuremath{\%
1838 \quad \vacuumpermeabilitymathsymbol\ssub{Q}{\langle m \rangle}, net}}
1839 \newcommand*{\RHSmaxwelliintma}[1][V]{\ensuremath{\%
1840 \quad \vacuumpermeabilitymathsymbol\volumeintegral\{#1\}{\msub{\rho}{m}}}}
1841 \newcommand*{\RHSmaxwelliintfree}{\ensuremath{0}}
1842 \newcommand*{\maxwelliint}[1][\partial V]{\ensuremath{\%
1843 \quad \LHSmaxwelliint\{#1\}=\RHSmaxwelliint}}
1844 \newcommand*{\maxwelliintm}[1][\partial V]{\ensuremath{\%
1845 \quad \LHSmaxwelliint\{#1\}=\RHSmaxwelliintm}}
1846 \newcommandx*{\maxwelliintma}[2][1={\partial V}, 2={V}, usedefault]{\ensuremath{\%
1847 \quad \LHSmaxwelliint\{#1\}=\RHSmaxwelliintma\{#2\}}}
1848 \newcommand*{\maxwelliintfree}[1][\partial V]{\ensuremath{\%
1849 \quad \LHSmaxwelliint\{#1\}=\RHSmaxwelliintfree}}
1850 \newcommand*{\LHSmaxwelliint}[1][\partial \Omega]{\ensuremath{\%
1851 \quad \closedlineintegral\{#1\}{\vect{E}}}}
1852 \newcommand*{\RHSmaxwelliint}[1][\Omega]{\ensuremath{\%
1853 \quad -\dbydt\opensurfaceintegral\{#1\}{\vect{B}}}}
1854 \newcommand*{\RHSmaxwelliintm}[1][\Omega]{\ensuremath{\%
1855 \quad -\dbydt\opensurfaceintegral\{#1\}{\vect{B}}}\%
1856 \quad -\vacuumpermeabilitymathsymbol\ssub{I}{\langle m \rangle}, net}}
1857 \newcommand*{\RHSmaxwelliintma}[1][\Omega]{\ensuremath{\%
1858 \quad -\dbydt\opensurfaceintegral\{#1\}{\vect{B}}}\%
1859 \quad -\vacuumpermeabilitymathsymbol\opensurfaceintegral\{#1\}{\vectsub{J}{\langle m \rangle}}}}
1860 \newcommand*{\RHSmaxwelliintfree}{\RHSmaxwelliint}
1861 \newcommandx*{\maxwelliint}[2][1={\partial \Omega}, 2={\Omega}, usedefault]{\%
1862 \quad \ensuremath{\LHSmaxwelliint\{#1\}=\RHSmaxwelliint\{#2\}}}
1863 \newcommandx*{\maxwelliintm}[2][1={\partial \Omega}, 2={\Omega}, usedefault]{\%
1864 \quad \ensuremath{\LHSmaxwelliint\{#1\}=\RHSmaxwelliintm\{#2\}}}

```

