The mandi package

Paul J. Heafner (heafnerj@gmail.com)

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1 Introduction

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

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

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

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

2 Building From Source

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

[1] See 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 five 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.
- **singleabsbars** 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.
- **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. If `mandi` detects that `commath` has been loaded, `commath`'s `\abs` command will be used rather than `mandi`'s. `mandi` no longer checks for the presence of the `physymb` package. That package now incorporates `mandi` dependencies, and the two are completely compatible.

4 Usage

So what does `mandi` allow you to do? There are two main design goals. The first is 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.

In introductory physics courses, students typically have trouble remembering which units go with which quantities and, more importantly, remembering to include units in numerical calculations. `mandi` is designed to help with these problems. Suppose you want to typeset a calculation of a particle's kinetic energy (assume the magnitude of the particle's velocity is much less than the magnitude of light's velocity). You could use

```
\[ K \approx \frac{1}{2}\left(\unit{2}{\kg}\right)\left(\unit{2}{\m\per\s}\right)^2 \]
```

$$K \approx \frac{1}{2}\left(2\,\mathrm{kg}\right)\left(2\,\mathrm{m/s}\right)^2$$

which is nearly incomprehensible for people new to LaTeX and that (probably) includes introductory physics students, but `mandi` lets you do something more logical and more readable, like this

```
\[ K \approx \onehalf (\mass{2})(\velocity{2})\squared \]
```

$$K \approx \frac{1}{2}\left(2\,\mathrm{kg}\right)\left(2\,\mathrm{m/s}\right)^2$$

which produces the same output. In the second example, note that the units are abstracted so the user need not remember them. This doesn't mean that students don't need to know what the various units are, but it does mean that now there is no way for units to be left out of a calculation. Note also that the commands correspond to the actual names of the quantities needed for the calculation. All the student needs to do is remember what quantities are needed and then construct the appropriate LaTeX expression in a way that is very similar to writing program code in a language like Python, with which many students will have had previous experience. This may make LaTeX easier for beginners to learn, and the second way is more readable if you come back to the source document, perhaps having not looked at it for a while.

Suppose you want to use vectors quantities. That's no problem because `mandi` handles vector quantities.

```
Calculate the magnitude of \momentum{\mivector{3,2,5}}.
```

Calculate the magnitude of $\langle 3, 2, 5\rangle\,\mathrm{kg \cdot m/s}$.

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.

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

```
\Efieldofparticle
```

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

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

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

This barely scratches the surface in describing `mandi` so continue reading this document to see everything it can do.

5 Features and Commands

5.1 Autosized Parentheses

An experimental feature of `mandi` is autosized parentheses in math mode. This means you need never use `\left(` or `\right)`. Just use unadorned parentheses and they will size correctly. Note that this only works in math mode, only works for parentheses and not for other delimiters.

```
(\oofpezmathsymbol) is how it looks in text mode.
```

($\frac{1}{4\pi\epsilon_0}$) is how it looks in text mode.

```
\( (\oofpezmathsymbol) \) is how it looks in math mode.
```

$\left(\frac{1}{4\pi\epsilon_0}\right)$ is how it looks in math mode.

5.2 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 invoked 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.

5.3 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

5.4 Defining Physics Quantities

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

Using this command causes several things to happen.

- A command `\newname{⟨magnitude⟩}`, where newname is the first argument of `\newphysicsquantity`, is created that takes one mandatory argument, a numerical magnitude. Subsequent use of your defined scalar quantity can be invoked by typing `\newname{⟨magnitude⟩}` and the units will be typeset according to the options given when `mandi` was loaded. Note that if the *drvdunits* and *tradunits* forms are not specified, they will be populated with the *baseunits* form.
- A command `\newnamebaseunit{⟨magnitude⟩}` is created that expresses the quantity and its units in *baseunits* form.
- A command `\newnamedrvdunit{⟨magnitude⟩}` is created that expresses the quantity and its units in *drvdunits* form. This command is created whether or not the first optional argument is provided.
- A command `\newnametradunit{⟨magnitude⟩}` is created that expresses the quantity and its units in *tradunits* form. This command is created whether or not the first optional argument is provided.
- A command `\newnameonlybaseunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in *baseunits* form.
- A command `\newnameonlydrvdunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in *drvdunits* form.
- A command `\newnameonlytradunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in *tradunits* form.
- A command `\newnamevalue{⟨magnitude⟩}` is created that expresses **only** the quantity's numerical value.

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

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

Momentum is a vector quantity, so obviously this command really refers to the magnitude of a momentum vector. There is an interesting, and as far as I can tell unwritten, convention in physics that we use the same name for a vector and its magnitude with one exception, and that is for velocity, the magnitude of which we sometimes call speed. Conceptually, however, velocity and speed are different entities. Therefore, `mandi` has different commands for them. Actually, the `\speed` command is just an alias for `\velocity` 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.

5.4.1 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, specify an argument consisting of a vector with components as a comma separated list in a `\mivector` command. So specifying a momentum vector is as simple as

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

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

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

5.5 First Semester Physics

The first semester of *Matter & Interactions* and indeed most traditional introductory calculus-based physics course, focuses on mechanics, dynamics, and statistical mechanics.

5.5.1 Predefined Quantities

The seven fundamental quantities are similarly defined and examples of their usage is given in the following table.

`\displacement{⟨magnitude⟩}`
Command for displacement.

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

a displacement of $5\,\mathrm{m}$
a displacement of $\langle 3, 2, -1\rangle \, \mathrm{m}$

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

```
a mass of \mass{5}
```

a mass of $5\,\mathrm{kg}$

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

```
a duration of \duration{5}
```

a duration of $5\,\mathrm{s}$

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

```
a current of \current{5}
```

a current of $5\,\mathrm{A}$

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

```
a temperature of \temperature{5}
```

a temperature of $5\,\mathrm{K}$

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

`an amount of \amount{5}`	an amount of 5 mol

\luminous{⟨*magnitude*⟩}
Command for luminous intensity.

`a luminous intensity of \luminous{5}`	a luminous intensity of 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.

`a plane angle of \planeangle{5}`	a plane angle of 5

\solidangle{⟨*magnitude*⟩}
Command for solidangle.

`a solid angle of \solidangle{5}`	a solid angle of 5

\indegrees{⟨*magnitude*⟩}
Command for plane angle in degrees.

`a plane angle of \indegrees{5}`	a plane angle of $5\,^{\circ}$

\inarcminutes{⟨*magnitude*⟩}
Command for plane angle in minutes of arc.

`an angle of \inarcminutes{5}`	an angle of $5\,'$

\inarcseconds{⟨*magnitude*⟩}
Command for plane angle in seconds of arc.

`an angle of \inarcseconds{5}`	an angle of $5\,''$

\inFarenheit{⟨*magnitude*⟩}
Command for temperature in degrees Farenheit.

`a temperature of \inFarenheit{68}`	a temperature of 68 °F

`\inCelsius{⟨magnitude⟩}`
Command for temperature in degrees Celsius.

`a temperature of \inCelsius{20}`	a temperature of 20 °C

`\ineV{⟨magnitude⟩}`
Command for energy in electron volts.

`an energy of \ineV{10.2}`	an energy of 10.2 eV

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

`a mass of \ineVocs{1.1}`	a mass of 1.1 eV/c^2

`\ineVoc{⟨magnitude⟩}`
Command for momentum in eV/c.

`a momentum of \ineVoc{3.6}`	a momentum of 3.6 eV/c

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

`an energy of \inMeV{2.2}`	an energy of 2.2 MeV

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

`a mass of \inMeVocs{0.511}`	a mass of 0.511 MeV/c^2

`\inMeVoc{⟨magnitude⟩}`
Command for momentum in MeV/c.

`a momentum of \inMeVoc{3.6}`	a momentum of 3.6 MeV/c

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

`an energy of \inGeV{2.2}`	an energy of 2.2 GeV

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

`a mass of \inGeVocs{0.511}`	a mass of 0.511 GeV/c^2

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

`a momentum of \inGeVoc{3.6}`	a momentum of 3.6 GeV/c

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

`an atomic mass of \inamu{4.002602}`	an atomic mass of 4.002602 u

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

`a semimajor axis of \inAU{5.2}`	a semimajor axis of 5.2 AU

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

`a distance of \inly{4.3}`	a distance of 4.3 ly

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

`a distance of \incyr{4.3}`	a distance of 4.3 $c \cdot$ year

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

`a distance of \inpc{4.3}`	a distance of 4.3 pc

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

`a luminosity of \insolarL{4.3}`	a luminosity of 4.3 $L_\odot$

`\insolarT{⟨magnitude⟩}`
Command for temperature in solar multiples.

`a temperature of \insolarT{2}`	a temperature of 2 $T_\odot$

`\insolarR{⟨magnitude⟩}`
Command for radius in solar multiples.

`a radius of \insolarR{4.3}`	a radius of 4.3 $R_\odot$

`\insolarM{⟨magnitude⟩}`
Command for mass in solar multiples.

`a mass of \insolarM{4.3}`	a mass of 4.3 $M_\odot$

`\insolarF{⟨magnitude⟩}`
Command for flux in solar multiples.

`a flux of \insolarF{4.3}`	a flux of 4.3 $F_\odot$

`\insolarf{⟨magnitude⟩}`
Command for apparent flux in solar multiples.

`an apparent flux of \insolarf{4.3}`	an apparent flux of 4.3 $f_\odot$

`\insolarMag{⟨magnitude⟩}`
Command for absolute magnitude in solar multiples.

`an absolute magnitude of \insolarMag{2}`	an absolute magnitude of 2 $M_\odot$

`\insolarmag{⟨magnitude⟩}`
Command for apparent magnitude in solar multiples.

`an apparent magnitude of \insolarmag{2}`	an apparent magnitude of 2 $m_\odot$

`\insolarD{⟨magnitude⟩}`
Command for distance in solar multiples.

```
a distance of \insolarD{2}
```

a distance of $2\,D_\odot$

\insolard{⟨*magnitude*⟩}

Identical to `\insolarD` but uses d.

```
a distance of \insolard{2}
```

a distance of $2\,d_\odot$

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 move on into first semester physics, defining quantities in the approximate order in which they appear in *Matter & Interactions*. Use `M\timestento{P}[U]` to get scientific notation, with the mantissa immediately preceding the command and the exponent as the required argument. `\timestento` has an optional second argument that specifies a unit, but that is not needed or used in the following examples.

\velocityc{⟨*magnitude or vector*⟩}

Command for velocity as a fraction of c.

```
a velocity of \velocityc{0.9987} \\
a velocity of \velocityc{\mivector{0,0.9987,0}} \\
a velocity of 
    \mivector{\velocityc{\frac{1}{\sqrt{3}}},\\
\velocityc{\frac{1}{\sqrt{3}}},\\
\velocityc{\frac{1}{\sqrt{3}}}}
```

a velocity of $0.9987c$
a velocity of $\langle 0, 0.9987, 0\rangle\, c$
a velocity of $\left\langle \frac{1}{\sqrt{3}}c, \frac{1}{\sqrt{3}}c, \frac{1}{\sqrt{3}}c \right\rangle$

\velocity{⟨*magnitude or vector*⟩}

Command for velocity.

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

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

\speed{⟨*magnitude*⟩}

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

```
a speed of \velocity{8.25}
```

a speed of $8.25\,\mathrm{m/s}$

\lorentz{⟨*magnitude*⟩}

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

`a Lorentz factor of \lorentz{2.34}`	a Lorentz factor of 2.34

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

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

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

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

```
an acceleration of \acceleration{2.34} \\
an acceleration of ⤸
      ⤹\acceleration{\mivector{3,2,-1}}
```

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

`\gravitationalfield{⟨magnitude or vector⟩}`
Command for gravitational field.

```
a gravitational field of ⤸
      ⤹\gravitationalfield{2.34} \\
a gravitational field of ⤸
      ⤹\gravitationalfield{\mivector{3,2,-1}}
```

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

`\gravitationalpotential{⟨magnitude⟩}`
Command for gravitational potential.

```
a gravitational potential of ⤸
      ⤹\gravitationalpotential{2.34}
```

a gravitational potential of $2.34\,\mathrm{J/kg}$

`\impulse{⟨magnitude or vector⟩}`
Command for impulse. Impulse and change in momentum are conceptually different and a case can be made for expressing the in different, but equivalent, units.

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

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

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

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

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

\springstiffness{⟨*magnitude*⟩}

Command for spring stiffness.

`a spring stiffness of \springstiffness{2.34}`	a spring stiffness of 2.34 N/m

\springstretch{⟨*magnitude*⟩}

Command for spring stretch.

`a spring stretch of \springstretch{2.34}`	a spring stretch of 2.34 m

\area{⟨*magnitude*⟩}

Command for area.

`an area of \area{2.34}`	an area of 2.34 m^2

\volume{⟨*magnitude*⟩}

Command for volume.

`a volume of \volume{2.34}`	a volume of 2.34 m^3

\linearmassdensity{⟨*magnitude*⟩}

Command for linear mass density.

`a linear mass density of \linearmassdensity{2.34}`	a linear mass density of 2.34 kg/m

\areamassdensity{⟨*magnitude*⟩}

Command for area mass density.

`an area mass density of \areamassdensity{2.34}`	an area mass density of 2.34 kg/m^2

\volumemassdensity{⟨*magnitude*⟩}

Command for volume mass density.

`a volume mass density of \volumemassdensity{2.34}`	a volume mass density of 2.34 kg/m^3

\youngsmodulus{⟨*magnitude*⟩}

Command for Young's modulus.

`a Young's modulus of \youngsmodulus{2.34\timestento{9}}`	a Young's modulus of 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.

`an amount of work \work{2.34}`	an amount of work $2.34\,\mathrm{N\cdot m}$

`\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.

`an amount of energy \energy{2.34}`	an amount of energy 2.34 J

`\power{⟨magnitude⟩}`
Command for power.

`an amount of power \power{2.34}`	an amount of power 2.34 W

`\specificheatcapacity{⟨magnitude⟩}`
Command for specific heat capacity.

`a specific heat capacity of \specificheatcapacity{4.18\xtento{3}}`	a specific heat capacity of $4.18 \times 10^3\,\mathrm{J/K\cdot kg}$

`\angularvelocity{⟨magnitude or vector⟩}`
Command for angular velocity.

`an angular velocity of \angularvelocity{2.34}`	an angular velocity of 2.34 rad/s

`\angularacceleration{⟨magnitude or vector⟩}`
Command for angular acceleration.

`an angular acceleration of \angularacceleration{2.34}`	an angular acceleration of $2.34\,\mathrm{rad/s^2}$

`\angularmomentum{⟨magnitude or vector⟩}`
Command for angular momentum.

`an angular momentum of \angularmomentum{2.34}`	an angular momentum of 2.34 $\mathrm{kg \cdot m^2/s}$

`\momentofinertia{`⟨*magnitude*⟩`}`
Command for moment of inertia.

`a moment of inertia of \momentofinertia{2.34}`	a moment of inertia of 2.34 $\mathrm{kg \cdot m^2}$

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

`a torque of \torque{2.34}`	a torque of 2.34 $\mathrm{N \cdot m}$

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

`an entropy of \entropy{2.34}`	an entropy of 2.34 $\mathrm{J/K}$

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

`a wavelength of \wavelength{4.00\timestento{-7}}`	a wavelength of $4.00 \times 10^{-7}\mathrm{m}$

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

`a wavenumber of \wavenumber{2.50\timestento{6}}`	a wavenumber of $2.50 \times 10^{6}/\mathrm{m}$

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

`a frequency of \frequency{7.50\timestento{14}}`	a frequency of $7.50 \times 10^{14}\mathrm{Hz}$

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

`an angular frequency of \angularfrequency{4.70\timestento{15}}`	an angular frequency of $4.70 \times 10^{15}\mathrm{rad/s}$

Two quick thoughts here. First, work and energy are similar to momentum and impulse in that they come from two different concepts. Work comes from force acting through a spatial displacement and energy is a fundamental property of matter. It is a coincidence that they have the same dimensions and thus the same unit. Second, notice that I didn't define speed. Velocity is the only quantity I can think of for which we have different names for the vector and the magnitude of the vector. I decided to put it on the same footing as momentum, acceleration, and force.

5.6 Second Semester Physics

The second semester of *Matter & Interactions* focuses on electromagnetic theory, and there are many primary and secondary quantities.

5.6.1 Predefined Quantities

`\charge{⟨magnitude⟩}`
Command for electric charge.

`a charge of \charge{2\timestento{-9}}`	a charge of $2 \times 10^{-9}\mathrm{C}$

`\permittivity{⟨magnitude⟩}`
Command for permittivity.

`a permittivity of \permittivity{9\timestento{-12}}`	a permittivity of $9 \times 10^{-12}\mathrm{C}^2/\mathrm{N}\cdot\mathrm{m}^2$

`\electricdipolemoment{⟨magnitude or vector⟩}`
Command for electric dipole moment.

`an electric dipole moment of \electricdipolemoment{2\timestento{5}}`	an electric dipole moment of $2 \times 10^{5}\mathrm{C}\cdot\mathrm{m}$

`\permeability{⟨magnitude⟩}`
Command for permeability.

`a permeability of \permeability{4\pi\timestento{-7}}`	a permeability of $4\pi \times 10^{-7}\mathrm{T}\cdot\mathrm{m}/\mathrm{A}$

`\magneticfield{⟨magnitude or vector⟩}`
Command for magnetic field (also called magnetic induction).

`a magnetic field of \magneticfield{1.25}`	a magnetic field of $1.25\,\mathrm{N}/\mathrm{C}\cdot(\mathrm{m}/\mathrm{s})$

`\cmagneticfield{⟨magnitude or vector⟩}`

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

`a magnetic field of \cmagneticfield{1.25}`	a magnetic field of $1.25\,\mathrm{N/C}$

`\linearchargedensity{⟨magnitude⟩}`

Command for linear charge density.

`a linear charge density of \linearchargedensity{4.5\timestento{-3}}`	a linear charge density of $4.5 \times 10^{-3}\mathrm{C/m}$

`\areachargedensity{⟨magnitude⟩}`

Command for area charge density.

`an area charge density of \areachargedensity{1.25}`	an area charge density of $1.25\,\mathrm{C/m^2}$

`\volumechargedensity{⟨magnitude⟩}`

Command for volume charge density.

`a volume charge density of \volumechargedensity{1.25}`	a volume charge density of $1.25\,\mathrm{C/m^3}$

`\mobility{⟨magnitude⟩}`

Command for electron mobility.

`a mobility of \areachargedensity{4.5\timestento{-3}}`	a mobility of $4.5 \times 10^{-3}\mathrm{C/m^2}$

`\numberdensity{⟨magnitude⟩}`

Command for electron number density.

`a number density of \numberdensity{2\timestento{18}}`	a number density of $2 \times 10^{18}/\mathrm{m^3}$

`\polarizability{⟨magnitude⟩}`

Command for polarizability.

`a polarizability of \polarizability{1.96\timestento{-40}}`	a polarizability of $1.96 \times 10^{-40}\mathrm{C \cdot m/\left(N/C\right)}$

`\electricpotential{⟨magnitude⟩}`
Command for electric potential.

`an electric potential of \electricpotential{1.5}`	an electric potential of 1.5 V

`\emf{⟨magnitude⟩}`
Command for emf.

`an emf of \emf{1.5}`	an emf of 1.5 V

`\dielectricconstant{⟨magnitude⟩}`
Command for dielectric constant.

`a dielectric constant of \dielectricconstant{1.5}`	a dielectric constant of 1.5

`\indexofrefraction{⟨magnitude⟩}`
Command for index of refraction.

`an index of refraction of \indexofrefraction{1.5}`	an index of refraction of 1.5

`\relativepermittivity{⟨magnitude⟩}`
Command for relative permittivity.

`a relative permittivity of \relativepermittivity{0.9}`	a relative permittivity of 0.9

`\relativepermeability{⟨magnitude⟩}`
Command for relative permeability.

`a relative permeability of \relativepermeability{0.9}`	a relative permeability of 0.9

`\energydensity{⟨magnitude⟩}`
Command for energy density.

`an energy density of \energydensity{1.25}`	an energy density of 1.25 J/m^3

`\energyflux{⟨magnitude⟩}`
Command for energy flux.

`an energy flux of \energyflux{4\timestento{26}}`	an energy flux of 4×10^{26}W/m^2

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

`an electron current of \electroncurrent{2\timestento{18}}`	an electron current of 2×10^{18}e/s

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

`a conventional current of \conventionalcurrent{0.003}`	a conventional current of 0.003 A

`\magneticdipolemoment`{⟨*magnitude or vector*⟩}
Command for magnetic dipole moment.

`a magnetic dipole moment of \magneticdipolemoment{1.25}`	a magnetic dipole moment of 1.25 A · m^2

`\currentdensity`{⟨*magnitude or vector*⟩}
Command for current density.