```

1865 \newcommandx*\maxwelliiiintma}[2][1={\partial\Omega},2={\Omega},usedefault]%
1866 {\ensuremath{\LHSmaxwelliiiint[#1]=\RHSmaxwelliiiintma[#2]}}
1867 \newcommand*\maxwelliiiintfree{\maxwelliiiint}
1868 \newcommand*\LHSmaxwellivint}[1][\partial\Omega]{\ensuremath{%
1869 \closedlineintegral{#1}\{\vect{B}\}}}
1870 \newcommand*\RHSmaxwellivint}[1][\Omega]{\ensuremath{%
1871 \vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol%
1872 \dbydt\opensurfaceintegral{#1}\{\vect{E}\}+%
1873 \vacuumpermeabilitymathsymbol\ssub{I}\{(e\),net)\}}}
1874 \newcommand*\RHSmaxwellivinta}[1][\Omega]{\ensuremath{%
1875 \vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol%
1876 \dbydt\opensurfaceintegral{#1}\{\vect{E}\}+%
1877 \vacuumpermeabilitymathsymbol\opensurfaceintegral{#1}\{\vectsub{J}\{(e\)\}}\}}}
1878 \newcommand*\RHSmaxwellivintfree}[1][\Omega]{\ensuremath{%
1879 \vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol%
1880 \dbydt\opensurfaceintegral{#1}\{\vect{E}\}}}
1881 \newcommandx*\maxwellivint}[2][1={\partial\Omega},2={\Omega},usedefault]%
1882 {\ensuremath{\LHSmaxwellivint[#1]=\RHSmaxwellivint[#2]}}
1883 \newcommandx*\maxwellivinta}[2][1={\partial\Omega},2={\Omega},usedefault]%
1884 {\ensuremath{\LHSmaxwellivint[#1]=\RHSmaxwellivinta[#2]}}
1885 \newcommandx*\maxwellivintfree}[2][1={\partial\Omega},2={\Omega},usedefault]%
1886 {\ensuremath{\LHSmaxwellivint[#1]=\RHSmaxwellivintfree[#2]}}
1887 \newcommand*\LHSmaxwellidif{\ensuremath{\divergence{\vect{E}}}}
1888 \newcommand*\RHSmaxwellidif{\ensuremath{\frac{\msub{\rho}{e}}}}
1889 {\vacuumpermittivitymathsymbol}}
1890 \newcommand*\RHSmaxwellidiffree{\ensuremath{0}}
1891 \newcommand*\maxwellidif{\ensuremath{\LHSmaxwellidif=\RHSmaxwellidif}}
1892 \newcommand*\maxwellidiffree{\ensuremath{\LHSmaxwellidif=\RHSmaxwellidiffree}}
1893 \newcommand*\LHSmaxwelliidif{\ensuremath{\divergence{\vect{B}}}}
1894 \newcommand*\RHSmaxwelliidif{\ensuremath{0}}
1895 \newcommand*\RHSmaxwelliidifm{\ensuremath{\vacuumpermeabilitymathsymbol%
1896 \msub{\rho}{m}}}}
1897 \newcommand*\RHSmaxwelliidiffree{\ensuremath{0}}
1898 \newcommand*\maxwelliidif{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidif}}
1899 \newcommand*\maxwelliidifm{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidifm}}
1900 \newcommand*\maxwelliidiffree{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidiffree}}
1901 \newcommand*\LHSmaxwelliidif{\ensuremath{\curl{\vect{E}}}}
1902 \newcommand*\RHSmaxwelliidif{\ensuremath{-\pbypt[\vect{B}]}}
1903 \newcommand*\RHSmaxwelliidifm{\ensuremath{-\pbypt[\vect{B}]-%
1904 \vacuumpermeabilitymathsymbol\vectsub{J}\{(m\)\}}}
1905 \newcommand*\RHSmaxwelliidiffree{\RHSmaxwelliidif}
1906 \newcommand*\maxwelliidif{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidif}}
1907 \newcommand*\maxwelliidifm{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidifm}}
1908 \newcommand*\maxwelliidiffree{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidif}}
1909 \newcommand*\LHSmaxwellivdif{\ensuremath{\curl{\vect{B}}}}
1910 \newcommand*\RHSmaxwellivdif{\ensuremath{\vacuumpermeabilitymathsymbol%
1911 \vacuumpermittivitymathsymbol\pbypt[\vect{E}]+%
1912 \vacuumpermeabilitymathsymbol\vectsub{J}\{(e\)\}}}
1913 \newcommand*\RHSmaxwellivdiffree{\ensuremath{\vacuumpermeabilitymathsymbol
1914 \vacuumpermittivitymathsymbol\pbypt[\vect{E}]}}

```



```

1915 \newcommand*{\maxwellivdif}{\ensuremath{\LHSmaxwellivdif=\RHSmaxwellivdif}}
1916 \newcommand*{\maxwellivdiffree}{\ensuremath{\LHSmaxwellivdif=\RHSmaxwellivdiffree}}
1917 \newcommand*{\RHSlorentzforce}{\ensuremath{\msub{q}{e}\left(\vect{E}+%
1918 \vectcrossvect{\vect{v}}{\vect{B}}\right)}}
1919 \newcommand*{\RHSlorentzforcem}{\ensuremath{\RHSlorentzforce+\msub{q}{m}\left(
1920 \vect{B}-\vectcrossvect{\vect{v}}{\frac{\vect{E}}{c^2}}\right)}}
1921 \newcommandx{\eulerlagrange}[1][1={q_i},usedefault]{\ensuremath{%
1922 \pby{\mathcal{L}}{\#1}-\dbydt\inpars{\pby{\mathcal{L}}{\dot{\#1}}} = 0}}
1923 \newcommandx{\Eulerlagrange}[1][1={q_i},usedefault]{\ensuremath{%
1924 \DbyD{\mathcal{L}}{\#1}-\DbyDt\inpars{\DbyD{\mathcal{L}}{\dot{\#1}}} = 0}}
1925 \newcommand*{\vpythonline}{\lstinline[style=vpython]}
1926 \newcommand*{\glowscripeline}{\lstinline[style=vpython]}
1927 \lstnewenvironment{vpythonblock}[1][\lstset{style=vpython,caption={#1}}]{
1928 \lstnewenvironment{glowscripblock}[1][\lstset{style=vpython,caption={#1}}]{
1929 \newcommand*{\vpythonfile}[1][\newpage\lstinputlisting[style=vpython,caption={#1}]]
1930 \newcommand*{\glowscripfile}[1][\%
1931 \newpage\lstinputlisting[style=vpython,caption={#1}]]
1932 \newcommandx{\emptyansw}[2][1=0.80,2=0.1,usedefault]
1933 {\begin{minipage}{#1\textwidth}\hfill\vspace{#2\textheight}\end{minipage}}
1934 \newenvironmentx{activityansw}[5][1=white,2=black,3=black,4=0.90,%
1935 5=0.10,usedefault]{%
1936 \def\skipper{#5}%
1937 \def\response@fbox{\fcolorbox{#2}{#1}}%
1938 \begin{center}%
1939 \begin{lrbox}{\@tempboxa}%
1940 \begin{minipage}[c]{#5\textheight}[c]{#4\textwidth}\color{#3}%
1941 \vspace{#5\textheight}}{%
1942 \vspace{\skipper\textheight}%
1943 \end{minipage}%
1944 \end{lrbox}%
1945 \response@fbox{\usebox{\@tempboxa}}%
1946 \end{center}%
1947 }%
1948 \newenvironmentx{adjactivityansw}[5][1=white,2=black,3=black,4=0.90,5=0.00,%
1949 usedefault]{%
1950 \def\skipper{#5}%
1951 \def\response@fbox{\fcolorbox{#2}{#1}}%
1952 \begin{center}%
1953 \begin{lrbox}{\@tempboxa}%
1954 \begin{minipage}[c]{#4\textwidth}\color{#3}%
1955 \vspace{#5\textheight}}{%
1956 \vspace{\skipper\textheight}%
1957 \end{minipage}%
1958 \end{lrbox}%
1959 \response@fbox{\usebox{\@tempboxa}}%
1960 \end{center}%
1961 }%
1962 \newcommandx{\emptybox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
1963 6=0.10,usedefault]{%
1964 {\begin{center}%

```