`a current density of \currentdensity{1.25}`	a current density of 1.25 A/m^2

`\electricflux`{⟨*magnitude*⟩}
Command for electric flux.

`an electric flux of \electricflux{1.25}`	an electric flux of 1.25 N · m^2/C

`\magneticflux`{⟨*magnitude*⟩}
Command for magnetic flux.

`a magnetic flux of \magneticflux{1.25}`	a magnetic flux of 1.25 T · m^2

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

`a capacitance of \capacitance{1.00}`	a capacitance of 1.00 C/V

`\inductance{⟨magnitude⟩}`
Command for inductance.

`an inductance of \inductance{1.00}`	an inductance of $1.00\,\mathrm{V}\cdot\mathrm{s}/\mathrm{A}$

`\conductivity{⟨magnitude⟩}`
Command for conductivity.

`a conductivity of \conductivity{1.25}`	a conductivity of $1.25\,\left(\mathrm{A}/\mathrm{m}^2\right)/\left(\mathrm{V}/\mathrm{m}\right)$

`\resistivity{⟨magnitude⟩}`
Command for resistivity.

`a resistivity of \resistivity{1.25}`	a resistivity of $1.25\,\left(\mathrm{V}/\mathrm{m}\right)/\left(\mathrm{A}/\mathrm{m}^2\right)$

`\resistance{⟨magnitude⟩}`
Command for resistance.

`a resistance of \resistance{1\timestento{6}}`	a resistance of $1\times10^{6}\,\Omega$

`\conductance{⟨magnitude⟩}`
Command for conductance.

`a conductance of \conductance{1\timestento{6}}`	a conductance of $1\times10^{6}\,\mathrm{S}$

`\magneticcharge{⟨magnitude⟩}`
Command for magnetic charge, in case it actually exists.

`a magnetic charge of \magneticcharge{1.25}`	a magnetic charge of $1.25\,\mathrm{m}\cdot\mathrm{A}$

5.7 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.

`a momentum of \hereusebaseunit{\momentum{3}}`	a momentum of $3\,\mathrm{m}\cdot\mathrm{kg}\cdot\mathrm{s}^{-1}$

`\hereusedrvdunit{⟨magnitude⟩}`
Command for using derived units in place.

`a momentum of \hereusedrvdunit{\momentum{3}}`	a momentum of $3\,\mathrm{N}\cdot\mathrm{s}$

`\hereusetradunit{⟨magnitude⟩}`
Command for using traditional units in place.

`a momentum of \hereusetradunit{\momentum{3}}`	a momentum of $3\,\mathrm{kg}\cdot\mathrm{m/s}$

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

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

Environment for using base units.

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

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

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

Environment for using derived units.

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

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

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

Environment for using traditional units.

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

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

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

`\perpusebaseunit`
: Command for perpetually using base units.

`\perpusedrvdunit`
: Command for perpetually using derived units..

`\perpusetradunit`
: Command for perpetually using traditional units..

Here are all the predefined quantities and their units.

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

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

name	baseunit	drvdunit	tradunit
`\torque`	$\mathrm{m^2 \cdot kg \cdot s^{-2}}$	$\mathrm{J/rad}$	$\mathrm{N \cdot m}$

name	baseunit	drvdunit	tradunit
`\entropy`	$\mathrm{m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}}$	$\mathrm{J/K}$	$\mathrm{J/K}$

name	baseunit	drvdunit	tradunit
`\wavelength`	m	m	m

name	baseunit	drvdunit	tradunit
`\wavenumber`	$\mathrm{m^{-1}}$	$\mathrm{/m}$	$\mathrm{/m}$

name	baseunit	drvdunit	tradunit
`\frequency`	$\mathrm{s^{-1}}$	Hz	Hz

name	baseunit	drvdunit	tradunit
`\angularfrequency`	$\mathrm{rad \cdot s^{-1}}$	$\mathrm{rad/s}$	$\mathrm{rad/s}$

name	baseunit	drvdunit	tradunit
`\charge`	$\mathrm{A \cdot s}$	C	C

name	baseunit	drvdunit	tradunit
`\permittivity`	$\mathrm{m^{-3} \cdot kg^{-1} \cdot s^{-4} \cdot A^2}$	$\mathrm{F/m}$	$\mathrm{C^2/N \cdot m^2}$

name	baseunit	drvdunit	tradunit
`\permeability`	$\mathrm{m \cdot kg \cdot s^{-2} \cdot A^{-2}}$	$\mathrm{H/m}$	$\mathrm{T \cdot m/A}$

name	baseunit	drvdunit	tradunit
`\electricfield`	$\mathrm{m \cdot kg \cdot s^{-3} \cdot A^{-1}}$	$\mathrm{V/m}$	$\mathrm{N/C}$

name	baseunit	drvdunit	tradunit
`\electricdipolemoment`	$\mathrm{m \cdot s \cdot A}$	$\mathrm{C \cdot m}$	$\mathrm{C \cdot m}$

name	baseunit	drvdunit	tradunit
`\electricflux`	$\mathrm{m^3 \cdot kg \cdot s^{-3} \cdot A^{-1}}$	$\mathrm{V \cdot m}$	$\mathrm{N \cdot m^2/C}$

name	baseunit	drvdunit	tradunit
`\magneticfield`	$\mathrm{kg \cdot s^{-2} \cdot A^{-1}}$	T	$\mathrm{N/C \cdot (m/s)}$

name	baseunit	drvdunit	tradunit
`\magneticflux`	$\mathrm{m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}}$	$\mathrm{V \cdot s}$	$\mathrm{T \cdot m^2}$

name	baseunit	drvdunit	tradunit
`\cmagneticfield`	$\mathrm{m \cdot kg \cdot s^{-3} \cdot A^{-1}}$	$\mathrm{V/m}$	$\mathrm{N/C}$

name	baseunit	drvdunit	tradunit
`\linearchargedensity`	$\mathrm{m^{-1} \cdot s \cdot A}$	$\mathrm{C/m}$	$\mathrm{C/m}$

name	baseunit	drvdunit	tradunit
`\areachargedensity`	$\mathrm{m^{-2} \cdot s \cdot A}$	$\mathrm{C/m^2}$	$\mathrm{C/m^2}$

name	baseunit	drvdunit	tradunit
`\volumechargedensity`	$\mathrm{m^{-3} \cdot s \cdot A}$	$\mathrm{C/m^3}$	$\mathrm{C/m^3}$

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

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

5.8 Symbolic Expressions with Vectors

5.8.1 Basic Vectors

\vect{⟨*kernel*⟩}
  Symbol for a vector quantity.

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

\magvect{⟨*kernel*⟩}
  Symbol for magnitude of a vector quantity.

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

\magsquaredvect{⟨*kernel*⟩}
  Symbol for squared magnitude of a vector quantity.

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

\magnvect{⟨*kernel*⟩}{⟨*exponent*⟩}
  Symbol for magnitude of a vector quantity to arbitrary power.

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

\dirvect{⟨*kernel*⟩}
  Symbol for direction of a vector quantity. Use `\direction` as an alias.

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

\mivector[⟨*printeddelimiter*⟩]{⟨*commadelimitedlistofcomps*⟩}[⟨*unit*⟩]
  Generic workhorse command for vectors formatted as in *Matter & Interactions*.

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

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

\ncompszerovect

Symbol for the zero vector expressed in components. Deprecated. Use \mivector instead.

```
\ncompszerovect
```

$\langle 0, 0, 0\rangle$

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

Expression for a vector's magnitude with numerical components and an optional unit. The first example is the preferred and recommended way to handle units when they are needed. The second example requires explicitly picking out the desired unit form. The third example demonstrates components of a unit vector. It is probably best for students to include components' units inside the radical than to write them outside the radical.

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

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

\scompsvect{⟨*kernel*⟩}

Expression for a vector's symbolic components.

```
\scompsvect{E}
```

$\langle E_x, E_y, E_z\rangle$

\compvect{⟨*kernel*⟩}{⟨*component*⟩}

Isolates one of a vector's symbolic components.

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

E_y

\magvectscomps{⟨*kernel*⟩}

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

```
\magvectscomps{B}
```

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

5.8.2 Differentials and Derivatives of Vectors

\dvect{⟨*kernel*⟩}

Symbol for the differential of a vector.

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

\Dvect{⟨*kernel*⟩}

Identical to `\dvect` but uses Δ.

`a change \Dvect{E} in electric field`	a change $\Delta\vec{E}$ in electric field

\dirdvect{⟨*kernel*⟩}

Symbol for the direction of a vector's differential.

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

\dirDvect{⟨*kernel*⟩}

Identical to `\dirdvect` but uses Δ.

`the direction \dirDvect{E} of the change`	the direction $\widehat{\Delta\vec{E}}$ of the change

\ddirvect{⟨*kernel*⟩}

Symbol for the differential of a vector's direction. Use `\ddirection` as an alias.

`the change \ddirvect{E} or \ddirection{E} in the direction of \vect{E}`	the change $\mathrm{d}\widehat{E}$ or $\mathrm{d}\widehat{E}$ in the direction of $\vec{E}$

\Ddirvect{⟨*kernel*⟩}

Identical to `\ddirvect` but uses Δ. Use `\Ddirection` as an alias.

`the direction \Ddirvect{E} or \Ddirection{E} of the change`	the direction $\Delta\widehat{E}$ or $\Delta\widehat{E}$ of the change

\magdvect{⟨*kernel*⟩}

Symbol for the magnitude of a vector's differential.

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

\magDvect{⟨*kernel*⟩}

Identical to `\magdvect` but uses Δ.

`the magnitude \magDvect{E} of the change`	the magnitude $\left\lVert\Delta\vec{E}\right\rVert$ of the change

`\dmagvect{⟨kernel⟩}`

Symbol for the differential of a vector's magnitude.

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

`\Dmagvect{⟨kernel⟩}`

Identical to `\dmagvect` but uses Δ.

`the change \Dmagvect{E} in the magnitude`	the change $\Delta\left\lVert\vec{E}\right\rVert$ in the magnitude

`\scompsdvect{⟨kernel⟩}`

Symbolic components of a vector.

`the vector \scompsdvect{E}`	the vector $\langle \mathrm{d}E_x, \mathrm{d}E_y, \mathrm{d}E_z \rangle$

`\scompsDvect{⟨kernel⟩}`

Identical to `\scompsdvect` but uses Δ.

`the vector \scompsDvect{E}`	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.

`the \compdvect{E}{y} component of the change`	the $\mathrm{d}E_y$ component of the change

`\compDvect{⟨kernel⟩}{⟨component⟩}`

Identical to `\compdvect` but uses Δ.

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

`\dervect{⟨kernel⟩}{⟨indvar⟩}`

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

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

`\Dervect{⟨kernel⟩}{⟨indvar⟩}`

Identical to `\dervect` but uses Δ.

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

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

`\dermagvect{⟨kernel⟩}{⟨indvar⟩}`

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

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

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

`\Dermagvect{⟨kernel⟩}{⟨indvar⟩}`

Identical to `\dermagvect` but uses Δ.

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

the derivative $\frac{\Delta\left\lVert\vec{E}\right\rVert}{\Delta t}$

`\derdirvect{⟨kernel⟩}{⟨indvar⟩}`

Symbol for the derivative of a vector's direction with respect to an independent variable. Use `\derdiraction` as an alias.

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

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

`\Derdirvect{⟨kernel⟩}{⟨indvar⟩}`

Identical to `\derdirvect` but uses Δ. Use `\Derdirection` as an alias.

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

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

`\scompsdervect{⟨kernel⟩}{⟨indvar⟩}`

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

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

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

`\scompsDervect{⟨kernel⟩}{⟨indvar⟩}`

Identical to `\scompsdervect` but uses Δ.

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

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

\compdervect{⟨*kernel*⟩}{⟨*component*⟩}{⟨*indvar*⟩}
Isolates one component of a vector's derivative with respect to an independent variable.

`the derivative \compdervect{E}{y}{t}`	the derivative $\frac{\mathrm{d}E_y}{\mathrm{d}t}$

\compDervect{⟨*kernel*⟩}{⟨*component*⟩}{⟨*indvar*⟩}
Identical to `\compdervect` but uses Δ.

`the derivative \compDervect{E}{y}{t}`	the derivative $\frac{\Delta E_y}{\Delta t}$

\magdervect{⟨*kernel*⟩}{⟨*indvar*⟩}
Symbol for the magnitude of a vector's derivative with respect to an independent variable.

`the derivative \magdervect{E}{t}`	the derivative $\left\lVert\frac{\mathrm{d}\vec{E}}{\mathrm{d}t}\right\rVert$

\magDervect{⟨*kernel*⟩}{⟨*indvar*⟩}
Identical to `\magdervect` but uses Δ.

`the derivative \magDervect{E}{t}`	the derivative $\left\lVert\frac{\Delta\vec{E}}{\Delta t}\right\rVert$

5.8.3 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.

5.8.4 Subscripted or Indexed Vectors

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

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

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

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

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

`\magvectsub{p}{ball}`	$\lVert\vec{p}_{\text{ball}}\rVert$

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

`\magsquaredvectsub{p}{ball}`	$\lVert\vec{p}_{\text{ball}}\rVert^2$

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

`\magnvectsub{r}{dipole}{5}`	$\lVert\vec{r}_{\text{dipole}}\rVert^5$

`\dirvectsub{⟨kernel⟩}{⟨sub⟩}`
Symbol for a subscripted vector's direction. Use `\directionsub` as an alias.

`\dirvectsub{p}{ball} or \directionsub{p}{ball}`	$\widehat{p}_{\text{ball}}$ or $\widehat{p}_{\text{ball}}$

`\scompsvectsub{⟨kernel⟩}{⟨sub⟩}`
Symbolic components of a subscripted vector.

`the vector \scompsvectsub{p}{ball}`	the vector $\left\langle p_{\text{ball},x}, p_{\text{ball},y}, p_{\text{ball},z}\right\rangle$

`\compvectsub{⟨kernel⟩}{⟨sub⟩}{⟨component⟩}`
Isolates one component of a subscripted vector.

`the component \compvectsub{p}{ball}{z}`	the component $p_{\text{ball},z}$

`\magvectsubscomps{⟨kernel⟩}{⟨sub⟩}`
Expression for a subscripted vector's magnitude in terms of symbolic components.

`the magnitude \magvectsubscomps{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.

`the change \dvectsub{p}{ball}`	the change $\mathrm{d}\vec{p}_{\text{ball}}$

`\Dvectsub`{⟨*kernel*⟩}{⟨*sub*⟩}

Identical to `\dvectsub` but uses Δ.

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

`\scompsdvectsub`{⟨*kernel*⟩}{⟨*sub*⟩}

Symbolic components of a subscripted vector's differential.

`the vector \scompsdvectsub{p}{ball}`	the vector $\left\langle \mathrm{d}p_{\text{ball},x}, \mathrm{d}p_{\text{ball},y}, \mathrm{d}p_{\text{ball},z} \right\rangle$

`\scompsDvectsub`{⟨*kernel*⟩}{⟨*sub*⟩}

Identical to `\scompsdvectsub` but uses Δ.

`the vector \scompsDvectsub{p}{ball}`	the vector $\left\langle \Delta p_{\text{ball},x}, \Delta p_{\text{ball},y}, \Delta p_{\text{ball},z} \right\rangle$

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

Isolates one component of a subscripted vector's differential.

`the component \compdvectsub{p}{ball}{y}`	the component $\mathrm{d}p_{\text{ball},y}$

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

Identical to `\compdvectsub` but uses Δ.

`the component \compDvectsub{p}{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.

`the derivative \dervectsub{p}{ball}{t}`	the derivative $\dfrac{\mathrm{d}\vec{p}_{\text{ball}}}{\mathrm{d}t}$

\Dervectsub{⟨*kernel*⟩}{⟨*sub*⟩}{⟨*indvar*⟩}
Identical to `\dervectsub` but uses Δ.

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

`the derivative \dermagvectsub{E}{ball}{t}`	the derivative $\frac{\mathrm{d}\left\Vert\vec{E}_{\text{ball}}\right\Vert}{\mathrm{d}t}$

\Dermagvectsub{⟨*kernel*⟩}{⟨*sub*⟩}{⟨*indvar*⟩}
Identical to `\dermagvectsub` but uses Δ.

`the derivative \Dermagvectsub{E}{ball}{t}`	the derivative $\frac{\Delta\left\Vert\vec{E}_{\text{ball}}\right\Vert}{\Delta t}$

\scompsdervectsub{⟨*kernel*⟩}{⟨*sub*⟩}{⟨*indvar*⟩}
Symbolic components of a subscripted vector's derivative with respect to an independent variable.

`the vector \scompsdervectsub{p}{ball}{t}`	the vector $\left\langle\frac{\mathrm{d}p_{\text{ball},x}}{\mathrm{d}t},\frac{\mathrm{d}p_{\text{ball},y}}{\mathrm{d}t},\frac{\mathrm{d}p_{\text{ball},z}}{\mathrm{d}t}\right\rangle$

\scompsDervectsub{⟨*kernel*⟩}{⟨*sub*⟩}{⟨*indvar*⟩}
Identical to `\scompsdervectsub` but uses Δ.

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

`the component \compdervectsub{p}{ball}{y}{t}`	the component $\frac{\mathrm{d}p_{\text{ball},y}}{\mathrm{d}t}$

\compDervectsub{⟨*kernel*⟩}{⟨*sub*⟩}{⟨*component*⟩}{⟨*indvar*⟩}
Identical to `\compdervectsub` but uses Δ.

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

`the derivative \magdervectsub{p}{ball}{t}`	the derivative $\left\lVert\frac{\mathrm{d}\vec{p}_{\mathrm{ball}}}{\mathrm{d}t}\right\rVert$

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

Identical to `\magdervectsub` but uses Δ.

`the derivative \magDervectsub{p}{ball}{t}`	the derivative $\left\lVert\frac{\Delta\vec{p}_{\mathrm{ball}}}{\Delta t}\right\rVert$

5.8.5 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{F}{r}`	$\langle F_x, F_y, F_z\rangle\bullet\langle \mathrm{d}r_x, \mathrm{d}r_y, \mathrm{d}r_z\rangle$

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

Identical to \vectdotsdvect but uses Δ.

`\vectdotsDvect{F}{r}`	$\langle F_x, F_y, F_z \rangle \bullet \langle \Delta r_x, \Delta r_y, \Delta r_z \rangle$

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

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

`\vectdotedvect{F}{r}`	$F_x \mathrm{d}r_x + F_y \mathrm{d}r_y + F_z \mathrm{d}r_z$

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

Identical to \vectdotedvect but uses Δ.

`\vectdoteDvect{F}{r}`	$F_x \Delta r_x + F_y \Delta r_y + F_z \Delta r_z$

\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{A}{ball}{B}{car}`	$\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z} \rangle \bullet \langle \mathrm{d}B_{\text{car},x}, \mathrm{d}B_{\text{car},y}, \mathrm{d}B_{\text{car},z} \rangle$

\vectsubdotsDvectsub{⟨*kernel1*⟩}{⟨*sub1*⟩}{⟨*kernel2*⟩}{⟨*sub2*⟩}

Identical to \vectsubdotsdvectsub but uses Δ.

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

\vectsubdotedvectsub{⟨*kernel1*⟩}{⟨*sub1*⟩}{⟨*kernel2*⟩}{⟨*sub2*⟩}

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

`\vectsubdotedvectsub{A}{ball}{B}{car}`	$A_{\text{ball},x} \mathrm{d}B_{\text{car},x} + A_{\text{ball},y} \mathrm{d}B_{\text{car},y} + A_{\text{ball},z} \mathrm{d}B_{\text{car},z}$

`\vectsubdoteDvectsub{⟨kernel1⟩}{⟨sub1⟩}{⟨kernel2⟩}{⟨sub2⟩}`

Identical to `\vectsubdotedvectsub` but uses Δ.

`\vectsubdoteDvectsub{A}{ball}{B}{car}`	$A_{\text{ball},x}\Delta B_{\text{car},x} + A_{\text{ball},y}\Delta B_{\text{car},y} + A_{\text{ball},z}\Delta B_{\text{car},z}$

`\vectsubdotsdvect{⟨kernel1⟩}{⟨sub1⟩}{⟨kernel2⟩}`

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

`\vectsubdotsdvect{A}{ball}{B}`	$\left\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z}\right\rangle \bullet \langle \mathrm{d}B_x, \mathrm{d}B_y, \mathrm{d}B_z\rangle$

`\vectsubdotsDvect{⟨kernel1⟩}{⟨sub1⟩}{⟨kernel2⟩}`

Identical to `\vectsubdotsdvect` but uses Δ.