```

1965     \fcolorbox{#3}{#2}{%
1966     \begin{minipage}[c][#6\textheight][c]{#5\textwidth}\color{#4}%
1967     {#1}%
1968     \end{minipage}}%
1969     \vspace{\baselineskip}%
1970 \end{center}%
1971 }%
1972 \newcommandx{\adjemptybox}[7][1=\hfill,2=white,3=black,4=black,5=0.90,6=,%
1973 7=0.0,usedefault]%
1974 {\begin{center}%
1975     \fcolorbox{#3}{#2}{%
1976     \begin{minipage}[c]{#5\textwidth}\color{#4}%
1977     \vspace{#7\textheight}%
1978     {#1}%
1979     \vspace{#7\textheight}%
1980     \end{minipage}}%
1981     \vspace{\baselineskip}%
1982 \end{center}%
1983 }%
1984 \newcommandx{\answerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
1985 6=0.1,usedefault]%
1986 {\ifthenelse{\equal{#1}{}}{%
1987     {\begin{center}%
1988         \fcolorbox{#3}{#2}{%
1989             \emptyanswer[#5][#6]}%
1990         \vspace{\baselineskip}%
1991         \end{center}}}%
1992     {\emptybox[#1][#2][#3][#4][#5][#6]}%
1993 }%
1994 \newcommandx{\adjanswerbox}[7][1=\hfill,2=white,3=black,4=black,5=0.90,%
1995 6=0.1,7=0.0,usedefault]%
1996 {\ifthenelse{\equal{#1}{}}{%
1997     {\begin{center}%
1998         \fcolorbox{#3}{#2}{%
1999             \emptyanswer[#5][#6]}%
2000         \vspace{\baselineskip}%
2001         \end{center}}}%
2002     {\adjemptybox[#1][#2][#3][#4][#5][#6][#7]}%
2003 }%
2004 \newcommandx{\smallanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
2005 6=0.10,usedefault]%
2006 {\ifthenelse{\equal{#1}{}}{%
2007     {\begin{center}%
2008         \fcolorbox{#3}{#2}{%
2009             \emptyanswer[#5][#6]}%
2010         \vspace{\baselineskip}%
2011         \end{center}}}%
2012     {\emptybox[#1][#2][#3][#4][#5][#6]}%
2013 }%
2014 \newcommandx{\smallanswerform}[4][1=q1,2=Response,3=0.10,4=0.90,usedefault]{%

```

```

2015 \vspace{\baselineskip}%
2016 \begin{Form}
2017 \begin{center}%
2018 \TextField[value={#2},%
2019 name=#1,%
2020 width=#4\linewidth,%
2021 height=#3\textheight,%
2022 backgroundcolor=formcolor,%
2023 multiline=true,%
2024 charsize=10pt,%
2025 bordercolor=black]{}%
2026 \end{center}%
2027 \end{Form}%
2028 \vspace{\baselineskip}%
2029 }%
2030 \newcommandx{\mediumanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
2031 6=0.20,usedefault]{%
2032 \ifthenelse{\equal{#1}{}}{%
2033 {\begin{center}%
2034 \fcolorbox{#3}{#2}{%
2035 \emptyanswer[#5][#6]}%
2036 \vspace{\baselineskip}%
2037 \end{center}}%
2038 {\emptybox[#1][#2][#3][#4][#5][#6]}%
2039 }%
2040 \newcommandx{\mediumanswerform}[4][1=q1,2=Response,3=0.20,4=0.90,usedefault]{%
2041 \vspace{\baselineskip}%
2042 \begin{Form}
2043 \begin{center}%
2044 \TextField[value={#2},%
2045 name=#1,%
2046 width=#4\linewidth,%
2047 height=#3\textheight,%
2048 backgroundcolor=formcolor,%
2049 multiline=true,%
2050 charsize=10pt,%
2051 bordercolor=black]{}%
2052 \end{center}%
2053 \end{Form}%
2054 \vspace{\baselineskip}%
2055 }%
2056 \newcommandx{\largeanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
2057 6=0.25,usedefault]{%
2058 \ifthenelse{\equal{#1}{}}{%
2059 {\begin{center}%
2060 \fcolorbox{#3}{#2}{%
2061 \emptyanswer[#5][#6]}%
2062 \vspace{\baselineskip}%
2063 \end{center}}%
2064 {\emptybox[#1][#2][#3][#4][#5][#6]}%

```