`\vectsubdotsDvect{A}{ball}{B}`	$\left\langle A_{\text{ball},x}, A_{\text{ball},y}, A_{\text{ball},z}\right\rangle \bullet \langle \Delta B_x, \Delta B_y, \Delta B_z\rangle$

`\vectsubdotedvect{⟨kernel1⟩}{⟨sub1⟩}{⟨kernel2⟩}`

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

`\vectsubdotedvect{A}{ball}{B}`	$A_{\text{ball},x}\mathrm{d}B_x + A_{\text{ball},y}\mathrm{d}B_y + A_{\text{ball},z}\mathrm{d}B_z$

`\vectsubdoteDvect{⟨kernel1⟩}{⟨sub1⟩}{⟨kernel2⟩}`

Identical to `\vectsubdotedvect` but uses Δ.

`\vectsubdoteDvect{A}{ball}{B}`	$A_{\text{ball},x}\Delta B_x + A_{\text{ball},y}\Delta B_y + A_{\text{ball},z}\Delta B_z$

`\dervectdotsvect{⟨kernel1⟩}{⟨indvar⟩}{⟨kernel2⟩}`

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

`\dervectdotsvect{A}{t}{B}`	$\left\langle \frac{\mathrm{d}A_x}{\mathrm{d}t}, \frac{\mathrm{d}A_y}{\mathrm{d}t}, \frac{\mathrm{d}A_z}{\mathrm{d}t}\right\rangle \bullet \langle B_x, B_y, B_z\rangle$

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

Identical to `\dervectdotsvect` but uses Δ.

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

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

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

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

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

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

Identical to `\dervectdotevect` but uses Δ.

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

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

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

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

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

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

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

Identical to `\vectdotsdervect` but uses Δ.

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

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

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

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

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

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

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

Identical to `\vectdotedervect` but uses Δ.

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

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

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

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

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

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

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

Identical to `\dervectdotsdvect` but uses Δ.

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

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

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

`\dervectdotedvect{A}{t}{B}`	$\frac{\mathrm{d}A_x}{\mathrm{d}t}\mathrm{d}B_x + \frac{\mathrm{d}A_y}{\mathrm{d}t}\mathrm{d}B_y + \frac{\mathrm{d}A_z}{\mathrm{d}t}\mathrm{d}B_z$

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

Identical to `\dervectdotedvect` but uses Δ.

`\DervectdoteDvect{A}{t}{B}`	$\frac{\Delta A_x}{\Delta t}\Delta B_x + \frac{\Delta A_y}{\Delta t}\Delta B_y + \frac{\Delta A_z}{\Delta t}\Delta B_z$

5.8.6 Expressions Containing Crosses

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

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

Cross of two vectors.

`\vectcrossvect{\vect{r}}{\vect{p}}`	$\vec{r} \times \vec{p}$

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

Symbol for left associated triple cross product.

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

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

Symbol for right associated triple cross product.

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

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

Symbol for left associated triple scalar product.

`\ltriplescalar{\vect{A}}{\vect{B}}{\vect{C}}`	$\vec{A} \times \vec{B} \bullet \vec{C}$

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

Symbol for right associated triple scalar product.

`\rtriplescalar{\vect{A}}{\vect{B}}{\vect{C}}`	$\vec{A} \bullet \vec{B} \times \vec{C}$

5.8.7 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.

`\ezero, \eone, \etwo, \ethree, \efour`	$\boldsymbol{e}_0$, $\boldsymbol{e}_1$, $\boldsymbol{e}_2$, $\boldsymbol{e}_3$, $\boldsymbol{e}_4$

`\uezero`

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

`\uezero, \ueone, \uetwo, \uethree, \uefour`	$\widehat{\boldsymbol{e}}_0$, $\widehat{\boldsymbol{e}}_1$, $\widehat{\boldsymbol{e}}_2$, $\widehat{\boldsymbol{e}}_3$, $\widehat{\boldsymbol{e}}_4$

`\ezerozero`

Symbols for basis bivectors with lower indices up to 4.

`\ezerozero, \ezeroone, \ezerotwo, \ezerothree, \ezerofour, up to \efourfour`	$\boldsymbol{e}_{00}$, $\boldsymbol{e}_{01}$, $\boldsymbol{e}_{02}$, $\boldsymbol{e}_{03}$, $\boldsymbol{e}_{04}$, up to $\boldsymbol{e}_{44}$

`\euzero`

Symbols for basis vectors with upper indices up to 4.

`\euzero, \euone, \eutwo, \euthree, \eufour`	$\boldsymbol{e}^0$, $\boldsymbol{e}^1$, $\boldsymbol{e}^2$, $\boldsymbol{e}^3$, $\boldsymbol{e}^4$

`\euzerozero`

Symbols for basis bivectors with upper indices up to 4.

`\euzerozero, \euzeroone, \euzerotwo, \euzerothree, \euzerofour, up to \eufourfour`	$\boldsymbol{e}^{00}$, $\boldsymbol{e}^{01}$, $\boldsymbol{e}^{02}$, $\boldsymbol{e}^{03}$, $\boldsymbol{e}^{04}$, up to $\boldsymbol{e}^{44}$

`\gzero`

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

`\gzero, \gone, \gtwo, \gthree, \gfour`	γ_0, γ_1, γ_2, γ_3, γ_4

`\guzero`

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

`\guzero, \guone, \gutwo, \guthree, \gufour`	γ^0, γ^1, γ^2, γ^3, γ^4

`\gzerozero`

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

`\gzerozero, \gzeroone, \gzerotwo, \gzerothree, \gzerofour, up to \gfourfour`	γ_{00}, γ_{01}, γ_{02}, γ_{03}, γ_{04}, up to γ_{44}

`\guzerozero`

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

`\guzerozero, \guzeroone, \guzerotwo, \guzerothree, \guzerofour, up to \gufourfour`	γ^{00}, γ^{01}, γ^{02}, γ^{03}, γ^{04}, up to γ^{44}

`\colvector`{⟨*commadelimitedlistofcomps*⟩}

Typesets column vectors.

`\colvector{x^0,x^1,x^2,x^3}`	$\begin{pmatrix} x^0 \\ x^1 \\ x^2 \\ x^3 \end{pmatrix}$

`\rowvector`{⟨*commadelimitedlistofcomps*⟩}

Typesets row vectors.

`\rowvector{x^0,x^1,x^2,x^3}`	$\begin{pmatrix} x^0 & x^1 & x^2 & x^3 \end{pmatrix}$

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

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

Allow for superscripts.

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

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

Allow for superscripts.

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

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

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

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

5.9 Physical Constants

5.9.1 Defining Physical Constants

\newphysicsconstant{⟨*newname*⟩}{⟨*symbol*⟩}{⟨*value*⟩}{⟨*baseunits*⟩}[⟨*drvdunits*⟩] [⟨*tradunits*⟩]

Defines a new physical constant.

```
Here is how \oofpez (the Coulomb constant) is defined internally.
\newphysicsconstant{oofpez}
{\ensuremath{\frac{1}{\phantom{_o}4\pi\ssub{\epsilon}{o}}}}
{9\timestento{9}}
{\ensuremath{\m\cubed\usk\kg\usk\s^{-4}\usk\A\rpsquared}}
[\m\per\farad]
[\newton\usk\m\squared\per\coulomb\squared]
```

Using this command causes several things to happen.

- A command `\newname` is created and contains the constant and units typeset according to the options given when `mandi` was loaded.
- A command `\newnamemathsymbol` is created that expresses **only** the constant's mathematical symbol.
- A command `\newnamevalue` is created that expresses **only** the constant's numerical value.
- A command `\newnamebaseunit` is created that expresses the constant and its units in *baseunits* form.
- A command `\newnamedrvdunit` is created that expresses the constant and its units in *drvdunits* form.
- A command `\newnametradunit` is created that expresses the constant and its units in *tradunits* form.
- A command `\newnameonlybaseunit` is created that expresses **only** the constant's units in *baseunits* form.

- A command `\newnameonlydrvdunit` is created that expresses **only** the constant's units in *drvdunits* form.
- A command `\newnameonlytradunit` is created that expresses **only** the constant's units in *tradunits* form.

None of these commands takes any arguments.

5.9.2 Predefined Physical Constants

`\oofpez`
Coulomb constant.

`\(\oofpezmathsymbol \approx \oofpez\)`	$\frac{1}{4\pi\epsilon_0} \approx 8.9876 \times 10^9 \mathrm{N} \cdot \mathrm{m}^2/\mathrm{C}^2$

`\oofpezcs`
Alternate form of Coulomb constant.

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

`\vacuumpermittivity`
Vacuum permittivity.

`\(\vacuumpermittivitymathsymbol \approx \vacuumpermittivity\)`	$\epsilon_0 \approx 8.8542 \times 10^{-12} \mathrm{C}^2/\mathrm{N} \cdot \mathrm{m}^2$

`\mzofp`
Biot-Savart constant.

`\(\mzofpmathsymbol \approx \mzofp\)`	$\frac{\mu_0}{4\pi} \approx 10^{-7} \mathrm{T} \cdot \mathrm{m}/\mathrm{A}$

`\vacuumpermeability`
Vacuum permeability.

`\(\vacuumpermeabilitymathsymbol \approx \vacuumpermeability\)`	$\mu_0 \approx 4\pi \times 10^{-7} \mathrm{T} \cdot \mathrm{m}/\mathrm{A}$

`\boltzmann`
Boltzmann constant.

`\(\boltzmannmathsymbol \approx \boltzmann\)`	$k_B \approx 1.3806 \times 10^{-23} \mathrm{J}/\mathrm{K}$

`\boltzmannineV`

Alternate form of Boltlzmann constant.

`\(\boltzmannineVmathsymbol \approx \boltzmannineV\)`	$k_B \approx 8.6173 \times 10^{-5}\mathrm{eV/K}$

`\stefan`

Stefan-Boltzmann constant.

`\(\stefanboltzmannmathsymbol \approx \stefanboltzmann\)`	$\sigma \approx 5.6704 \times 10^{-8}\mathrm{W/m^2 \cdot K^4}$

`\planck`

Planck constant.

`\(\planckmathsymbol \approx \planck\)`	$h \approx 6.6261 \times 10^{-34}\mathrm{J \cdot s}$

`\planckineV`

Alternate form of Planck constant.

`\(\planckmathsymbol \approx \planckineV\)`	$h \approx 4.1357 \times 10^{-15}\mathrm{eV \cdot s}$

`\planckbar`

Reduced Planck constant (Dirac constant).

`\(\planckbarmathsymbol \approx \planckbar\)`	$\hbar \approx 1.0546 \times 10^{-34}\mathrm{J \cdot s}$

`\planckbarineV`

Alternate form of reduced Planck constant (Dirac constant).

`\(\planckbarmathsymbol \approx \planckbarineV\)`	$\hbar \approx 6.5821 \times 10^{-16}\mathrm{eV \cdot s}$

`\planckc`

Planck constant times light speed.

`\(\planckcmathsymbol \approx \planckc\)`	$hc \approx 1.9864 \times 10^{-25}\mathrm{J \cdot m}$

`\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.

`\(\surfacegravfieldmathsymbol \approx \surfacegravfield\)`	$g \approx 9.80\,\text{N}/\text{kg}$

`\clight`

Magnitude of light's velocity (photon constant).

`\(\clightmathsymbol \approx \clight\)`	$c \approx 2.9979 \times 10^{8}\text{m}/\text{s}$

`\clightinfeet`

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

`\(\clightinfeetmathsymbol \approx \clightinfeet\)`	$c \approx 0.9836\,\mathrm{ft/ns}$

`\Ratom`

Approximate atomic radius.

`\(\Ratommathsymbol \approx \Ratom\)`	$r_{\mathrm{atom}} \approx 10^{-10}\mathrm{m}$

`\Mproton`

Proton mass.

`\(\Mprotonmathsymbol \approx \Mproton\)`	$m_p \approx 1.6726 \times 10^{-27}\mathrm{kg}$

`\Mneutron`

Neutron mass.

`\(\Mneutronmathsymbol \approx \Mneutron\)`	$m_n \approx 1.6749 \times 10^{-27}\mathrm{kg}$

`\Mhydrogen`

Hydrogen atom mass.

`\(\Mhydrogenmathsymbol \approx \Mhydrogen\)`	$m_H \approx 1.6737 \times 10^{-27}\mathrm{kg}$

`\Melectron`

Electron mass.

`\(\Melectronmathsymbol \approx \Melectron\)`	$m_e \approx 9.1094 \times 10^{-31}\mathrm{kg}$

`\echarge`

Elementary charge quantum.

`\(\echargemathsymbol \approx \echarge\)`	$e \approx 1.6022 \times 10^{-19}\mathrm{C}$

`\Qelectron`

Electron charge.

`\(\Qelectronmathsymbol \approx \Qelectron\)`	$Q_e \approx -1.6022 \times 10^{-19}\mathrm{C}$

`\qelectron`
Alias for `\Qelectron`.

`\Qproton`
Proton charge.

`\(\Qprotonmathsymbol \approx \Qproton\)`	$Q_p \approx +1.6022 \times 10^{-19}\mathrm{C}$

`\qproton`
Alias for `\Qproton`.

`\MEarth`
Earth's mass.

`\(\MEarthmathsymbol \approx \MEarth\)`	$M_{\mathrm{Earth}} \approx 5.9736 \times 10^{24}\mathrm{kg}$

`\MMoon`
Moon's mass.

`\(\MMoonmathsymbol \approx \MMoon\)`	$M_{\mathrm{Moon}} \approx 7.3459 \times 10^{22}\mathrm{kg}$

`\MSun`
Sun's mass.

`\(\MSunmathsymbol \approx \MSun\)`	$M_{\mathrm{Sun}} \approx 1.9891 \times 10^{30}\mathrm{kg}$

`\REarth`
Earth's radius.

`\(\REarthmathsymbol \approx \REarth\)`	$R_{\mathrm{Earth}} \approx 6.3675 \times 10^{6}\mathrm{m}$

`\RMoon`
Moon's radius.

`\(\RMoonmathsymbol \approx \RMoon\)`	$R_{\mathrm{Moon}} \approx 1.7375 \times 10^{6}\mathrm{m}$

`\RSun`
Sun's radius.

`\(\RSunmathsymbol \approx \RSun\)`	$R_{\mathrm{Sun}} \approx 6.9634 \times 10^{8}\mathrm{m}$

`\ESdist`
: Earth-Sun distance.

`\(\ESdistmathsymbol \approx \SEdist\)`	$\lVert\vec{r}_{\mathrm{ES}}\rVert \approx 1.4960 \times 10^{11}\,\mathrm{m}$

`\SEdist`
: Alias for `\ESdist`.

`\EMdist`
: Earth-Moon distance.

`\(\EMdistmathsymbol \approx \EMdist\)`	$\lVert\vec{r}_{\mathrm{EM}}\rVert \approx 3.8440 \times 10^{8}\,\mathrm{m}$

`\MEdist`
: Alias for `\EMdist`.

5.10 Astronomical Constants and Quantities

`\LSun`
: Sun's luminosity.

`\(\LSunmathsymbol \approx \LSun\)`	$L_{\mathrm{Sun}} \approx 3.8460 \times 10^{26}\,\mathrm{J/s}$

`\TSun`
: Sun's effective temperature.

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

`\MagSun`
: Sun's absolute magnitude.

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

`\magSun`
: Sun's apparent magnitude.

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

`\Lstar[`⟨*object*⟩`]`
: Symbol for stellar luminosity.

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

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

`\Lsolar`	$L_\odot$

`\Tstar[⟨object⟩]`
Symbol for stellar temperature.

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

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

`\Tsolar`	$T_\odot$

`\Rstar[⟨object⟩]`
Symbol for stellar radius.

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

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

`\Rsolar`	$R_\odot$

`\Mstar[⟨object⟩]`
Symbol for stellar mass.

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

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

`\Msolar`	$M_\odot$

`\Fstar[⟨object⟩]`
Symbol for stellar flux.

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

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

`\Fsolar`	$F_\odot$

`\fstar`
Alias for `\Fstar`.

`\fsolar`
Alias for `\fsolar`.

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

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

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

`\Magsolar`	$M_\odot$

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

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

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

`\magsolar`	$m_\odot$

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

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

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

\Dsolar	$D_\odot$

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

\dsolar
Alias for \Dsolar that uses a lower case d.

Here are all the predefined constants and their units.

name	symbol	value	baseunit	drvdunit	tradunit
`\oofpez`	$\frac{1}{4\pi\epsilon_0}$	8.9876×10^{9}	$\mathrm{m^3 \cdot kg \cdot s^{-4} \cdot A^{-2}}$	$\mathrm{m/F}$	$\mathrm{N \cdot m^2/C^2}$
name	symbol	value	baseunit	drvdunit	tradunit
`\oofpezcs`	$\frac{1}{4\pi\epsilon_0 c^2}$	10^{-7}	$\mathrm{m \cdot kg \cdot s^{-2} \cdot A^{-2}}$	$\mathrm{T \cdot m^2}$	$\mathrm{N \cdot s^2/C^2}$
name	symbol	value	baseunit	drvdunit	tradunit
`\vacuumpermittivity`	ϵ_0	8.8542×10^{-12}	$\mathrm{m^{-3} \cdot kg^{-1} \cdot s^4 \cdot A^2}$	$\mathrm{F/m}$	$\mathrm{C^2/N \cdot m^2}$
name	symbol	value	baseunit	drvdunit	tradunit
`\mzofp`	$\frac{\mu_0}{4\pi}$	10^{-7}	$\mathrm{m \cdot kg \cdot s^{-2} \cdot A^{-2}}$	$\mathrm{H/m}$	$\mathrm{T \cdot m/A}$
name	symbol	value	baseunit	drvdunit	tradunit
`\vacuumpermeability`	μ_0	$4\pi \times 10^{-7}$	$\mathrm{m \cdot kg \cdot s^{-2} \cdot A^{-2}}$	$\mathrm{H/m}$	$\mathrm{T \cdot m/A}$
name	symbol	value	baseunit	drvdunit	tradunit
`\boltzmann`	k_B	1.3806×10^{-23}	$\mathrm{m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}}$	$\mathrm{J/K}$	$\mathrm{J/K}$
name	symbol	value	baseunit	drvdunit	tradunit
`\boltzmannineV`	k_B	8.6173×10^{-5}	$\mathrm{eV \cdot K^{-1}}$	$\mathrm{eV/K}$	$\mathrm{eV/K}$
name	symbol	value	baseunit	drvdunit	tradunit
`\stefanboltzmann`	σ	5.6704×10^{-8}	$\mathrm{kg \cdot s^{-3} \cdot K^{-4}}$	$\mathrm{W/m^2 \cdot K^4}$	$\mathrm{W/m^2 \cdot K^4}$
name	symbol	value	baseunit	drvdunit	tradunit
`\planck`	h	6.6261×10^{-34}	$\mathrm{m^2 \cdot kg \cdot s^{-1}}$	$\mathrm{J \cdot s}$	$\mathrm{J \cdot s}$
name	symbol	value	baseunit	drvdunit	tradunit
`\planckineV`	h	4.1357×10^{-15}	$\mathrm{eV \cdot s}$	$\mathrm{eV \cdot s}$	$\mathrm{eV \cdot s}$
name	symbol	value	baseunit	drvdunit	tradunit
`\planckbar`	$\hbar$	1.0546×10^{-34}	$\mathrm{m^2 \cdot kg \cdot s^{-1}}$	$\mathrm{J \cdot s}$	$\mathrm{J \cdot s}$
name	symbol	value	baseunit	drvdunit	tradunit
`\planckbarineV`	$\hbar$	6.5821×10^{-16}	$\mathrm{eV \cdot s}$	$\mathrm{eV \cdot s}$	$\mathrm{eV \cdot s}$
name	symbol	value	baseunit	drvdunit	tradunit
`\planckc`	hc	1.9864×10^{-25}	$\mathrm{m^3 \cdot kg \cdot s^{-2}}$	$\mathrm{J \cdot m}$	$\mathrm{J \cdot m}$
name	symbol	value	baseunit	drvdunit	tradunit
`\planckcineV`	hc	1.9864×10^{-25}	$\mathrm{eV \cdot nm}$	$\mathrm{eV \cdot nm}$	$\mathrm{eV \cdot nm}$
name	symbol	value	baseunit	drvdunit	tradunit
`\rydberg`	R_∞	1.0974×10^{7}	$\mathrm{m^{-1}}$	$\mathrm{m^{-1}}$	$\mathrm{m^{-1}}$
name	symbol	value	baseunit	drvdunit	tradunit
`\bohrradius`	a_0	5.2918×10^{-11}	m	m	m

name	symbol	value	baseunit	drvdunit	tradunit
\finestructure	α	7.2974×10^{-3}			
name	symbol	value	baseunit	drvdunit	tradunit
\avogadro	N_A	6.0221×10^{23}	mol^{-1}	mol^{-1}	mol^{-1}
name	symbol	value	baseunit	drvdunit	tradunit
\universalgrav	G	6.6738×10^{-11}	$\mathrm{m}^3 \cdot \mathrm{kg}^{-1} \cdot \mathrm{s}^{-2}$	$\mathrm{J} \cdot \mathrm{m}/\mathrm{kg}^2$	$\mathrm{N} \cdot \mathrm{m}^2/\mathrm{kg}^2$
name	symbol	value	baseunit	drvdunit	tradunit
\surfacegravfield	g	9.80	$\mathrm{m} \cdot \mathrm{s}^{-2}$	N/kg	N/kg
name	symbol	value	baseunit	drvdunit	tradunit
\clight	c	2.9979×10^{8}	$\mathrm{m} \cdot \mathrm{s}^{-1}$	m/s	m/s
name	symbol	value	baseunit	drvdunit	tradunit
\clightinfeet	c	0.9836	$\mathrm{ft} \cdot \mathrm{ns}^{-1}$	ft/ns	ft/ns
name	symbol	value	baseunit	drvdunit	tradunit
\Ratom	r_{atom}	10^{-10}	m	m	m
name	symbol	value	baseunit	drvdunit	tradunit
\Mproton	m_p	1.6726×10^{-27}	kg	kg	kg
name	symbol	value	baseunit	drvdunit	tradunit
\Mneutron	m_n	1.6749×10^{-27}	kg	kg	kg
name	symbol	value	baseunit	drvdunit	tradunit
\Mhydrogen	m_H	1.6737×10^{-27}	kg	kg	kg
name	symbol	value	baseunit	drvdunit	tradunit
\Melectron	m_e	9.1094×10^{-31}	kg	kg	kg
name	symbol	value	baseunit	drvdunit	tradunit
\echarge	e	1.6022×10^{-19}	$\mathrm{A} \cdot \mathrm{s}$	C	C
name	symbol	value	baseunit	drvdunit	tradunit
\Qelectron	Q_e	-1.6022×10^{-19}	$\mathrm{A} \cdot \mathrm{s}$	C	C
name	symbol	value	baseunit	drvdunit	tradunit
\qelectron	q_e	-1.6022×10^{-19}	$\mathrm{A} \cdot \mathrm{s}$	C	C
name	symbol	value	baseunit	drvdunit	tradunit
\Qproton	Q_p	$+1.6022 \times 10^{-19}$	$\mathrm{A} \cdot \mathrm{s}$	C	C
name	symbol	value	baseunit	drvdunit	tradunit
\qproton	q_p	$+1.6022 \times 10^{-19}$	$\mathrm{A} \cdot \mathrm{s}$	C	C
name	symbol	value	baseunit	drvdunit	tradunit
\MEarth	M_{Earth}	5.9736×10^{24}	kg	kg	kg
name	symbol	value	baseunit	drvdunit	tradunit
\MMoon	M_{Moon}	7.3459×10^{22}	kg	kg	kg

name	symbol	value	baseunit	drvdunit	tradunit
`\MSun`	M_{Sun}	1.9891×10^{30}	kg	kg	kg

name	symbol	value	baseunit	drvdunit	tradunit
`\REarth`	R_{Earth}	6.3675×10^{6}	m	m	m

name	symbol	value	baseunit	drvdunit	tradunit
`\RMoon`	R_{Moon}	1.7375×10^{6}	m	m	m

name	symbol	value	baseunit	drvdunit	tradunit
`\RSun`	R_{Sun}	6.9634×10^{8}	m	m	m

name	symbol	value	baseunit	drvdunit	tradunit
`\ESdist`	$\lVert \vec{r}_{\text{ES}} \rVert$	1.4960×10^{11}	m	m	m

name	symbol	value	baseunit	drvdunit	tradunit
`\EMdist`	$\lVert \vec{r}_{\text{EM}} \rVert$	3.8440×10^{8}	m	m	m

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

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

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

5.11 Frequently Used Fractions

\onehalf

Small fractions with numerator 1 and denominators up to 10.

`\(\onehalf \cdots \onetenth\)`	$\frac{1}{2} \cdots \frac{1}{10}$

\twooneths

Small fractions with numerator 2 and denominators up to 10.

`\(\twooneths \cdots \twotenths\)`	$\frac{2}{1} \cdots \frac{2}{10}$

\threeoneths

Small fractions with numerator 3 and denominators up to 10.

`\(\threeoneths \cdots \threetenths\)`	$\frac{3}{1} \cdots \frac{3}{10}$

\fouroneths{⟨*magnitude*⟩}

Small fractions with numerator 4 and denominators up to 10.

`\(\fouroneths \cdots \fourtenths\)`	$\frac{4}{1} \cdots \frac{4}{10}$

5.12 Calculus

\sumoverall{⟨*variable*⟩}

Properly typesets summation over all of some user specified entities.

`\( \sumoverall{particles} \)`	$\sum_{\text{all particles}}$

\dx{⟨*variable*⟩}

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

`\( \dx{y} \)`	$\mathrm{d}y$

\evalfromto{⟨*antiderivative*⟩}{⟨*lower*⟩}{⟨*upper*⟩}

Properly typesets the evaluation of definite integrals.

```
\( \evalfromto{\onethird y^3}{0}{3} \)
```

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

Combine with \evaluatedat?

`\evalat{⟨expression⟩}{⟨evaluationpoint⟩}`

Properly typesets quantities evaluated at a particular point or value.

```
\( \evalat{\dbydt[x]}{t=1} \)
```

$\left.\frac{\mathrm{d}x}{\mathrm{d}t}\right|_{t=1}$

`\evaluatedat{⟨evaluationpoint⟩}`

Properly indicates evaluation at a particular point or value without specifying the quantity.

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

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

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

Typesets indefinite and definite integrals.

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

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

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

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

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

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

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

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

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

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

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

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

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

`\[ \openlineintegral{C}{\vect{E}} \]`	$$\int_C \vec{E} \bullet \hat{t}\,\mathrm{d}\ell$$

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

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

`\[ \closedlineintegral{C}{\vect{E}} \]`	$$\oint_C \vec{E} \bullet \hat{t}\,\mathrm{d}\ell$$

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

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

Integral over a volume.

`\[ \volumeintegral{V}{\rho} \]`	$$\iiint_V \rho\,\mathrm{d}V$$

`\dbydt`[⟨*operand*⟩]

First time derivative operator. Use `\DbyDt` to get Δ instead of d.

`\( \dbydt \) or \( \dbydt x \) or \dbydt[x]`	$\frac{\mathrm{d}}{\mathrm{d}t}$ or $\frac{\mathrm{d}}{\mathrm{d}t}x$ or $\frac{\mathrm{d}x}{\mathrm{d}t}$

`\ddbydt`[⟨*operand*⟩]

Second time derivative operator. Use `\DDbyDt` to get Δ instead of d.

`\( \ddbydt \) or \( \ddbydt x \) or \ddbydt[x]`	$\frac{\mathrm{d}^2}{\mathrm{d}t^2}$ or $\frac{\mathrm{d}^2}{\mathrm{d}t^2}x$ or $\frac{\mathrm{d}^2x}{\mathrm{d}t^2}$

`\pbypt`[⟨*operand*⟩]

First partial time derivative operator.

`\( \pbypt \) or \( \pbypt x \) or \pbypt[x]`	$\frac{\partial}{\partial t}$ or $\frac{\partial}{\partial t}x$ or $\frac{\partial x}{\partial t}$

`\ppbypt`[⟨*operand*⟩]

Second partial time derivative operator.

`\( \ppbypt \) or \( \ppbypt x \) or \ppbypt[x]`	$\frac{\partial^2}{\partial t^2}$ or $\frac{\partial^2}{\partial t^2}x$ or $\frac{\partial^2 x}{\partial t^2}$

\dbyd{⟨*dependentvariable*⟩}{⟨*indvar*⟩}
Generic first derivative operator. Use `\DbyD` to get Δ instead of d.

`\( \dbyd{f}{y} \)`	$\frac{\mathrm{d}f}{\mathrm{d}y}$

\ddbyd{⟨*dependentvariable*⟩}{⟨*indvar*⟩}
Generic second derivative operator. Use `\DDbyD` to get Δ instead of d.

`\( \ddbyd{f}{y} \)`	$\frac{\mathrm{d}^2f}{\mathrm{d}y^2}$

\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
Gradient operator.

`\gradient`	$\boldsymbol{\nabla}$

\divergence
Divergente operator.

`\divergence`	$\boldsymbol{\nabla}\bullet$

\curl
Curl operator.

`\curl`	$\boldsymbol{\nabla}\times$

\laplacian
Laplacian operator.

`\laplacian`	$\boldsymbol{\nabla}^2$

`\dalembertian`
D'Alembertian operator.

`\dalembertian`	$\square$

`\seriesfofx`
Series expansion of $f\left(x\right)$ around $x = a$.

```
\seriesfofx
```

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

`\seriesexpx`
Series expansion of e^x.

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

`\seriessinx`
Series expansion of $\sin x$.

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

`\seriescosx`
Series expansion of $\cos x$.

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

`\seriestanx`
Series expansion of $\tan x$.

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

`\seriesatox`
Series expansion of a^x.

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

`\serieslnoneplusx`
Series expansion of $\ln(1+x)$.

`\serieslnoneplusx`	$\ln(1 \pm x) \approx \pm\, x - \frac{x^2}{2} \pm \frac{x^3}{3} - \frac{x^4}{4} \pm \ldots$

`\binomialseries`
Series expansion of $(1+x)^n$.

`\binomialseries`	$(1+x)^n \approx 1 + nx + \frac{n(n-1)}{2!} x^2 + \ldots$

`\diracdelta{⟨arg⟩}`
Dirac delta function.

`\diracdelta{x}`	$\delta(\mathrm{x})$

`\orderof{⟨arg⟩}`
Order of indicator.

`\orderof{x^2}`	$\mathcal{O}\left(x^2\right)$

5.13 Other Useful Commands

`\asin`
Symbol for inverse sine and other inverse circular trig functions.

`\( \asin, \acos, \atan, \asec, \acsc, \acot \)`	$\sin^{-1}, \cos^{-1}, \tan^{-1}, \sec^{-1}, \csc^{-1}, \cot^{-1}$

`\sech`
Hyperbolic and inverse hyperbolic functions not defined in LaTeX.

`\( \sech, \csch, \asinh, \acosh, \atanh, \asech, \acsch, \acoth \)`	$\mathrm{sech}, \mathrm{csch}, \sinh^{-1}, \cosh^{-1}, \tanh^{-1}, \mathrm{sech}^{-1}, \mathrm{csch}^{-1}, \coth^{-1}$

`\sgn{⟨arg⟩}`
Signum function.

`\( \sgn \)`	sgn

`\dex`
Decimal exponentiation function (used in astrophysics).

`\( \dex \)`	dex

`\logb[⟨base⟩]`
Logarithm to an arbitrary base.

`\logb 8, \logb[2] 8`	$\log 8$, $\log_2 8$

`\cB`
Alternate symbol for magnetic field inspired by Tom Moore.

`\cB, \vect{\cB}`	cB, $\vec{cB}$

`\newpi`
Bob Palais' symbol for 2π.

`\newpi`	π

`\scripty{⟨kernel⟩}`
Command to get fonts in Griffith's electrodynamics textbook.

`\scripty{r}`	𝓇

`\flux[⟨label⟩]`
Symbol for flux of a vector field.

`\flux, \flux[E]`	Φ, Φ_{E}

`\abs{⟨arg⟩}`
Absolute value function.

`\abs{-4}`	$\lvert -4 \rvert$

`\magof{⟨arg⟩}`

Magnitude of a quantity (lets you selectively use double bars even when the **singleabsbars** option is use when loading the package).

`\magof{\vect{E}}`	$\left\lVert \vec{E} \right\rVert$

`\dimsof{⟨arg⟩}`

Notation for showing the dimensions of a quantity.

`\( \dimsof{\vect{v}} = L \cdot T^{-1} \)`	$[\vec{v}] = L \cdot T^{-1}$

`\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.

`\unitsof{\vect{v}} = \velocityonlytradunit`	$[\vec{v}]_u = \mathrm{m/s}$

`\Changein{⟨arg⟩}`

Notation for *the change in a quantity*.

`\Changein{\vect{E}}`	$\Delta\vec{E}$

`\scin[⟨mantissa⟩]{⟨exponent⟩}[⟨unit⟩]`

Command for scientific notation with an optional unit. Deprecated. Use `\timestento` or `\xtento` instead.

`2.99\timestento{8}[\velocityonlytradunit]`	$2.99 \times 10^{8}\ \mathrm{m/s}$

`\xtento{⟨exponent⟩}[⟨unit⟩]`

Command for scientific notation with an optional unit. Alias for `\timestento`.

`2.99\xtento{8}[\velocityonlytradunit]`	$2.99 \times 10^{8}\ \mathrm{m/s}$

`\ee{⟨mantissa⟩}{⟨exponent⟩}`

Command for scientific notation for computer code. Use `\EE` for `EE`.

`\ee{2.99}{8}`	`2.99e8`

`\dms{⟨deg⟩}{⟨min⟩}{⟨sec⟩}`

Command for formatting angles and time. Use `\hms` for time. Note that other packages may do this better.

```
\dms{23}{34}{10.27} \\
\hms{23}{34}{10.27}
```

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

`\clockreading`{⟨*hrs*⟩}{⟨*min*⟩}{⟨*sec*⟩}

Command for formatting a clock reading. Really an alias for `\hms`, but conceptually a very different idea that introductory textbooks don't do a good enough job at articulating.

```
\clockreading{23}{34}{10.27}
```

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

`\latitude`{⟨*arg*⟩}

Command for formatting latitude, useful in astronomy. Use `\latitudeN` or `\latitudeS` to include a letter.

```
\latitude{+35}, \latitudeN{35}, \latitudeS{35}
```

$+35\,^{\circ}$, $35\,^{\circ}$ N, $35\,^{\circ}$ S

`\longitude`{⟨*arg*⟩}

Command for formatting longitude, useful in astronomy. Use `\longitudeE` or `\longitudeW` to include a letter.

```
\longitude{-81}, \longitudeE{81}, \longitudeW{81}
```

$-81\,^{\circ}$, $81\,^{\circ}$ E, $81\,^{\circ}$ W

`\ssup`{⟨*kernel*⟩}{⟨*sup*⟩}

Command for typesetting text superscripts.

```
\ssup{N}{contact}
```

N^{contact}

`\ssub`{⟨*kernel*⟩}{⟨*sub*⟩}

Command for typesetting text subscripts.

```
\ssub{N}{AB}
```

N_{AB}

`\ssud`{⟨*sup*⟩}{⟨*sub*⟩}

Command for typesetting text superscripts and subscripts.

```
\ssud{N}{contact}{AB}
```

$N^{\text{contact}}_{\text{AB}}$

`\msub`{⟨*kernel*⟩}{⟨*sub*⟩}

Command for typesetting mathematical subscripts.

```
\msub{R}{\alpha\beta}
```

$R_{\alpha\beta}$

\msud{⟨*kernel*⟩}{⟨*sup*⟩}{⟨*sub*⟩}
Command for typesetting mathematical superscripts and subscripts.

`\msud{\Gamma}{\gamma}{\alpha\beta}`	$\Gamma^{\gamma}_{\alpha\beta}$

\levicivita{⟨*indices*⟩}
Command for Levi-Civita symbol.

`\levicivita{ijk}`	ε_{ijk}

\kronecker{⟨*indices*⟩}
Command for Kronecker delta symbol.

`\kronecker{ij}`	δ_{ij}

\xaxis
Command for coordinate axes.

`\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.

```
\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. Use `\fcuberoot` to get fractional exponent.

`\cuberoot{x}, \fcuberoot{x}`	$\sqrt[3]{x}$, $x^{\frac{1}{3}}$

`\fourthroot`{⟨*arg*⟩}

Command for fourth root of an argument. Use `\ffourthroot` to get fractional exponent.

`\fourthroot{x}, \ffourthroot{x}`	$\sqrt[4]{x}$, $x^{\frac{1}{4}}$

`\fifthroot`{⟨*arg*⟩}

Command for fifth root of an argument. Use `\ffifthroot` to get fractional exponent.

`\fifthroot{x}, \ffifthroot{x}`	$\sqrt[5]{x}$, $x^{\frac{1}{5}}$

`\relgamma`{⟨*arg*⟩}

Expression for Lorentz factor. Use `\frelgamma` to get fractional exponent.

```
\begin{align*}
\gamma&=\relgamma{\magvect{v}}\\
\gamma&=\relgamma{(0.5c)}\\
\gamma&=\frelgamma{\magvect{v}}\\
\gamma&=\frelgamma{(0.5c)}
\end{align*}
```

$$\begin{aligned}\gamma&=\frac{1}{\sqrt{1-\left(\frac{\|\vec{v}\|}{c}\right)^2}}\\ \gamma&=\frac{1}{\sqrt{1-\left(\frac{(0.5c)}{c}\right)^2}}\\ \gamma&=\left(1-\frac{\|\vec{v}\|^2}{c^2}\right)^{-\frac{1}{2}}\\ \gamma&=\left(1-\frac{(0.5c)^2}{c^2}\right)^{-\frac{1}{2}}\end{aligned}$$

\oosqrtomxs{⟨*arg*⟩}

Commands for expressions convenient in numerically evaluating Lorentz factors. Say each expression out loud and you'll see where the command names come from.

```
\oosqrtomxs{0.22},
\oosqrtomx{0.22},
\ooomx{0.22},
\ooopx{0.11}
```

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

5.14 Custom Operators

The = operator is frequently misused. We need other operators for other cases.

\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. Use `\pwordoperator` to get parentheses around the operator.

```
\wordoperator{added}{to} \\
\pwordoperator{added}{to}
```

$\substack{\text{added}\\\text{to}}$
$\left(\substack{\text{added}\\\text{to}}\right)$

\definedas

Commands for frequently used word operators. Prepend `p` to each to get parentheses around the operator.