```

2065 }%
2066 \newcommand{\largeanswerform}[4] [1=q1,2=Response,3=0.25,4=0.90,usedefault]{%
2067   \vspace{\baselineskip}%
2068   \begin{Form}
2069     \begin{center}%
2070       \TextField[value={#2},%
2071         name=#1,%
2072         width=#4\linewidth,%
2073         height=#3\textheight,%
2074         backgroundcolor=formcolor,%
2075         multiline=true,%
2076         charsize=10pt,%
2077         bordercolor=black]{}%
2078     \end{center}%
2079   \end{Form}%
2080   \vspace{\baselineskip}%
2081 }%
2082 \newcommand{\largeranswerbox}[6] [1=\hfill,2=white,3=black,4=black,5=0.90,%
2083   6=0.33,usedefault]{%
2084   \ifthenelse{\equal{#1}{}}%
2085     {\begin{center}%
2086       \fcolorbox{#3}{#2}{%
2087         \emptyanswer[#5][#6]}%
2088       \vspace{\baselineskip}%
2089     \end{center}}%
2090     {\emptybox[#1][#2][#3][#4][#5][#6]}%
2091 }%
2092 \newcommand{\largeranswerform}[4] [1=q1,2=Response,3=0.33,4=0.90,%
2093   usedefault]{%
2094   \vspace{\baselineskip}%
2095   \begin{Form}
2096     \begin{center}%
2097       \TextField[value={#2},%
2098         name=#1,%
2099         width=#4\linewidth,%
2100         height=#3\textheight,%
2101         backgroundcolor=formcolor,%
2102         multiline=true,%
2103         charsize=10pt,%
2104         bordercolor=black]{}%
2105     \end{center}%
2106   \end{Form}%
2107   \vspace{\baselineskip}%
2108 }%
2109 \newcommand{\hugeanswerbox}[6] [1=\hfill,2=white,3=black,4=black,5=0.90,%
2110   6=0.50,usedefault]{%
2111   \ifthenelse{\equal{#1}{}}%
2112     {\begin{center}%
2113       \fcolorbox{#3}{#2}{%
2114         \emptyanswer[#5][#6]}%

```

```

2115     \vspace{\baselineskip}%
2116     \end{center}}}%
2117     {\emptybox[#1][#2][#3][#4][#5][#6]}}%
2118 }%
2119 \newcommandx{\hugeanswerform}[4][1=q1,2=Response,3=0.50,4=0.90,usedefault]{%
2120   \vspace{\baselineskip}%
2121   \begin{Form}
2122     \begin{center}%
2123       \TextField[value={#2},%
2124         name=#1,%
2125         width=#4\linewidth,%
2126         height=#3\textheight,%
2127         backgroundcolor=formcolor,%
2128         multiline=true,%
2129         charsize=10pt,%
2130         bordercolor=black]{}%
2131     \end{center}%
2132   \end{Form}%
2133   \vspace{\baselineskip}%
2134 }%
2135 \newcommandx{\hugeranswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
2136   6=0.75,usedefault]{%
2137   \ifthenelse{\equal{#1}{}}{%
2138     {\begin{center}%
2139       \fcolorbox{#3}{#2}{%
2140         \emptyanswer[#5][#6]}}%
2141     \vspace{\baselineskip}%
2142     \end{center}}}%
2143   {\emptybox[#1][#2][#3][#4][#5][#6]}}%
2144 }%
2145 \newcommandx{\hugeranswerform}[4][1=q1,2=Response,3=0.75,4=0.90,usedefault]{%
2146   \vspace{\baselineskip}%
2147   \begin{Form}
2148     \begin{center}%
2149       \TextField[value={#2},%
2150         name=#1,%
2151         width=#4\linewidth,%
2152         height=#3\textheight,%
2153         backgroundcolor=formcolor,%
2154         multiline=true,%
2155         charsize=10pt,%
2156         bordercolor=black]{}%
2157     \end{center}%
2158   \end{Form}%
2159   \vspace{\baselineskip}%
2160 }%
2161 \newcommandx{\fullpageanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,%
2162   6=1.00,usedefault]{%
2163   \ifthenelse{\equal{#1}{}}{%
2164     {\begin{center}%

```