```
\definedas and \associated and \adjustedby    \\
\earlierthan and \laterthan and \forevery     \\
\pdefinedas and \passociated and \padjustedby \\
\pearlierthan and \platerthan and \pforevery
```

$\substack{\text{defined}\\\text{as}}$ and $\substack{\text{associated}\\\text{with}}$ and $\substack{\text{adjusted}\\\text{by}}$
$\substack{\text{earlier}\\\text{than}}$ and $\substack{\text{later}\\\text{than}}$ and $\substack{\text{for}\\\text{every}}$
$\left(\substack{\text{defined}\\\text{as}}\right)$ and $\left(\substack{\text{associated}\\\text{with}}\right)$ and $\left(\substack{\text{adjusted}\\\text{by}}\right)$
$\left(\substack{\text{earlier}\\\text{than}}\right)$ and $\left(\substack{\text{later}\\\text{than}}\right)$ and $\left(\substack{\text{for}\\\text{every}}\right)$

\defines

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

```
\vect{p} \defines \(\gamma m\)\vect{v}
```

$\vec{p} \stackrel{\text{def}}{=} \gamma m \vec{v}$

\inframe[⟨*frame*⟩]

Command for operator indicating the coordinate representation of a vector in a particular reference frame denoted by a capital letter.

Make the arrow's length fixed.

`\vect{p} \inframe[S] \momentum{\mivector{1,2,3}} \\ \vect{p} \inframe[S'] \momentum{\mivector{\sqrt{14},0,0}}`	$\vec{p} \underset{S}{\longrightarrow} \langle 1,2,3\rangle\,\mathrm{kg\cdot m/s}$ $\vec{p} \underset{S'}{\longrightarrow} \left\langle \sqrt{14},0,0\right\rangle\,\mathrm{kg\cdot m/s}$

`\associates`
Command for *associated with* or *associates with* operator (for verbal concepts).

`kinetic energy \associates velocity`	kinetic energy $\xrightarrow{\text{assoc}}$ velocity

`\becomes`
Command for *becomes* operator.

`\(\gamma m\)\vect{v} \becomes \(m\)\vect{v}`	$\gamma m\vec{v} \xrightarrow{\text{becomes}} m\vec{v}$

`\rrelatedto{⟨leftoperation⟩}`
Command for left-to-right relationship.

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

`\lrelatedto{⟨roperation⟩}`
Command for right-to-left relationship.

`(flux ratio) \lrelatedto{exponentiation} (mag diff)`	(flux ratio) $\xLeftarrow[\text{exponentiation}]{}$ (mag diff)

`\brelatedto{⟨leftoperation⟩}{⟨roperation⟩}`
Command for bidirectional relationship.

`(mag diff) \brelatedto{taking logarithm}{exponentiation}(flux ratio)`	(mag diff) $\underset{\text{taking logarithm}}{\overset{\text{exponentiation}}{\Longleftrightarrow}}$(flux ratio)

5.15 Commands Specific to *Matter & Interactions*

`\momentumprinciple`
Expression for the momentum principle. Prepend `\LHS` to get just the left hand side and `\RHS` to get just the right hand side.

`\momentumprinciple`	$\vec{p}_{\text{sys,final}} = \vec{p}_{\text{sys,initial}} + \vec{F}_{\text{net,sys}}\Delta t$

`\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. Prepend `\LHS` to get just the left hand side and `\RHS` to get just the right hand side. Processes other than work and thermal energy transfer (e.g. radiation) are neglected.

`\energyprinciple`	$E_{\text{sys,final}} = E_{\text{sys,initial}} + W + Q$

`\energyprinciplediff`
Expression for the energy principle in differential form.

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

`\angularmomentumprinciple`
Expression for the angular momentum principle. Prepend `\LHS` to get just the left hand side and `\RHS` to get just the right hand side.

`\angularmomentumprinciple`	$\vec{L}_{A,\text{sys,final}} = \vec{L}_{A,\text{sys,initial}} + \vec{\tau}_{A,\text{net}}\Delta t$

`\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`	$G\dfrac{M_1 M_2}{\lVert\vec{r}_{12}\rVert^2}\left(-\widehat{r}_{12}\right)$

`\electricinteraction`
Expression for electric interaction.

`\electricinteraction`	$\dfrac{1}{4\pi\epsilon_0}\dfrac{Q_1 Q_2}{\lVert\vec{r}_{12}\rVert^2}\widehat{r}_{12}$

\springinteraction

Expression for spring interaction.

`\springinteraction`	$k_s \left\| \vec{s} \right\| (-\widehat{s})$

\Efieldofparticle

Expression for a particle's electric field.

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

\Bfieldofparticle

Expression for a particle's magnetic field.

`\Bfieldofparticle`	$\frac{\mu_0}{4\pi}\frac{Q\left\| \vec{v} \right\|}{\left\| \vec{r} \right\|^2}\widehat{v}\times\widehat{r}$

In the commands that take an optional label, note how to specify initial and final values of quantities.

\Esys[⟨*label*⟩]

Symbol for system energy.

`\Esys, \Esys[final], \Esys[initial]`	E_{sys}, $E_{\text{sys,final}}$, $E_{\text{sys,initial}}$

\Us[⟨*label*⟩]

Symbol for spring potential energy.

`\Us, \Us[final], \Us[initial]`	U_s, $U_{s,\text{final}}$, $U_{s,\text{initial}}$

\Ug[⟨*label*⟩]

Symbol for gravitational potential energy.

`\Ug, \Ug[final], \Ug[initial]`	U_g, $U_{g,\text{final}}$, $U_{g,\text{initial}}$

\Ue[⟨*label*⟩]

Symbol for electric potential energy.

`\Ue, \Ue[final], \Ue[initial]`	U_e, $U_{e,\text{final}}$, $U_{e,\text{initial}}$

\Ktrans[⟨*label*⟩]

Symbol for translational kinetic energy.

`\Ktrans, \Ktrans[final], \Ktrans[initial]`	K_{trans}, $K_{\text{trans,final}}$, $K_{\text{trans,initial}}$

`\Krot[⟨label⟩]`
Symbol for rotational kinetic energy.

`\Krot, \Krot[final], \Krot[initial]`	K_{rot}, $K_{\text{rot,final}}$, $K_{\text{rot,initial}}$

`\Kvib[⟨label⟩]`
Symbol for vibrational kinetic energy.

`\Kvib, \Evib[final], \Evib[initial]`	K_{vib}, $E_{\text{vib,final}}$, $E_{\text{vib,initial}}$

`\Eparticle[⟨label⟩]`
Symbol for particle energy.

`\Eparticle, \Eparticle[final], \Eparticle[initial]`	E_{particle}, $E_{\text{particle,final}}$, $E_{\text{particle,initial}}$

`\Einternal[⟨label⟩]`
Symbol for internal energy.

`\Einternal, \Einternal[final], \Einternal[initial]`	E_{internal}, $E_{\text{internal,final}}$, $E_{\text{internal,initial}}$

`\Erest[⟨label⟩]`
Symbol for rest energy.

`\Erest, \Erest[final], \Erest[initial]`	E_{rest}, $E_{\text{rest,final}}$, $E_{\text{rest,initial}}$

`\Echem[⟨label⟩]`
Symbol for chemical energy.

`\Echem, \Echem[final], \Echem[initial]`	E_{chem}, $E_{\text{chem,final}}$, $E_{\text{chem,initial}}$

`\Etherm[⟨label⟩]`
Symbol for thermal energy.

`\Etherm, \Etherm[final], \Etherm[initial]`	E_{therm}, $E_{\text{therm,final}}$, $E_{\text{therm,initial}}$

`\Evib[⟨label⟩]`
Symbol for vibrational energy.

`\Evib, \Evib[final], \Evib[initial]`	E_{vib}, $E_{\text{vib,final}}$, $E_{\text{vib,initial}}$

`\Ephoton[⟨label⟩]`
Symbol for photon energy.

`\Ephoton, \Ephoton[final], \Ephoton[initial]`	E_{photon}, $E_{\text{photon,final}}$, $E_{\text{photon,initial}}$

`\DEsys`
Symbol for change in system energy.

`\DEsys`	ΔE_{sys}

`\DUs`
Symbol for change in spring potential energy.

`\DUs`	ΔU_s

`\DUg`
Symbol for change in gravitational potential energy.

`\DUg`	ΔU_g

`\DUe`
Symbol for change in electric potential energy.

`\DUe`	ΔU_e

`\DKtrans`
Symbol for change in translational kinetic energy.

`\DKtrans`	ΔK_{trans}

`\DKrot`
Symbol for change in rotational kinetic energy.

`\DKrot`	ΔK_{rot}

`\DKvib`
Symbol for change in vibrational kinetic energy.

`\DKvib`	ΔK_{vib}

`\DEparticle`
Symbol for change in particle energy.

`\DEparticle`	$\Delta E_{\text{particle}}$

`\DEinternal`
Symbol for change in internal energy.

`\DEinternal`	$\Delta E_{\text{internal}}$

`\DErest`
Symbol for change in rest energy.

`\DErest`	ΔE_{rest}

`\DEchem`
Symbol for change in chemical energy.

`\DEchem`	ΔE_{chem}

`\DEtherm`
Symbol for change in thermal energy.

`\DEtherm`	ΔE_{therm}

`\DEvib`
Symbol for change in vibrational energy.

`\DEvib`	ΔE_{vib}

`\DEphoton`
Symbol for change in photon energy.

`\DEphoton`	ΔE_{photon}

`\springpotentialenergy`
Expression for spring potential energy.

`\springpotentialenergy`	$\frac{1}{2}\ k_s \lVert \vec{s} \rVert^2$

`\finalspringpotentnialenergy`
Expression for final spring potential energy.

`\finalspringpotentialenergy`	$\left(\frac{1}{2} k_s \lVert \vec{s} \rVert^2\right)_{\text{final}}$

`\initialspringpotentialenergy`
Expression for initial spring potential energy.

`\initialspringpotentialenergy`	$\left(\frac{1}{2} k_s \lVert \vec{s} \rVert^2\right)_{\text{initial}}$

`\electricpotentialenergy`
Expression for electric potential energy.

`\electricpotentialenergy`	$\frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{\lVert \vec{r}_{12} \rVert}$

`\finalelectricpotentialenergy`
Expression for final electric potential energy.

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

`\initialelectricpotentialenergy`
Expression for initial electric potential energy.

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

`\gravitationalpotentialenergy`
Expression for gravitational potential energy.

`\gravitationalpotentialenergy`	$-G\frac{M_1 M_2}{\lVert \vec{r}_{12} \rVert}$

`\finalgravitationalpotentialenergy`
Expression for final gravitational potential energy.

```
\finalgravitationalpotentialenergy
```

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

\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}
```

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

\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{align*}
  &\LHSmaxwelliint \\
  &\LHSmaxwelliint[S]
\end{align*}
```

$$\oiint_{\partial V} \vec{E} \bullet \widehat{n}\, \mathrm{d}A$$
$$\oiint_{S} \vec{E} \bullet \widehat{n}\, \mathrm{d}A$$

\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{align*}
  &\RHSmaxwelliinta \\
  &\RHSmaxwelliinta[\upsilon]
\end{align*}
```

$$\frac{1}{\epsilon_0}\iiint_V \rho_e \,\mathrm{d}V$$
$$\frac{1}{\epsilon_0}\iiint_\upsilon \rho_e \,\mathrm{d}V$$

\RHSmaxwelliintfree

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

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

$$0$$

\maxwelliint[⟨*surfacename*⟩]

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

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

$$\oiint_{\partial V} \vec{E} \bullet \widehat{n}\,\mathrm{d}A = \frac{Q_{e,\text{net}}}{\epsilon_0}$$
$$\oiint_{S} \vec{E} \bullet \widehat{n}\,\mathrm{d}A = \frac{Q_{e,\text{net}}}{\epsilon_0}$$

\maxwelliinta[⟨*surfacename*⟩][⟨*volumename*⟩]

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

```
\begin{align*}
  &\maxwelliinta \\
  &\maxwelliinta[S][\upsilon]
\end{align*}
```

$$\oiint_{\partial V} \vec{E} \bullet \widehat{n}\,\mathrm{d}A = \frac{1}{\epsilon_0}\iiint_V \rho_e \,\mathrm{d}V$$
$$\oiint_{S} \vec{E} \bullet \widehat{n}\,\mathrm{d}A = \frac{1}{\epsilon_0}\iiint_\upsilon \rho_e \,\mathrm{d}V$$

\maxwelliintfree[⟨*surfacename*⟩]

Maxwell's first equation in integral form in free space. Note the default value of the optional argument.

```
\begin{align*}
  &\maxwelliintfree \\
  &\maxwelliintfree[S]
\end{align*}
```

$$\oiint_{\partial V} \vec{E} \bullet \widehat{n}\,\mathrm{d}A = 0$$
$$\oiint_{S} \vec{E} \bullet \widehat{n}\,\mathrm{d}A = 0$$

\LHSmaxwelliiint[⟨*surfacename*⟩]

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

```
\begin{align*}
  &\LHSmaxwelliiint \\
  &\LHSmaxwelliiint[S]
\end{align*}
```

$$\oiint_{\partial V} \vec{B} \bullet \widehat{n}\,\mathrm{d}A$$
$$\oiint_{S} \vec{B} \bullet \widehat{n}\,\mathrm{d}A$$

\RHSmaxwelliiint

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

```
\[ \RHSmaxwelliiint \]
```

$$0$$

\RHSmaxwelliiintm

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

```
\[ \RHSmaxwelliiintm \]
```

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

\RHSmaxwelliiintma[⟨*volumename*⟩]

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

```
\begin{align*}
  &\RHSmaxwelliiintma \\
  &\RHSmaxwelliiintma[\upsilon]
\end{align*}
```

$$\mu_0 \iiint_V \rho_m\,\mathrm{d}V$$
$$\mu_0 \iiint_\upsilon \rho_m\,\mathrm{d}V$$

\RHSmaxwelliiintfree

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

```
\[ \RHSmaxwelliiintfree \]
```

$$0$$

\maxwelliiint[⟨*surfacename*⟩]

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

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

$$\oiint_{\partial V} \vec{B} \bullet \widehat{n}\,\mathrm{d}A = 0$$
$$\oiint_{S} \vec{B} \bullet \widehat{n}\,\mathrm{d}A = 0$$

`\maxwelliiintm[⟨surfacename⟩]`

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

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

$$\oiint_{\partial V} \vec{B} \bullet \widehat{n}\,\mathrm{d}A = \mu_0 Q_{m,\text{net}}$$
$$\oiint_{S} \vec{B} \bullet \widehat{n}\,\mathrm{d}A = \mu_0 Q_{m,\text{net}}$$

`\maxwelliiintma[⟨surfacename⟩][⟨volumename⟩]`

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

```
\begin{align*}
  &\maxwelliiintma \\
  &\maxwelliiintma[S][\upsilon]
\end{align*}
```

$$\oiint_{\partial V} \vec{B} \bullet \widehat{n}\,\mathrm{d}A = \mu_0 \iiint_{V} \rho_m \,\mathrm{d}V$$
$$\oiint_{S} \vec{B} \bullet \widehat{n}\,\mathrm{d}A = \mu_0 \iiint_{\upsilon} \rho_m \,\mathrm{d}V$$

`\maxwelliiintfree[⟨surfacename⟩]`

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

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

$$\oiint_{\partial V} \vec{B} \bullet \widehat{n}\,\mathrm{d}A = 0$$
$$\oiint_{S} \vec{B} \bullet \widehat{n}\,\mathrm{d}A = 0$$

`\LHSmaxwelliiiint[⟨boundaryname⟩]`

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

```
\begin{align*}
  &\LHSmaxwelliiiint \\
  &\LHSmaxwelliiiint[C]
\end{align*}
```

$$\oint_{\partial\Omega} \vec{E} \bullet \widehat{t}\,\mathrm{d}\ell$$
$$\oint_{C} \vec{E} \bullet \widehat{t}\,\mathrm{d}\ell$$

`\RHSmaxwelliiiint[⟨surfacename⟩]`

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

```
\begin{align*}
  &\RHSmaxwelliiiint \\
  &\RHSmaxwelliiiint[S]
\end{align*}
```

$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega}\vec{B}\bullet\widehat{n}\,\mathrm{d}A$$
$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S}\vec{B}\bullet\widehat{n}\,\mathrm{d}A$$

\RHSmaxwelliiiintm[⟨*surfacename*⟩]

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

```
\begin{align*}
  &\RHSmaxwelliiiintm \\
  &\RHSmaxwelliiiintm[S]
\end{align*}
```

$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega}\vec{B}\bullet\widehat{n}\,\mathrm{d}A-\mu_0 I_{m,\mathrm{net}}$$
$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S}\vec{B}\bullet\widehat{n}\,\mathrm{d}A-\mu_0 I_{m,\mathrm{net}}$$

\RHSmaxwelliiiintma[⟨*surfacename*⟩]

Alternate form of right hand side of Maxwell's third equation in integral form with magnetic monopoles. Note the default value of the optional argument.

```
\begin{align*}
  &\RHSmaxwelliiiintma \\
  &\RHSmaxwelliiiintma[S]
\end{align*}
```

$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega}\vec{B}\bullet\widehat{n}\,\mathrm{d}A-\mu_0\iint_{\Omega}\vec{J}_m\bullet\widehat{n}\,\mathrm{d}A$$
$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S}\vec{B}\bullet\widehat{n}\,\mathrm{d}A-\mu_0\iint_{S}\vec{J}_m\bullet\widehat{n}\,\mathrm{d}A$$

\RHSmaxwelliiiintfree[⟨*surfacename*⟩]

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

```
\begin{align*}
  &\RHSmaxwelliiiintfree \\
  &\RHSmaxwelliiiintfree[S]
\end{align*}
```

$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega}\vec{B}\bullet\widehat{n}\,\mathrm{d}A$$
$$-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S}\vec{B}\bullet\widehat{n}\,\mathrm{d}A$$

\maxwelliiiint[⟨*boundaryname*⟩][⟨*surfacename*⟩]

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

```
\begin{align*}
  &\maxwelliiiint \\
  &\maxwelliiiint[C][S]
\end{align*}
```

$$\oint_{\partial\Omega}\vec{E}\bullet\widehat{t}\,\mathrm{d}\ell=-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{\Omega}\vec{B}\bullet\widehat{n}\,\mathrm{d}A$$
$$\oint_{C}\vec{E}\bullet\widehat{t}\,\mathrm{d}\ell=-\frac{\mathrm{d}}{\mathrm{d}t}\iint_{S}\vec{B}\bullet\widehat{n}\,\mathrm{d}A$$

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

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

```
\begin{align*}
  &\maxwelliiiintm \\
  &\maxwelliiiintm[C][S]
\end{align*}
```

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

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

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

```
\begin{align*}
  &\maxwelliiiintma \\
  &\maxwelliiiintma[C][S]
\end{align*}
```

$$\oint_{\partial\Omega} \vec{E} \bullet \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Omega} \vec{B} \bullet \hat{n}\,\mathrm{d}A - \mu_0 \iint_{\Omega} \vec{J}_m \bullet \hat{n}\,\mathrm{d}A$$
$$\oint_{C} \vec{E} \bullet \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{d}t} \iint_{S} \vec{B} \bullet \hat{n}\,\mathrm{d}A - \mu_0 \iint_{S} \vec{J}_m \bullet \hat{n}\,\mathrm{d}A$$

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

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

```
\begin{align*}
  &\maxwelliiiintfree \\
  &\maxwelliiiintfree[C][S]
\end{align*}
```

$$\oint_{\partial\Omega} \vec{E} \bullet \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Omega} \vec{B} \bullet \hat{n}\,\mathrm{d}A$$
$$\oint_{C} \vec{E} \bullet \hat{t}\,\mathrm{d}\ell = -\frac{\mathrm{d}}{\mathrm{d}t} \iint_{S} \vec{B} \bullet \hat{n}\,\mathrm{d}A$$

`\LHSmaxwellivint[⟨boundaryname⟩]`

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

```
\begin{align*}
  &\LHSmaxwellivint \\
  &\LHSmaxwellivint[C]
\end{align*}
```

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

`\RHSmaxwellivint[⟨surfacename⟩]`

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

```
\begin{align*}
  &\RHSmaxwellivint \\
  &\RHSmaxwellivint[S]
\end{align*}
```

$$\mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Omega} \vec{E} \bullet \widehat{n}\,\mathrm{d}A + \mu_0 I_{e,\mathrm{net}}$$
$$\mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{S} \vec{E} \bullet \widehat{n}\,\mathrm{d}A + \mu_0 I_{e,\mathrm{net}}$$

\RHSmaxwellivinta[⟨*surfacename*⟩]

Alternate form of right hand side of Maxwell's fourth equation in integral form. Note the default value of the optional argument.

```
\begin{align*}
  &\RHSmaxwellivinta \\
  &\RHSmaxwellivinta[S]
\end{align*}
```

$$\mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Omega} \vec{E} \bullet \widehat{n}\,\mathrm{d}A + \mu_0 \iint_{\Omega} \vec{J}_e \bullet \widehat{n}\,\mathrm{d}A$$
$$\mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{S} \vec{E} \bullet \widehat{n}\,\mathrm{d}A + \mu_0 \iint_{S} \vec{J}_e \bullet \widehat{n}\,\mathrm{d}A$$

\RHSmaxwellivintfree[⟨*surfacename*⟩]

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

```
\begin{align*}
  &\RHSmaxwellivintfree \\
  &\RHSmaxwellivintfree[S]
\end{align*}
```

$$\mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Omega} \vec{E} \bullet \widehat{n}\,\mathrm{d}A$$
$$\mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{S} \vec{E} \bullet \widehat{n}\,\mathrm{d}A$$

\maxwellivint[⟨*boundaryname*⟩][⟨*surfacename*⟩]

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

```
\begin{align*}
  &\maxwellivint \\
  &\maxwellivint[C][S]
\end{align*}
```

$$\oint_{\partial\Omega} \vec{B} \bullet \widehat{t}\,\mathrm{d}\ell = \mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Omega} \vec{E} \bullet \widehat{n}\,\mathrm{d}A + \mu_0 I_{e,\mathrm{net}}$$
$$\oint_{C} \vec{B} \bullet \widehat{t}\,\mathrm{d}\ell = \mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{S} \vec{E} \bullet \widehat{n}\,\mathrm{d}A + \mu_0 I_{e,\mathrm{net}}$$

\maxwellivinta[⟨*boundaryname*⟩][⟨*surfacename*⟩]

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

```
\begin{align*}
  &\maxwellivinta \\
  &\maxwellivinta[C][S]
\end{align*}
```

$$\oint_{\partial\Omega} \vec{B} \bullet \widehat{t}\,\mathrm{d}\ell = \mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Omega} \vec{E} \bullet \widehat{n}\,\mathrm{d}A + \mu_0 \iint_{\Omega} \vec{J}_e \bullet \widehat{n}\,\mathrm{d}A$$
$$\oint_{C} \vec{B} \bullet \widehat{t}\,\mathrm{d}\ell = \mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{S} \vec{E} \bullet \widehat{n}\,\mathrm{d}A + \mu_0 \iint_{S} \vec{J}_e \bullet \widehat{n}\,\mathrm{d}A$$

\maxwellivintfree[⟨*boundaryname*⟩][⟨*surfacename*⟩]

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

```
\begin{align*}
  &\maxwellivintfree \\
  &\maxwellivintfree[C][S]
\end{align*}
```

$$\oint_{\partial\Omega} \vec{B} \bullet \hat{t}\,\mathrm{d}\ell = \mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{\Omega} \vec{E} \bullet \hat{n}\,\mathrm{d}A$$
$$\oint_{C} \vec{B} \bullet \hat{t}\,\mathrm{d}\ell = \mu_0\epsilon_0 \frac{\mathrm{d}}{\mathrm{d}t} \iint_{S} \vec{E} \bullet \hat{n}\,\mathrm{d}A$$

\LHSmaxwellidif

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

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

$$\boldsymbol{\nabla} \bullet \vec{E}$$

\RHSmaxwellidif

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

```
\[ \RHSmaxwellidif \]
```

$$\frac{\rho_e}{\epsilon_0}$$

\RHSmaxwellidiffree

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

```
\[ \RHSmaxwellidiffree \]
```

$$0$$

\maxwellidif

Maxwell's first equation in differential form.