```

2165     \fcolorbox{#3}{#2}{%
2166     \emptyanswer[#5][#6]}%
2167     \vspace{\baselineskip}%
2168     \end{center}}%
2169     {\emptybox[#1][#2][#3][#4][#5][#6]}%
2170 }%
2171 \newcommandx{\fullpageanswerform}[4][1=q1,2=Response,3=1.00,4=0.90,usedefault]{%
2172     \vspace{\baselineskip}%
2173     \begin{Form}
2174     \begin{center}%
2175         \TextField[value={#2},%
2176             name=#1,%
2177             width=#4\linewidth,%
2178             height=#3\textheight,%
2179             backgroundcolor=formcolor,%
2180             multiline=true,%
2181             charsize=10pt,%
2182             bordercolor=black]{}%
2183     \end{center}%
2184     \end{Form}%
2185     \vspace{\baselineskip}%
2186 }%
2187 \mdfdefinestyle{miinstructornotestyle}{%
2188     hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
2189     leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
2190     nobreak=true,
2191     frametitle={INSTRUCTOR NOTE},
2192     frametitlebackgroundcolor=cyan!60,frametitlerule=true,frametitlerulewidth=1,
2193     backgroundcolor=cyan!25,
2194     linecolor=black,fontcolor=black,shadow=true}
2195 \NewEnviron{miinstructornote}{%
2196     \begin{mdframed}[style=miinstructornotestyle]
2197     \begin{adjactivityanswer}[cyan!25][cyan!25][black]
2198         \BODY
2199     \end{adjactivityanswer}
2200     \end{mdframed}
2201 }%
2202 \mdfdefinestyle{mistudentnotestyle}{%
2203     hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
2204     leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
2205     nobreak=true,
2206     frametitle={STUDENT NOTE},
2207     frametitlebackgroundcolor=cyan!60,frametitlerule=true,frametitlerulewidth=1,
2208     backgroundcolor=cyan!25,
2209     linecolor=black,fontcolor=black,shadow=true}
2210 \NewEnviron{mistudentnote}{%
2211     \begin{mdframed}[style=mistudentnotestyle]
2212     \begin{adjactivityanswer}[cyan!25][cyan!25][black]
2213         \BODY
2214     \end{adjactivityanswer}

```

```

2215 \end{mdframed}
2216 }%
2217 \mdfdefinestyle{miderivationstyle}{%
2218     hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
2219     leftmargin=0pt,rightmargin=0pt,linewidth=1,roundcorner=10,
2220     nobreak=true,
2221     frametitle={DERIVATION},
2222     frametitlebackgroundcolor=orange!60,frametitlerule=true,frametitlerulewidth=1,
2223     backgroundcolor=orange!25,
2224     linecolor=black,fontcolor=black,shadow=true}
2225 \NewEnviron{miderivation}{%
2226     \begin{mdframed}[style=miderivationstyle]
2227     \setcounter{equation}{0}
2228     \begin{align}
2229     \BODY
2230     \end{align}
2231     \end{mdframed}
2232 }%
2233 \NewEnviron{miderivation*}{%
2234     \begin{mdframed}[style=miderivationstyle]
2235     \setcounter{equation}{0}
2236     \begin{align*}
2237     \BODY
2238     \end{align*}
2239     \end{mdframed}
2240 }%
2241 \mdfdefinestyle{bwinstructornotestyle}{%
2242     hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
2243     leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
2244     nobreak=true,
2245     frametitle={INSTRUCTOR NOTE},
2246     frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
2247     backgroundcolor=gray!20,
2248     linecolor=black,fontcolor=black,shadow=true}
2249 \NewEnviron{bwinstructornote}{%
2250     \begin{mdframed}[style=bwinstructornotestyle]
2251     \begin{adjactivityanswer}[gray!20][gray!20][black]
2252     \BODY
2253     \end{adjactivityanswer}
2254     \end{mdframed}
2255 }%
2256 \mdfdefinestyle{bwstudentnotestyle}{%
2257     hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
2258     leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
2259     nobreak=true,
2260     frametitle={STUDENT NOTE},
2261     frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
2262     backgroundcolor=gray!20,
2263     linecolor=black,fontcolor=black,shadow=true}
2264 \NewEnviron{bwstudentnote}{%

```