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

$$\boldsymbol{\nabla} \bullet \vec{E} = \frac{\rho_e}{\epsilon_0}$$

\maxwellidiffree

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

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

$$\boldsymbol{\nabla} \bullet \vec{E} = 0$$

\LHSmaxwelliidif

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

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

$$\boldsymbol{\nabla} \bullet \vec{B}$$

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

`\[ \RHSmaxwelliidif \]`	0

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

`\[ \RHSmaxwelliidifm \]`	$\mu_0\rho_m$

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

`\[ \RHSmaxwelliidiffree \]`	0

\maxwelliidif
Maxwell's second equation in differential form.

`\[ \maxwelliidif \]`	$\boldsymbol{\nabla} \bullet \vec{B} = 0$

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

`\[ \maxwelliidifm \]`	$\boldsymbol{\nabla} \bullet \vec{B} = \mu_0\rho_m$

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

`\[ \maxwelliidiffree \]`	$\boldsymbol{\nabla} \bullet \vec{B} = 0$

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

`\[ \LHSmaxwelliiidif \]`	$\boldsymbol{\nabla}\times\vec{E}$

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

```
\[ \RHSmaxwelliiidif \]
```

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

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

```
\[ \RHSmaxwelliiidifm \]
```

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

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

```
\[ \RHSmaxwelliiidiffree \]
```

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

`\maxwelliiidif`
Maxwell's third equation in differential form.

```
\[ \maxwelliiidif \]
```

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

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

```
\[ \maxwelliiidifm \]
```

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

`\maxwelliiidiffree`
Maxwell's third equation in differential form in free space.

```
\[ \maxwelliiidiffree \]
```

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

`\LHSmaxwellivdif`
Left hand side of Maxwell's fourth equation in differential form.

```
\[ \LHSmaxwellivdif \]
```

$$\boldsymbol{\nabla} \times \vec{B}$$

`\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.

```
\[ \maxwellivdif \]
```

$$\boldsymbol{\nabla}\times\vec{B}=\mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t}+\mu_0\vec{J}_e$$

\maxwellivdiffree
Maxwell's fourth equation in differential form in free space.

```
\[ \maxwellivdiffree \]
```

$$\boldsymbol{\nabla}\times\vec{B}=\mu_0\epsilon_0\frac{\partial\vec{E}}{\partial t}$$

\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.

```
\[ \RHSlorentzforcem \]
```

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

\vpythonline{⟨*vpythoncode*⟩}
Command for a single line of VPython code used inline.

```
\vpythonline{from visual import *}
```

from visual import *

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

Environment for a block of VPython code.

```
\begin{vpythonblock}
  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}
```

```
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
```

`\vpythonfile`⟨*filename*⟩

Typesets a file in the current directory containing VPython code.

```
\vpythonfile{vdemo.py}
```

```
from __future__ import division,print_function
from visual import *

G = 6.7e-11

# create objects
giant = sphere(pos=vector(-1e11,0,0),radius=2e10,mass=2e30,color=color.red)
giant.p = vector(0,0,-1e4) * giant.mass
dwarf = sphere(pos=vector(1.5e11,0,0),radius=1e10,mass=1e30,color=color.yellow)
dwarf.p = -giant.p

for a in [giant,dwarf]:
  a.orbit = curve(color=a.color,radius=2e9)

dt = 86400
while 1:
  rate(100)
  dist = dwarf.pos - giant.pos
  force = G * giant.mass * dwarf.mass * dist / mag(dist)**3
  giant.p = giant.p + force*dt
  dwarf.p = dwarf.p - force*dt
  for a in [giant,dwarf]:
    a.pos = a.pos + a.p/a.mass * dt
    a.orbit.append(pos=a.pos)
```

5.16 Boxes and Environments

\emptyanswer[⟨*wdth*⟩][⟨*hght*⟩]

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

```
\emptyanswer[0.75][0.2]
```

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

Main environment for typesetting boxed answers.

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

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

\begin{adjactivityanswer}[⟨*bgclr*⟩][⟨*frmclr*⟩][⟨*txtclr*⟩][⟨*wdth*⟩][⟨*hght*⟩]
⟨*environment content*⟩
\end{adjactivityanswer}

Like `\activityanswer` but adjusts vertically to tightly surround text.

```
\begin{adjactivityanswer}
  Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi
  commodo, ipsum sed pharetra gravida, orci magna rhoncus neque,
  id pulvinar odio lorem non turpis. Nullam sit amet enim.
  Suspendisse id velit vitae ligula volutpat condimentum. Aliquam
  erat volutpat. Sed quis velit. Nulla facilisi. Nulla libero.
  Vivamus pharetra posuere sapien. Nam consectetuer. Sed aliquam,
  nunc eget euismod ullamcorper, lectus nunc ullamcorper orci,
  fermentum bibendum enim nibh eget ipsum. Donec porttitor ligula
  eu dolor. Maecenas vitae nulla consequat libero cursus venenatis.
  Nam magna enim, accumsan eu, blandit sed, blandit a, eros.
\end{adjactivityanswer}
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim. Suspendisse id velit vitae ligula volutpat condimentum. Aliquam erat volutpat. Sed quis velit. Nulla facilisi. Nulla libero. Vivamus pharetra posuere sapien. Nam consectetuer. Sed aliquam, nunc eget euismod ullamcorper, lectus nunc ullamcorper orci, fermentum bibendum enim nibh eget ipsum. Donec porttitor ligula eu dolor. Maecenas vitae nulla consequat libero cursus venenatis. Nam magna enim, accumsan eu, blandit sed, blandit a, eros.

`\emptybox`[⟨*txt*⟩][⟨*bgclr*⟩][⟨*frmclr*⟩][⟨*txtclr*⟩][⟨*wdth*⟩][⟨*hght*⟩]

Provides a fixed-size box with optional text.

```
\emptybox[Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque,
id pulvinar odio lorem non turpis. Nullam sit amet enim.]
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

`\adjemptybox`[⟨*txt*⟩][⟨*bgclr*⟩][⟨*frmclr*⟩][⟨*txtclr*⟩][⟨*wdth*⟩][⟨*hght*⟩]

Like `\emptybox` but adjusts vertically to tightly surround text.

```
\adjemptybox[Lorem ipsum dolor sit amet, consectetuer adipiscing
elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus
neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.]
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

`\answerbox`[⟨*txt*⟩][⟨*bgclr*⟩][⟨*frmclr*⟩][⟨*txtclr*⟩][⟨*wdth*⟩][⟨*hght*⟩]

Wrapper for \emptybox.

```
\answerbox[Lorem ipsum dolor sit amet, consectetuer adipiscing elit.
Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque,
id pulvinar odio lorem non turpis. Nullam sit amet enim.]
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

\adjanswerbox[⟨*txt*⟩][⟨*bgclr*⟩][⟨*frmclr*⟩][⟨*txtclr*⟩][⟨*wdth*⟩][⟨*hght*⟩]

Wrapper for \adjemptybox.

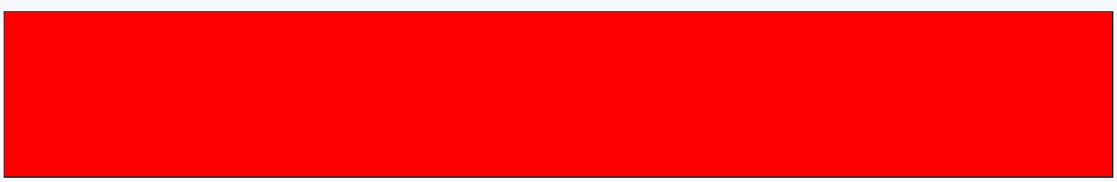
```
\adjanswerbox[Lorem ipsum dolor sit amet, consectetuer adipiscing
elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus
neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.]
```

Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.

\smallanswerbox[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 0.10 that of current \textheight and width 0.90 that of current \linewidth.

```
\smallanswerbox[][red]
```



\mediumanswerbox[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 0.20 that of current \textheight and width 0.90 that of current \linewidth.

```
\mediumanswerbox[][lightgray]
```

\largeanswerbox[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 0.25 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\largeanswerbox[][lightgray]
```

\largeranswerbox[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 0.33 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\largeranswerbox[][lightgray]
```

\hugeanswerbox[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 0.50 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\hugeanswerbox[][lightgray]
```

\hugeranswerbox[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 0.75 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\hugeranswerbox[][lightgray]
```

\fullpageanswerbox[⟨*txt*⟩][⟨*bgclr*⟩]

Answer box with height 1.00 that of current `\textheight` and width 0.90 that of current `\linewidth` (too large to show here).

```
\fullpageanswerbox[][lightgray]
```

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

Environment for highlighting notes to instructors.

```
\begin{miinstructornote}
  Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
  enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
  neque dolor, adipiscing sed, consectetuer et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetuer in, blandit sed,
  suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
  mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
  purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
  Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
  interdum sapien.
\end{miinstructornote}
```

INSTRUCTOR NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetuer et, lacinia sit amet, quam. Suspendisse wisi quam, consectetuer in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

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

Environment for highlighting notes to students.

```
\begin{mistudentnote}
  Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
  enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
  neque dolor, adipiscing sed, consectetuer et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetuer in, blandit sed,
  suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
  mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
  purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
  Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
  interdum sapien.
\end{mistudentnote}
```

STUDENT NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetuer et, lacinia sit amet, quam. Suspendisse wisi quam, consectetuer in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

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

Environment for mathematical derivations based on the `align` environment.

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

DERIVATION

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

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

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

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

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

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

Environment for highlighting notes to instructors.

```
\begin{bwinstructornote}
  Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
  enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
  neque dolor, adipiscing sed, consectetuer et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetuer in, blandit sed,
  suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
  mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
  purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
  Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
  interdum sapien.
\end{bwinstructornote}
```

INSTRUCTOR NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetuer et, lacinia sit amet, quam. Suspendisse wisi quam, consectetuer in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

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

Environment for highlighting notes to students.

```
\begin{bwstudentnote}
  Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
  enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
  neque dolor, adipiscing sed, consectetuer et, lacinia sit amet,
  quam. Suspendisse wisi quam, consectetuer in, blandit sed,
  suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
  mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
  purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
  Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
  interdum sapien.
\end{bwstudentnote}
```

STUDENT NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetuer et, lacinia sit amet, quam. Suspendisse wisi quam, consectetuer in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

```
\begin{bwderivation}
  ⟨environment content⟩
\end{bwderivation}
```

Environment for mathematical derivations based on the `align` environment.

```
\begin{bwderivation}
  \gamma &= \relgamma{\magvect{v}}
    && \text{given} \\
  \gamma\squared &= \ooomx{(\frac{\magvect{v}}{c})\squared}
    &&\text{square both sides}\\
  \frac{1}{\gamma\squared} &= 1-(\frac{\magvect{v}}{c})\squared
    &&\text{reciprocal of both sides} \\
  (\frac{\magvect{v}}{c})\squared &= 1-\frac{1}{\gamma\squared}
    &&\text{rearrange} \\
  \frac{\magvect{v}}{c}&=\sqrt{1-\frac{1}{\gamma\squared}}
    &&\text{square root of both sides}
\end{bwderivation}
```

DERIVATION

$$\begin{aligned}
\gamma &= \frac{1}{\sqrt{1-\left(\frac{\|\vec{v}\|}{c}\right)^2}} && \text{given} \\
\gamma^2 &= \frac{1}{1-\left(\frac{\|\vec{v}\|}{c}\right)^2} && \text{square both sides} \\
\frac{1}{\gamma^2} &= 1-\left(\frac{\|\vec{v}\|}{c}\right)^2 && \text{reciprocal of both sides} \\
\left(\frac{\|\vec{v}\|}{c}\right)^2 &= 1-\frac{1}{\gamma^2} && \text{rearrange} \\
\frac{\|\vec{v}\|}{c} &= \sqrt{1-\frac{1}{\gamma^2}} && \text{square root of both sides}
\end{aligned}$$

```
\begin{mysolution}
  ⟨environment content⟩
\end{mysolution}
```

Alias for simple environment for mathematical derivations based on the `align` environment.

```
\begin{mysolution}
  \gamma &= \relgamma{\magvect{v}}
    && \text{given} \\
  \gamma\squared &= \ooomx{(\frac{\magvect{v}}{c})\squared}
    &&\text{square both sides}\\
  \frac{1}{\gamma\squared} &= 1-(\frac{\magvect{v}}{c})\squared
    &&\text{reciprocal of both sides} \\
  (\frac{\magvect{v}}{c})\squared &= 1-\frac{1}{\gamma\squared}
    &&\text{rearrange} \\
  \frac{\magvect{v}}{c} &= \sqrt{1-\frac{1}{\gamma\squared}}
    &&\text{square root of both sides}
\end{mysolution}
```

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

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

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

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

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

5.17 Miscellaneous Commands

`\checkpoint`

Centered checkpoint for student discussion.

```
\checkpoint
```

|——— CHECKPOINT ———|

`\image{⟨imagefilename⟩}{⟨caption⟩}`

Centered figure displayed actual size with caption.

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

`\sneakyone{⟨thing⟩}`

Sshows factors dividing to a sneaky one.

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

$$\cancelto{1}{\frac{m}{m}}$$

6 Source Code

Note the packages that must be present.

```
\RequirePackage{amsmath}
\RequirePackage{amssymb}
\RequirePackage{array}
\RequirePackage{cancel}
\RequirePackage[dvipsnames]{xcolor}
\RequirePackage{environ}
\RequirePackage{esint}
\RequirePackage[g]{esvect}
\RequirePackage{etoolbox}
\RequirePackage{filehook}
\RequirePackage{extarrows}
\RequirePackage[T1]{fontenc}
\RequirePackage{graphicx}
\RequirePackage{epstopdf}
\RequirePackage{textcomp}
\RequirePackage{letltxmacro}
\RequirePackage{listings}
\RequirePackage[framemethod=TikZ]{mdframed}
\RequirePackage{suffix}
\RequirePackage{xargs}
\RequirePackage{xparse}
\RequirePackage{xspace}
\RequirePackage{ifthen}
\RequirePackage{calligra}
\RequirePackage{hyperref}
\DeclareMathAlphabet{\mathcalligra}{T1}{calligra}{m}{n}
\DeclareFontShape{T1}{calligra}{m}{n}{<->s*[2.2]callig15}{}
\DeclareGraphicsRule{.tif}{png}{.png}{`convert #1 `basename #1 .tif`.png}
\DeclareMathAlphabet{\mathpzc}{OT1}{pzc}{m}{it}
\usetikzlibrary{shadows}
%\changes{v2.4.0}{2014/12/16}{Introduced a uniform style for VPython code.}
\definecolor{vbgcolor}{rgb}{1,1,1}
\definecolor{vshadowcolor}{rgb}{0.5,0.5,0.5}
\lstdefinestyle{vpython}{%                % style for VPython code
  language=Python,%                       % select language
  morekeywords={visual,arrow,box,cone,%   % VPython specific keywords
  convex,curve,cylinder,ellipsoid,extrusion,faces,helix,label,points,pyramid,ring,%
  sphere,text,frame,graphs,vector,pos,axis,radius,color,opacity,material,up,%
  make_trail,trail_type,trail_object,scene,mag,mag2,norm,dot,cross,proj,comp,%
  diff_angle,rotate,astuple,radians,shaftwidth,headwidth,headlength,height,width,%
  size,degrees,interval,retain,__future__,division,print_function,rate},%
  frame=shadowbox,%                       % shadowbox around listing
  rulesepcolor=\color{vshadowcolor},%     % shadow color
  basicstyle=\footnotesize,%              % basic font for code listings
  commentstyle=\bfseries\color{red},      % font for comments
  keywordstyle=\bfseries\color{blue},%    % font for keywords
```

```
  showstringspaces=true,%                 % show spaces in strings
  numbers=left,%                          % where to put line numbers
  numberstyle=\tiny,%                     % set to 'none' for no line numbers
  xleftmargin=20pt,%                      % extra left margin
  backgroundcolor=\color{vbgcolor},%      % some people find this annoying
  upquote=true,%                          % how to typeset quotes
  breaklines=true}%                       % break long lines
\newcolumntype{C}[1]{>{\centering}m{#1}}
\newboolean{@optromanvectors}
\newboolean{@optboldvectors}
\newboolean{@optsingleabsbars}
\newboolean{@optbaseunits}
\newboolean{@optdrvdunits}
\newboolean{@optapproxconsts}
\setboolean{@optromanvectors}{false}   % this is where you set the default option
\setboolean{@optboldvectors}{false}    % this is where you set the default option
\setboolean{@optsingleabsbars}{false}  % this is where you set the default option
\setboolean{@optbaseunits}{false}      % this is where you set the default option
\setboolean{@optdrvdunits}{false}      % this is where you set the default option
\setboolean{@optapproxconsts}{false}   % this is where you set the default option
\DeclareOption{romanvectors}{\setboolean{@optromanvectors}{true}}
\DeclareOption{boldvectors}{\setboolean{@optboldvectors}{true}}
\DeclareOption{singleabsbars}{\setboolean{@optsingleabsbars}{true}}
\DeclareOption{baseunits}{\setboolean{@optbaseunits}{true}}
\DeclareOption{drvdunits}{\setboolean{@optdrvdunits}{true}}
\DeclareOption{approxconsts}{\setboolean{@optapproxconsts}{true}}
\ProcessOptions\relax
```

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

```
\@ifpackageloaded{amssymb}{%
  \csundef{square}
  \typeout{mandi: Package amssymb detected. Its \protect\square\space has been
  redefined.}
}{%
  \typeout{mandi: Package amssymb not detected.}
}%
```

```
\newcommand*{\mandiversion}{2.4.0}
\typeout{mandi: You're using mandi version \mandiversion.}
```

This block of code defines unit names and symbols.

```
\newcommand*{\per}{\ensuremath{/}}
\newcommand*{\usk}{\ensuremath{\cdot}}
\newcommand*{\unit}[2]{\ensuremath{{#1}\,{#2}}}
\newcommand*{\ampere}{\ensuremath{\mathrm{A}}}
\newcommand*{\arcminute}{\ensuremath{'}}
\newcommand*{\arcsecond}{\ensuremath{''}}
\newcommand*{\atomicmassunit}{\ensuremath{\mathrm{u}}}
\newcommand*{\candela}{\ensuremath{\mathrm{cd}}}
```

```
\newcommand*{\coulomb}{\ensuremath{\mathrm{C}}}
\newcommand*{\degree}{\ensuremath{^{\circ}}}
\newcommand*{\electronvolt}{\ensuremath{\mathrm{eV}}}
\newcommand*{\eV}{\electronvolt}
\newcommand*{\farad}{\ensuremath{\mathrm{F}}}
\newcommand*{\henry}{\ensuremath{\mathrm{H}}}
\newcommand*{\hertz}{\ensuremath{\mathrm{Hz}}}
\newcommand*{\hour}{\ensuremath{\mathrm{h}}}
\newcommand*{\joule}{\ensuremath{\mathrm{J}}}
\newcommand*{\kelvin}{\ensuremath{\mathrm{K}}}
\newcommand*{\kilogram}{\ensuremath{\mathrm{kg}}}
\newcommand*{\metre}{\ensuremath{\mathrm{m}}}
\newcommand*{\minute}{\ensuremath{\mathrm{min}}}
\newcommand*{\mole}{\ensuremath{\mathrm{mol}}}
\newcommand*{\newton}{\ensuremath{\mathrm{N}}}
\newcommand*{\ohm}{\ensuremath{\Omega}}
\newcommand*{\pascal}{\ensuremath{\mathrm{Pa}}}
\newcommand*{\radian}{\ensuremath{\mathrm{rad}}}
\newcommand*{\second}{\ensuremath{\mathrm{s}}}
\newcommand*{\siemens}{\ensuremath{\mathrm{S}}}
\newcommand*{\steradian}{\ensuremath{\mathrm{sr}}}
\newcommand*{\tesla}{\ensuremath{\mathrm{T}}}
\newcommand*{\volt}{\ensuremath{\mathrm{V}}}
\newcommand*{\watt}{\ensuremath{\mathrm{W}}}
\newcommand*{\weber}{\ensuremath{\mathrm{Wb}}}
\newcommand*{\C}{\coulomb}
\newcommand*{\F}{\farad}
%\H is already defined as a LaTeX accent
\newcommand*{\J}{\joule}
\newcommand*{\N}{\newton}
\newcommand*{\Pa}{\pascal}
\newcommand*{\rad}{\radian}
\newcommand*{\sr}{\steradian}
%\S is already defined as a LaTeX symbol
\newcommand*{\T}{\tesla}
\newcommand*{\V}{\volt}
\newcommand*{\W}{\watt}
\newcommand*{\Wb}{\weber}
\newcommand*{\square}[1]{\ensuremath{{#1}^2}}               % prefix   2
\newcommand*{\cubic}[1]{\ensuremath{{#1}^3}}                % prefix   3
\newcommand*{\quartic}[1]{\ensuremath{{#1}^4}}              % prefix   4
\newcommand*{\reciprocal}[1]{\ensuremath{{#1}^{-1}}}        % prefix  -1
\newcommand*{\reciprocalsquare}[1]{\ensuremath{{#1}^{-2}}}  % prefix  -2
\newcommand*{\reciprocalcubic}[1]{\ensuremath{{#1}^{-3}}}   % prefix  -3
\newcommand*{\reciprocalquartic}[1]{\ensuremath{{#1}^{-4}}} % prefix  -4
\newcommand*{\squared}{\ensuremath{^2}}                     % postfix  2
\newcommand*{\cubed}{\ensuremath{^3}}                       % postfix  3
\newcommand*{\quarted}{\ensuremath{^4}}                     % postfix  4
\newcommand*{\reciprocaled}{\ensuremath{^{-1}}}             % postfix -1
\newcommand*{\reciprocalsquared}{\ensuremath{^{-2}}}        % postfix -2
```

```
\newcommand*{\reciprocalcubed}{\ensuremath{^{-3}}}          % postfix -3
\newcommand*{\reciprocalquarted}{\ensuremath{^{-4}}}        % postfix -4
```

Define a new named physics quantity or physical constant and commands for selecting units. My thanks to Ulrich Diez for contributing this code.

```
\newcommand*\mi@exchangeargs[2]{#2#1}%
\newcommand*\mi@name{}%
\long\def\mi@name#1#{\romannumeral0\mi@innername{#1}}%
\newcommand*\mi@innername[2]{%
  \expandafter\mi@exchangeargs\expandafter{\csname#2\endcsname}{#1}}%
\begingroup
\@firstofone{%
  \endgroup
  \newcommand*\mi@forkifnull[3]{%
    \romannumeral\iffalse{\fi\expandafter\@secondoftwo\expandafter%
    {\expandafter{\string#1}\expandafter\@secondoftwo\string}%
    \expandafter\@firstoftwo\expandafter{\iffalse}\fi0 #3}{0 #2}}}%
\newcommand*\selectbaseunit[3]{#1}
\newcommand*\selectdrvdunit[3]{#2}
\newcommand*\selecttradunit[3]{#3}
\newcommand*\selectunit{}
\newcommand*\perpusebaseunit{\let\selectunit=\selectbaseunit}
\newcommand*\perpusedrvdunit{\let\selectunit=\selectdrvdunit}
\newcommand*\perpusetradunit{\let\selectunit=\selecttradunit}
\newcommand*\hereusebaseunit[1]{%
  \begingroup\perpusebaseunit#1\endgroup}%
\newcommand*\hereusedrvdunit[1]{%
  \begingroup\perpusedrvdunit#1\endgroup}%
\newcommand*\hereusetradunit[1]{%
  \begingroup\perpusetradunit#1\endgroup}%
\newenvironment{usebaseunit}{\perpusebaseunit}{}%
\newenvironment{usedrvdunit}{\perpusedrvdunit}{}%
\newenvironment{usetradunit}{\perpusetradunit}{}%
\newcommand*\newphysicsquantity{\definephysicsquantity{\newcommand}}
\newcommand*\redefinephysicsquantity{\definephysicsquantity{\renewcommand}}
\newcommandx*\definephysicsquantity[5][4=,5=]{%
  \innerdefinewhatsoeverquantityfork{#3}{#4}{#5}{#1}{#2}{}{[1]}{##1}}%
\newcommand*\newphysicsconstant{\definephysicsconstant{\newcommand}}
\newcommand*\redefinephysicsconstant{\definephysicsconstant{\renewcommand}}
\newcommandx*\definephysicsconstant[7][6=,7=]{%
  \innerdefinewhatsoeverquantityfork{#5}{#6}{#7}{#1}{#2}{#3}{}{#4}}%
\newcommand*\innerdefinewhatsoeverquantityfork[3]{%
  \expandafter\innerdefinewhatsoeverquantity\romannumeral0%
  \mi@forkifnull{#3}{\mi@forkifnull{#2}{{#1}}{{#2}}{#1}}%
                 {\mi@forkifnull{#2}{{#1}}{{#2}}{#3}}{#1}}%
\newcommand*\innerdefinewhatsoeverquantity[8]{%
  \mi@name#4{#5}#7{\unit{#8}{\selectunit{#3}{#1}{#2}}}%
  \mi@name#4{#5baseunit}#7{\unit{#8}{#3}}%
  \mi@name#4{#5drvdunit}#7{\unit{#8}{#1}}%
  \mi@name#4{#5tradunit}#7{\unit{#8}{#2}}%
```

```
  \mi@name#4{#5onlyunit}{\selectunit{#3}{#1}{#2}}%
  \mi@name#4{#5onlybaseunit}{\ensuremath{#3}}%
  \mi@name#4{#5onlydrvdunit}{\ensuremath{#1}}%
  \mi@name#4{#5onlytradunit}{\ensuremath{#2}}%
  \mi@name#4{#5value}#7{\ensuremath{#8}}%
  \mi@forkifnull{#7}{%
    \ifx#4\renewcommand\mi@name\let{#5mathsymbol}=\relax\fi
    \mi@name\newcommand*{#5mathsymbol}{\ensuremath{#6}}}{}}%
```

This block of code processes the options.

```
\ifthenelse{\boolean{@optboldvectors}}
  {\typeout{mandi: You'll get bold vectors.}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\typeout{mandi: You'll get Roman vectors.}}
   {\typeout{mandi: You'll get italic vectors.}}}
\ifthenelse{\boolean{@optsingleabsbars}}
  {\typeout{mandi: You'll get single absolute value bars.}}
  {\typeout{mandi: You'll get double absolute value bars.}}
\ifthenelse{\boolean{@optbaseunits}}
  {\perpusebaseunit %
   \typeout{mandi: You'll get base units.}}
  {\ifthenelse{\boolean{@optdrvdunits}}
     {\perpusedrvdunit %
      \typeout{mandi: You'll get derived units.}}
     {\perpusetradunit %
      \typeout{mandi: You'll get traditional units.}}}
\ifthenelse{\boolean{@optapproxconsts}}
  {\typeout{mandi: You'll get approximate constants.}}
  {\typeout{mandi: You'll get precise constants.}}
```

This is a utility command for picking constants.

```
\ifthenelse{\boolean{@optapproxconsts}}
  {\newcommand*{\mi@p}[2]{#1}} % approximate value
  {\newcommand*{\mi@p}[2]{#2}} % precise value
```

This block of code makes parentheses adjustable.

```
\def\resetMathstrut@{%
  \setbox\z@\hbox{%
    \mathchardef\@tempa\mathcode`\[\relax
    \def\@tempb##1"##2##3{\the\textfont"##3\char"}%
    \expandafter\@tempb\meaning\@tempa \relax}%
  \ht\Mathstrutbox@\ht\z@ \dp\Mathstrutbox@\dp\z@}
\begingroup
  \catcode`(\active \xdef({\left\string(}
  \catcode`)\active \xdef){\right\string)}
\endgroup
\mathcode`(="8000 \mathcode`)="8000
\typeout{mandi: Parentheses have been made adjustable in math mode.}
```