```

2265 \begin{mdframed}[style=bwstudentnotestyle]
2266   \begin{adjactivityanswer}[gray!20][gray!20][black]
2267     \BODY
2268   \end{adjactivityanswer}
2269 \end{mdframed}
2270 }%
2271 \mdfdefinestyle{bwderivationstyle}{%
2272   hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
2273   leftmargin=Opt,rightmargin=Opt,linewidth=1,roundcorner=10,
2274   nobreak=true,
2275   frametitle={DERIVATION},
2276   frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
2277   backgroundcolor=gray!20,
2278   linecolor=black,fontcolor=black,shadow=true}
2279 \NewEnviron{bwderivation}{%
2280   \begin{mdframed}[style=bwderivationstyle]
2281     \setcounter{equation}{0}
2282     \begin{align}
2283       \BODY
2284     \end{align}
2285   \end{mdframed}
2286 }%
2287 \NewEnviron{bwderivation*}{%
2288   \begin{mdframed}[style=bwderivationstyle]
2289     \setcounter{equation}{0}
2290     \begin{align*}
2291       \BODY
2292     \end{align*}
2293   \end{mdframed}
2294 }%
2295 \NewEnviron{mysolution}{%
2296   \setcounter{equation}{0}
2297   \begin{align}
2298     \BODY
2299   \end{align}
2300 }%
2301 \NewEnviron{mysolution*}{%
2302   \setcounter{equation}{0}
2303   \begin{align*}
2304     \BODY
2305   \end{align*}
2306 }%
2307 \newenvironment{problem}[1]{%
2308   \newpage%
2309   \section*{#1}%
2310   \newlist{parts}{enumerate}{2}%
2311   \setlist[parts]{label=(\alph*)}{\newpage}
2312 \newcommand{\problempart}{\item}%
2313 \newcommand{\reason}[1]{\parbox{2cm}{#1}}
2314 \newcommand*{\checkpoint}{%

```



```

2315 \vspace{1cm}\begin{center}%
2316 \colorbox{yellow!80}{|----- CHECKPOINT -----|}%
2317 \end{center}}%
2318 \newcommand*{\image}[2]{%
2319 \begin{figure}[h!]
2320 \begin{center}%
2321 \includegraphics[scale=1]{#1}%
2322 \caption{#2}%
2323 \label{#1}%
2324 \end{center}%
2325 \end{figure}}
2326 %\changes{v2.5.0}{2015/09/13}{Changed behavior of \cs{sneakyone}.}
2327 \newcommand*{\sneakyone}[1]{\ensuremath{\cancelto{1}{#1}}}
2328 \newcommand*{\qed}{\ensuremath{\text{ Q.E.D.}}}
2329 \newcommand*{\chkquantity}[1]{%
2330 \begin{center}
2331 \begin{tabular}{C{4.5cm} C{4cm} C{4cm} C{4cm}}
2332 name & baseunit & drvdunit & tradunit \tabularnewline
2333 \cs{#1} & \csname #1onlybaseunit\endcsname & \csname #1onlydrvdunit\endcsname &
2334 \csname #1onlytradunit\endcsname
2335 \end{tabular}
2336 \end{center}
2337 }%
2338 \newcommand*{\chkconstant}[1]{%
2339 \begin{center}
2340 \begin{tabular}{C{4cm} C{2cm} C{3cm} C{3cm} C{3cm} C{3cm}}
2341 name & symbol & value & baseunit & drvdunit & tradunit \tabularnewline
2342 \cs{#1} & \csname #1mathsymbol\endcsname & \csname #1value\endcsname &
2343 \csname #1onlybaseunit\endcsname & \csname #1onlydrvdunit\endcsname &
2344 \csname #1onlytradunit\endcsname
2345 \end{tabular}
2346 \end{center}
2347 }%

```

7 Acknowledgements

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