SI base unit of length or spatial displacement

```
\newcommand*{\m}{\metre}
```

SI base unit of mass

```
\newcommand*{\kg}{\kilogram}
```

SI base unit of time or temporal displacement

```
\newcommand*{\s}{\second}
```

SI base unit of electric current

```
\newcommand*{\A}{\ampere}
```

SI base unit of thermodynamic temperature

```
\newcommand*{\K}{\kelvin}
```

SI base unit of amount

```
\newcommand*{\mol}{\mole}
```

SI base unit of luminous intensity

```
\newcommand*{\cd}{\candela}
```

```
\newcommand*{\dimdisplacement}{\ensuremath{\mathrm{L}}}
\newcommand*{\dimmass}{\ensuremath{\mathrm{M}}}
\newcommand*{\dimduration}{\ensuremath{\mathrm{T}}}
\newcommand*{\dimcurrent}{\ensuremath{\mathrm{I}}}
\newcommand*{\dimtemperature}{\ensuremath{\mathrm{\Theta}}}
\newcommand*{\dimamount}{\ensuremath{\mathrm{N}}}
\newcommand*{\dimluminous}{\ensuremath{\mathrm{J}}}
\newphysicsquantity{displacement}{\m}[\m][\m]
\newphysicsquantity{mass}{\kg}[\kg][\kg]
\newphysicsquantity{duration}{\s}[\s][\s]
\newphysicsquantity{current}{\A}[\A][\A]
\newphysicsquantity{temperature}{\K}[\K][\K]
\newphysicsquantity{amount}{\mol}[\mol][\mol]
\newphysicsquantity{luminous}{\cd}[\cd][\cd]
\newphysicsquantity{planeangle}{\m\usk\reciprocal\m}[\rad][\relax]
\newphysicsquantity{solidangle}{\m\squared\usk\reciprocalsquare\m}[\sr][\relax]
\newcommand*{\indegrees}[1]{\unit{#1}{\degree}}
\newcommand*{\inFarenheit}[1]{\unit{#1}{\degree\mathrm{F}}}
\newcommand*{\inCelsius}[1]{\unit{#1}{\degree\mathrm{C}}}
\newcommand*{\inarcminutes}[1]{\unit{#1}{\arcminute}}
\newcommand*{\inarcseconds}[1]{\unit{#1}{\arcsecond}}
\newcommand*{\ineV}[1]{\unit{#1}{\electronvolt}}
\newcommand*{\ineVocs}[1]{\unit{#1}{\mathrm{eV}\per c^2}}
\newcommand*{\ineVoc}[1]{\unit{#1}{\mathrm{eV}\per c}}
```

```
\newcommand*{\inMeV}[1]{\unit{#1}{\mathrm{MeV}}}
\newcommand*{\inMeVocs}[1]{\unit{#1}{\mathrm{MeV}\per c^2}}
\newcommand*{\inMeVoc}[1]{\unit{#1}{\mathrm{MeV}\per c}}
\newcommand*{\inGeV}[1]{\unit{#1}{\mathrm{GeV}}}
\newcommand*{\inGeVocs}[1]{\unit{#1}{\mathrm{GeV}\per c^2}}
\newcommand*{\inGeVoc}[1]{\unit{#1}{\mathrm{GeV}\per c}}
\newcommand*{\inamu}[1]{\unit{#1}{\mathrm{u}}}
\newcommand*{\ingram}[1]{\unit{#1}{\mathrm{g}}}
\newcommand*{\ingrampercubiccm}[1]{\unit{#1}{\mathrm{g}\per\cubic\mathrm{cm}}}
\newcommand*{\inAU}[1]{\unit{#1}{\mathrm{AU}}}
\newcommand*{\inly}[1]{\unit{#1}{\mathrm{ly}}}
\newcommand*{\incyr}[1]{\unit{#1}{c\usk\mathrm{year}}}
\newcommand*{\inpc}[1]{\unit{#1}{\mathrm{pc}}}
\newcommand*{\insolarL}[1]{\unit{#1}{\Lsolar}}
\newcommand*{\insolarT}[1]{\unit{#1}{\Tsolar}}
\newcommand*{\insolarR}[1]{\unit{#1}{\Rsolar}}
\newcommand*{\insolarM}[1]{\unit{#1}{\Msolar}}
\newcommand*{\insolarF}[1]{\unit{#1}{\Fsolar}}
\newcommand*{\insolarf}[1]{\unit{#1}{\fsolar}}
\newcommand*{\insolarMag}[1]{\unit{#1}{\Magsolar}}
\newcommand*{\insolarmag}[1]{\unit{#1}{\magsolar}}
\newcommand*{\insolarD}[1]{\unit{#1}{\Dsolar}}
\newcommand*{\insolard}[1]{\unit{#1}{\dsolar}}
\newcommand*{\velocityc}[1]{\ensuremath{#1c}}
\newphysicsquantity{velocity}{\m\usk\reciprocal\s}[\m\usk\reciprocal\s][\m\per\s]
\newcommand*{\speed}{\velocity}
\newphysicsquantity{acceleration}{\m\usk\s\reciprocalsquared}[\N\per\kg]%
  [\m\per\s\squared]
\newphysicsquantity{gravitationalfield}{\m\usk\s\reciprocalsquared}[\N\per\kg]%
  [\N\per\kg]
\newphysicsquantity{gravitationalpotential}{\square\m\usk\reciprocalsquare\s}%
  [\J\per\kg][\J\per\kg]
\newcommand*{\lorentz}[1]{\ensuremath{#1}}
\newphysicsquantity{momentum}{\m\usk\kg\usk\reciprocal\s}[\N\usk\s][\kg\usk\m\per\s]
\newphysicsquantity{impulse}{\m\usk\kg\usk\reciprocal\s}[\N\usk\s][\N\usk\s]
\newphysicsquantity{force}{\m\usk\kg\usk\s\reciprocalsquared}[\N][\N]
\newphysicsquantity{springstiffness}{\kg\usk\s\reciprocalsquared}[\N\per\m][\N\per\m]
\newphysicsquantity{springstretch}{\m}
\newphysicsquantity{area}{\m\squared}
\newphysicsquantity{volume}{\cubic\m}
\newphysicsquantity{linearmassdensity}{\reciprocal\m\usk\kg}[\kg\per\m][\kg\per\m]
\newphysicsquantity{areamassdensity}{\m\reciprocalsquared\usk\kg}[\kg\per\m\squared]%
  [\kg\per\m\squared]
\newphysicsquantity{volumemassdensity}{\m\reciprocalcubed\usk\kg}[\kg\per\m\cubed]%
  [\kg\per\m\cubed]
\newphysicsquantity{youngsmodulus}{\reciprocal\m\usk\kg\usk\s\reciprocalsquared}%
  [\N\per\m\squared][\Pa]
\newphysicsquantity{stress}{\reciprocal\m\usk\kg\usk\s\reciprocalsquared}%
  [\N\per\m\squared][\Pa]
\newphysicsquantity{pressure}{\reciprocal\m\usk\kg\usk\s\reciprocalsquared}%
```

```
  [\N\per\m\squared][\Pa]
\newphysicsquantity{strain}{\relax}[\relax][\relax]
\newphysicsquantity{work}{\m\squared\usk\kg\usk\s\reciprocalsquared}[\J][\N\usk\m]
\newphysicsquantity{energy}{\m\squared\usk\kg\usk\s\reciprocalsquared}[\N\usk\m][\J]
\newphysicsquantity{power}{\m\squared\usk\kg\usk\s\reciprocalcubed}[\J\per\s][\W]
\newphysicsquantity{specificheatcapacity}{\J\per\K\usk\kg}[\J\per\K\usk\kg]%
  [\J\per\K\usk\kg]
\newphysicsquantity{angularvelocity}{\rad\usk\reciprocal\s}[\rad\per\s][\rad\per\s]
\newphysicsquantity{angularacceleration}{\rad\usk\s\reciprocalsquared}%
  [\rad\per\s\squared][\rad\per\s\squared]
\newphysicsquantity{angularmomentum}{\m\squared\usk\kg\usk\reciprocal\s}[\J\usk\s]%
  [\kg\usk\m\squared\per\s]
\newphysicsquantity{momentofinertia}{\m\squared\usk\kg}[\J\usk\s\squared]%
  [\kg\usk\m\squared]
\newphysicsquantity{torque}{\m\squared\usk\kg\usk\s\reciprocalsquared}[\J\per\rad]%
  [\N\usk\m]
\newphysicsquantity{entropy}{\m\squared\usk\kg\usk\s\reciprocalsquared\usk\reciprocal\K}
  [\J\per\K][\J\per\K]
\newphysicsquantity{wavelength}{\m}[\m][\m]
\newphysicsquantity{wavenumber}{\reciprocal\m}[\per\m][\per\m]
\newphysicsquantity{frequency}{\reciprocal\s}[\hertz][\hertz]
\newphysicsquantity{angularfrequency}{\rad\usk\reciprocal\s}[\rad\per\s][\rad\per\s]
\newphysicsquantity{charge}{\A\usk\s}[\C][\C]
\newphysicsquantity{permittivity}
{\m\reciprocalcubed\usk\reciprocal\kg\usk\s\reciprocalquarted\usk\A\squared}%
  [\F\per\m][\C\squared\per\N\usk\m\squared]
\newphysicsquantity{permeability}%
  {\m\usk\kg\usk\s\reciprocalsquared\usk\A\reciprocalsquared}[\henry\per\m]%
  [\T\usk\m\per\A]
\newphysicsquantity{electricfield}{\m\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}%
  [\V\per\m][\N\per\C]
\newphysicsquantity{electricdipolemoment}{\m\usk\s\usk\A}[\C\usk\m][\C\usk\m]
\newphysicsquantity{electricflux}%
  {\m\cubed\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}%
  [\V\usk\m][\N\usk\m\squared\per\C]
\newphysicsquantity{magneticfield}{\kg\usk\s\reciprocalsquared\usk\reciprocal\A}[\T]%
  [\N\per\C\usk(\m\per\s)] % also \Wb\per\m\squared
\newphysicsquantity{magneticflux}%
  {\m\squared\usk\kg\usk\s\reciprocalsquared\usk\reciprocal\A}[\volt\usk\s]%
  [\T\usk\m\squared] % also \Wb and \J\per\A
\newphysicsquantity{cmagneticfield}{\m\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}%
  [\V\per\m][\N\per\C]
\newphysicsquantity{linearchargedensity}{\reciprocal\m\usk\s\usk\A}[\C\per\m][\C\per\m]
\newphysicsquantity{areachargedensity}{\reciprocalsquare\m\usk\s\usk\A}%
  [\C\per\square\m][\C\per\square\m]
\newphysicsquantity{volumechargedensity}{\reciprocalcubic\m\usk\s\usk\A}%
  [\C\per\cubic\m][\C\per\cubic\m]
\newphysicsquantity{mobility}%
 {\m\squared\usk\kg\usk\s\reciprocalquarted\usk\reciprocal\A}[\m\squared\per\volt\usk\s]
 [(\m\per\s)\per(\N\per\C)]
```

```
\newphysicsquantity{numberdensity}{\reciprocalcubic\m}[\per\cubic\m][\per\cubic\m]
\newphysicsquantity{polarizability}{\reciprocal\kg\usk\s\quarted\usk\square\A}%
  [\C\usk\square\m\per\V][\C\usk\m\per(\N\per\C)]
\newphysicsquantity{electricpotential}%
  {\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocal\A}[\J\per\C][\V]
\newphysicsquantity{emf}{\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocal\A}%
  [\J\per\C][\V]
\newphysicsquantity{dielectricconstant}{}[][]
\newphysicsquantity{indexofrefraction}{}[][]
\newphysicsquantity{relativepermittivity}{}[][]
\newphysicsquantity{relativepermeability}{}[][]
\newphysicsquantity{energydensity}{\m\reciprocaled\usk\kg\usk\reciprocalsquare\s}%
  [\J\per\cubic\m][\J\per\cubic\m]
\newphysicsquantity{energyflux}{\kg\usk\s\reciprocalcubed}%
  [\W\per\m\squared][\W\per\m\squared]
\newphysicsquantity{electroncurrent}{\reciprocal\s}%
  [\ensuremath{\mathrm{e}}\per\s][\ensuremath{\mathrm{e}}\per\s]
\newphysicsquantity{conventionalcurrent}{\A}[\C\per\s][\A]
\newphysicsquantity{magneticdipolemoment}{\square\m\usk\A}[\J\per\T][\A\usk\square\m]
\newphysicsquantity{currentdensity}{\reciprocalsquare\m\usk\A}[\C\usk\s\per\square\m]%
  [\A\per\square\m]
\newphysicsquantity{capacitance}%
  {\reciprocalsquare\m\usk\reciprocal\kg\usk\quartic\s\usk\square\A}[\F][\C\per\V]
  % also \C\squared\per\N\usk\m, \s\per\ohm
\newphysicsquantity{inductance}%
  {\square\m\usk\kg\usk\reciprocalsquare\s\usk\reciprocalsquare\A}[\henry]%
  [\volt\usk\s\per\A] % also \square\m\usk\kg\per\C\squared, \Wb\per\A
\newphysicsquantity{conductivity}%
  {\reciprocalcubic\m\usk\reciprocal\kg\usk\cubic\s\usk\square\A}[\siemens\per\m]%
  [(\A\per\square\m)\per(\V\per\m)]
\newphysicsquantity{resistivity}%
  {\cubic\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocalsquare\A}[\ohm\usk\m]%
  [(\V\per\m)\per(\A\per\square\m)]
\newphysicsquantity{resistance}%
  {\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocalsquare\A}[\V\per\A][\ohm]
\newphysicsquantity{conductance}%
  {\reciprocalsquare\m\usk\reciprocal\kg\usk\cubic\s\usk\square\A}[\A\per\V][\siemens]
\newphysicsquantity{magneticcharge}{\m\usk\A}[\m\usk\A][\m\usk\A]
\newcommand*{\lv}{\ensuremath{\left\langle}}
\newcommand*{\rv}{\ensuremath{\right\rangle}}
\ExplSyntaxOn % Written in LaTeX3
\NewDocumentCommand{\magvectncomps}{ m O{} }
  {%
    \sum_of_squares:nn { #1 }{ #2 }
  }%
\cs_new:Npn \sum_of_squares:nn #1 #2
  {%
    \tl_if_empty:nTF { #2 }
      {%
        \clist_set:Nn \l_tmpa_clist { #1 }
```

```
         \ensuremath{%
          \sqrt{(\clist_use:Nnnn \l_tmpa_clist { )^2+( } { )^2+( } { )^2+( } )^2 }
        }%
      }%
      {%
        \clist_set:Nn \l_tmpa_clist { #1 }
        \ensuremath{%
          \sqrt{(\clist_use:Nnnn \l_tmpa_clist {\;{ #2 })^2+(} {\;{ #2 })^2+(}
          {\;{ #2 })^2+(} \;{ #2 })^2}
        }%
      }%
  }%
\ExplSyntaxOff
%
\newcommand*{\zerovect}{\vect{0}}
\newcommand*{\ncompszerovect}{\mivector{0,0,0}}
\ifthenelse{\boolean{@optboldvectors}}
  {\newcommand*{\vect}[1]{\ensuremath{\boldsymbol{#1}}}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\newcommand*{\vect}[1]{\ensuremath{\vv{\mathrm{#1}}}}}
   {\newcommand*{\vect}[1]{\ensuremath{\vv{#1}}}}}
\ifthenelse{\boolean{@optsingleabsbars}}
  {\newcommand*{\magvect}[1]{\ensuremath{\abs{\vect{#1}}}}}
  {\newcommand*{\magvect}[1]{\ensuremath{\magof{\vect{#1}}}}}
\newcommand*{\magsquaredvect}[1]{\ensuremath{\magvect{#1}\squared}}
\newcommand*{\magnvect}[2]{\ensuremath{\magvect{#1}^{#2}}}
\newcommand*{\dmagvect}[1]{\ensuremath{\dx{\magvect{#1}}}}
\newcommand*{\Dmagvect}[1]{\ensuremath{\Delta\!\magvect{#1}}}
\ifthenelse{\boolean{@optboldvectors}}
  {\newcommand*{\dirvect}[1]{\ensuremath{\widehat{\boldsymbol{#1}}}}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\newcommand*{\dirvect}[1]{\ensuremath{\widehat{\mathrm{#1}}}}}
   {\newcommand*{\dirvect}[1]{\ensuremath{\widehat{#1}}}}}
\newcommand*{\direction}{\dirvect}
\ifthenelse{\boolean{@optromanvectors}}
  {\newcommand*{\compvect}[2]{\ensuremath{\ssub{\mathrm{#1}}{\(#2\)}}}}
  {\newcommand*{\compvect}[2]{\ensuremath{\ssub{#1}{\(#2\)}}}}
\newcommand*{\scompsvect}[1]{\ensuremath{\lv%
  \compvect{#1}{x},%
  \compvect{#1}{y},%
  \compvect{#1}{z}\rv}}
\newcommand*{\magvectscomps}[1]{\ensuremath{\sqrt{%
  \compvect{#1}{x}\squared +%
  \compvect{#1}{y}\squared +%
  \compvect{#1}{z}\squared}}}
\newcommand*{\dvect}[1]{\ensuremath{\mathrm{d}\vect{#1}}}
\newcommand*{\Dvect}[1]{\ensuremath{\Delta\vect{#1}}}
\newcommand*{\dirdvect}[1]{\ensuremath{\widehat{\dvect{#1}}}}
\newcommand*{\dirDvect}[1]{\ensuremath{\widehat{\Dvect{#1}}}}
\newcommand*{\ddirvect}[1]{\ensuremath{\mathrm{d}\dirvect{#1}}}
```

```
\newcommand*{\ddirection}{\ddirvect}
\newcommand*{\Ddirvect}[1]{\ensuremath{\Delta\dirvect{#1}}}
\newcommand*{\Ddirection}{\Ddirvect}
\ifthenelse{\boolean{@optsingleabsbars}}
  {\newcommand*{\magdvect}[1]{\ensuremath{\abs{\dvect{#1}}}}
   \newcommand*{\magDvect}[1]{\ensuremath{\abs{\Dvect{#1}}}}}
  {\newcommand*{\magdvect}[1]{\ensuremath{\magof{\dvect{#1}}}}
   \newcommand*{\magDvect}[1]{\ensuremath{\magof{\Dvect{#1}}}}}
\newcommand*{\compdvect}[2]{\ensuremath{\mathrm{d}\compvect{#1}{#2}}}
\newcommand*{\compDvect}[2]{\ensuremath{\Delta\compvect{#1}{#2}}}
\newcommand*{\scompsdvect}[1]{\ensuremath{\lv%
  \compdvect{#1}{x},%
  \compdvect{#1}{y},%
  \compdvect{#1}{z}\rv}}
\newcommand*{\scompsDvect}[1]{\ensuremath{\lv%
  \compDvect{#1}{x},%
  \compDvect{#1}{y},%
  \compDvect{#1}{z}\rv}}
\newcommand*{\dervect}[2]{\ensuremath{\frac{\dvect{#1}}{\mathrm{d}{#2}}}}
\newcommand*{\Dervect}[2]{\ensuremath{\frac{\Dvect{#1}}{\Delta{#2}}}}
\newcommand*{\compdervect}[3]{\ensuremath{\dbyd{\compvect{#1}{#2}}{#3}}}
\newcommand*{\compDervect}[3]{\ensuremath{\DbyD{\compvect{#1}{#2}}{#3}}}
\newcommand*{\scompsdervect}[2]{\ensuremath{\lv%
  \compdervect{#1}{x}{#2},%
  \compdervect{#1}{y}{#2},%
  \compdervect{#1}{z}{#2}\rv}}
\newcommand*{\scompsDervect}[2]{\ensuremath{\lv%
  \compDervect{#1}{x}{#2},%
  \compDervect{#1}{y}{#2},%
  \compDervect{#1}{z}{#2}\rv}}
\ifthenelse{\boolean{@optsingleabsbars}}
  {\newcommand*{\magdervect}[2]{\ensuremath{\abs{\dervect{#1}{#2}}}}
   \newcommand*{\magDervect}[2]{\ensuremath{\abs{\Dervect{#1}{#2}}}}}
  {\newcommand*{\magdervect}[2]{\ensuremath{\magof{\dervect{#1}{#2}}}}
   \newcommand*{\magDervect}[2]{\ensuremath{\magof{\Dervect{#1}{#2}}}}}
\newcommand*{\dermagvect}[2]{\ensuremath{\dbyd{\magvect{#1}}{#2}}}
\newcommand*{\Dermagvect}[2]{\ensuremath{\DbyD{\magvect{#1}}{#2}}}
\newcommand*{\derdirvect}[2]{\ensuremath{\dbyd{\dirvect{#1}}{#2}}}
\newcommand*{\derdirection}{\derdirvect}
\newcommand*{\Derdirvect}[2]{\ensuremath{\DbyD{\dirvect{#1}}{#2}}}
\newcommand*{\Derdirection}{\Derdirvect}
\ifthenelse{\boolean{@optboldvectors}}
  {\newcommand*{\vectsub}[2]{\ensuremath{\boldsymbol{#1}_{\text{\tiny{}#2}}}}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\newcommand*{\vectsub}[2]{\ensuremath{\vv{\mathrm{#1}}_{\text{\tiny{#2}}}}}}
   {\newcommand*{\vectsub}[2]{\ensuremath{\vv{#1}_{\text{\tiny{#2}}}}}}}
\ifthenelse{\boolean{@optromanvectors}}
  {\newcommand*{\compvectsub}[3]{\ensuremath{\ssub{\mathrm{#1}}{#2,\(#3\)}}}}
  {\newcommand*{\compvectsub}[3]{\ensuremath{\ssub{#1}{#2,\(#3\)}}}}
\newcommand*{\scompsvectsub}[2]{\ensuremath{\lv%
```

```
  \compvectsub{#1}{#2}{x},%
  \compvectsub{#1}{#2}{y},%
  \compvectsub{#1}{#2}{z}\rv}}
\ifthenelse{\boolean{@optsingleabsbars}}
  {\newcommand*{\magvectsub}[2]{\ensuremath{\abs{\vectsub{#1}{#2}}}}}
  {\newcommand*{\magvectsub}[2]{\ensuremath{\magof{\vectsub{#1}{#2}}}}}
\newcommand*{\magsquaredvectsub}[2]{\ensuremath{\magvectsub{#1}{#2}\squared}}
\newcommand*{\magnvectsub}[3]{\ensuremath{\magvectsub{#1}{#2}^{#3}}}
\newcommand*{\magvectsubscomps}[2]{\ensuremath{\sqrt{%
    \compvectsub{#1}{#2}{x}\squared +%
    \compvectsub{#1}{#2}{y}\squared +%
    \compvectsub{#1}{#2}{z}\squared}}}
\ifthenelse{\boolean{@optromanvectors}}
  {\newcommand*{\dirvectsub}[2]{\ensuremath{\ssub{\widehat{\mathrm{#1}}}{#2}}}}
  {\newcommand*{\dirvectsub}[2]{\ensuremath{\ssub{\widehat{#1}}{#2}}}}
\newcommand*{\directionsub}{\dirvectsub}
\newcommand*{\dvectsub}[2]{\ensuremath{\mathrm{d}\vectsub{#1}{#2}}}
\newcommand*{\Dvectsub}[2]{\ensuremath{\Delta\vectsub{#1}{#2}}}
\newcommand*{\compdvectsub}[3]{\ensuremath{\mathrm{d}\compvectsub{#1}{#2}{#3}}}
\newcommand*{\compDvectsub}[3]{\ensuremath{\Delta\compvectsub{#1}{#2}{#3}}}
\newcommand*{\scompsdvectsub}[2]{\ensuremath{\lv%
  \compdvectsub{#1}{#2}{x},%
  \compdvectsub{#1}{#2}{y},%
  \compdvectsub{#1}{#2}{z}\rv}}
\newcommand*{\scompsDvectsub}[2]{\ensuremath{\lv%
  \compDvectsub{#1}{#2}{x},%
  \compDvectsub{#1}{#2}{y},%
  \compDvectsub{#1}{#2}{z}\rv}}
\newcommand*{\dermagvectsub}[3]{\ensuremath{\dbyd{\magvectsub{#1}{#2}}{#3}}}
\newcommand*{\Dermagvectsub}[3]{\ensuremath{\DbyD{\magvectsub{#1}{#2}}{#3}}}
\newcommand*{\dervectsub}[3]{\ensuremath{\dbyd{\vectsub{#1}{#2}}{#3}}}
\newcommand*{\Dervectsub}[3]{\ensuremath{\DbyD{\vectsub{#1}{#2}}{#3}}}
\ifthenelse{\boolean{@optsingleabsbars}}
  {\newcommand*{\magdervectsub}[3]{\ensuremath{\abs{\dervectsub{#1}{#2}{#3}}}}
   \newcommand*{\magDervectsub}[3]{\ensuremath{\abs{\Dervectsub{#1}{#2}{#3}}}}}
  {\newcommand*{\magdervectsub}[3]{\ensuremath{\magof{\dervectsub{#1}{#2}{#3}}}}
   \newcommand*{\magDervectsub}[3]{\ensuremath{\magof{\Dervectsub{#1}{#2}{#3}}}}}
\newcommand*{\compdervectsub}[4]{\ensuremath{\dbyd{\compvectsub{#1}{#2}{#3}}{#4}}}
\newcommand*{\compDervectsub}[4]{\ensuremath{\DbyD{\compvectsub{#1}{#2}{#3}}{#4}}}
\newcommand*{\scompsdervectsub}[3]{\ensuremath{\lv%
  \compdervectsub{#1}{#2}{x}{#3},%
  \compdervectsub{#1}{#2}{y}{#3},%
  \compdervectsub{#1}{#2}{z}{#3}\rv}}
\newcommand*{\scompsDervectsub}[3]{\ensuremath{\lv%
  \compDervectsub{#1}{#2}{x}{#3},%
  \compDervectsub{#1}{#2}{y}{#3},%
  \compDervectsub{#1}{#2}{z}{#3}\rv}}
\newcommand*{\vectdotvect}[2]{\ensuremath{{#1}\bullet{#2}}}
\newcommand*{\vectdotsvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsvect{#2}}}
\newcommand*{\vectdotevect}[2]{\ensuremath{%
```

```
  \compvect{#1}{x}\compvect{#2}{x}+%
  \compvect{#1}{y}\compvect{#2}{y}+%
  \compvect{#1}{z}\compvect{#2}{z}}}
\newcommand*{\vectdotsdvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsdvect{#2}}}
\newcommand*{\vectdotsDvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsDvect{#2}}}
\newcommand*{\vectdotedvect}[2]{\ensuremath{%
  \compvect{#1}{x}\compdvect{#2}{x}+%
  \compvect{#1}{y}\compdvect{#2}{y}+%
  \compvect{#1}{z}\compdvect{#2}{z}}}
\newcommand*{\vectdoteDvect}[2]{\ensuremath{%
  \compvect{#1}{x}\compDvect{#2}{x}+%
  \compvect{#1}{y}\compDvect{#2}{y}+%
  \compvect{#1}{z}\compDvect{#2}{z}}}
\newcommand*{\vectsubdotsvectsub}[4]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsvectsub{#3}{#4}}}
\newcommand*{\vectsubdotevectsub}[4]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compvectsub{#3}{#4}{x}+%
  \compvectsub{#1}{#2}{y}\compvectsub{#3}{#4}{y}+%
  \compvectsub{#1}{#2}{z}\compvectsub{#3}{#4}{z}}}
\newcommand*{\vectsubdotsdvectsub}[4]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsdvectsub{#3}{#4}}}
\newcommand*{\vectsubdotsDvectsub}[4]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsDvectsub{#3}{#4}}}
\newcommand*{\vectsubdotedvectsub}[4]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compdvectsub{#3}{#4}{x}+%
  \compvectsub{#1}{#2}{y}\compdvectsub{#3}{#4}{y}+%
  \compvectsub{#1}{#2}{z}\compdvectsub{#3}{#4}{z}}}
\newcommand*{\vectsubdoteDvectsub}[4]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compDvectsub{#3}{#4}{x}+%
  \compvectsub{#1}{#2}{y}\compDvectsub{#3}{#4}{y}+%
  \compvectsub{#1}{#2}{z}\compDvectsub{#3}{#4}{z}}}
\newcommand*{\vectsubdotsdvect}[3]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsdvect{#3}}}
\newcommand*{\vectsubdotsDvect}[3]{\ensuremath{%
  \scompsvectsub{#1}{#2}\bullet\scompsDvect{#3}}}
\newcommand*{\vectsubdotedvect}[3]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compdvect{#3}{x}+%
  \compvectsub{#1}{#2}{y}\compdvect{#3}{y}+%
  \compvectsub{#1}{#2}{z}\compdvect{#3}{z}}}
\newcommand*{\vectsubdoteDvect}[3]{\ensuremath{%
  \compvectsub{#1}{#2}{x}\compDvect{#3}{x}+%
  \compvectsub{#1}{#2}{y}\compDvect{#3}{y}+%
  \compvectsub{#1}{#2}{z}\compDvect{#3}{z}}}
\newcommand*{\dervectdotsvect}[3]{\ensuremath{%
  \scompsdervect{#1}{#2}\bullet\scompsvect{#3}}}
\newcommand*{\Dervectdotsvect}[3]{\ensuremath{%
  \scompsDervect{#1}{#2}\bullet\scompsvect{#3}}}
\newcommand*{\dervectdotevect}[3]{\ensuremath{%
  \compdervect{#1}{x}{#2}\compvect{#3}{x}+%
  \compdervect{#1}{y}{#2}\compvect{#3}{y}+%
```

```
  \compdervect{#1}{z}{#2}\compvect{#3}{z}}}
\newcommand*{\Dervectdotevect}[3]{\ensuremath{%
  \compDervect{#1}{x}{#2}\compvect{#3}{x}+%
  \compDervect{#1}{y}{#2}\compvect{#3}{y}+%
  \compDervect{#1}{z}{#2}\compvect{#3}{z}}}
\newcommand*{\vectdotsdervect}[3]{\ensuremath{%
  \scompsvect{#1}\bullet\scompsdervect{#2}{#3}}}
\newcommand*{\vectdotsDervect}[3]{\ensuremath{%
  \scompsvect{#1}\bullet\scompsDervect{#2}{#3}}}
\newcommand*{\vectdotedervect}[3]{\ensuremath{%
  \compvect{#1}{x}\compdervect{#2}{x}{#3}+%
  \compvect{#1}{y}\compdervect{#2}{y}{#3}+%
  \compvect{#1}{z}\compdervect{#2}{z}{#3}}}
\newcommand*{\vectdoteDervect}[3]{\ensuremath{%
  \compvect{#1}{x}\compDervect{#2}{x}{#3}+%
  \compvect{#1}{y}\compDervect{#2}{y}{#3}+%
  \compvect{#1}{z}\compDervect{#2}{z}{#3}}}
\newcommand*{\dervectdotsdvect}[3]{\ensuremath{%
  \scompsdervect{#1}{#2}\bullet\scompsdvect{#3}}}
\newcommand*{\DervectdotsDvect}[3]{\ensuremath{%
  \scompsDervect{#1}{#2}\bullet\scompsDvect{#3}}}
\newcommand*{\dervectdotedvect}[3]{\ensuremath{%
  \compdervect{#1}{x}{#2}\compdvect{#3}{x}+%
  \compdervect{#1}{y}{#2}\compdvect{#3}{y}+%
  \compdervect{#1}{z}{#2}\compdvect{#3}{z}}}
\newcommand*{\DervectdoteDvect}[3]{\ensuremath{%
  \compDervect{#1}{x}{#2}\compDvect{#3}{x}+%
  \compDervect{#1}{y}{#2}\compDvect{#3}{y}+%
  \compDervect{#1}{z}{#2}\compDvect{#3}{z}}}
\newcommand*{\vectcrossvect}[2]{\ensuremath{{#1}\boldsymbol{\times}{#2}}}
\newcommand*{\ltriplecross}[3]{\ensuremath{({#1}\boldsymbol{\times}{#2})%
  \boldsymbol{\times}{#3}}}
\newcommand*{\rtriplecross}[3]{\ensuremath{{#1}\boldsymbol{\times}%
  ({#2}\boldsymbol{\times}{#3})}}
\newcommand*{\ltriplescalar}[3]{\ensuremath{{#1}\boldsymbol{\times}{#2}\bullet{#3}}}
\newcommand*{\rtriplescalar}[3]{\ensuremath{{#1}\bullet{#2}\boldsymbol{\times}{#3}}}
\newcommand*{\ezero}{\ensuremath{\msub{\boldsymbol{e}}{0}}}
\newcommand*{\eone}{\ensuremath{\msub{\boldsymbol{e}}{1}}}
\newcommand*{\etwo}{\ensuremath{\msub{\boldsymbol{e}}{2}}}
\newcommand*{\ethree}{\ensuremath{\msub{\boldsymbol{e}}{3}}}
\newcommand*{\efour}{\ensuremath{\msub{\boldsymbol{e}}{4}}}
\newcommand*{\ek}[1]{\ensuremath{\msub{\boldsymbol{e}}{#1}}}
\newcommand*{\e}{\ek}
\newcommand*{\uezero}{\ensuremath{\msub{\widehat{\boldsymbol{e}}}{0}}}
\newcommand*{\ueone}{\ensuremath{\msub{\widehat{\boldsymbol{e}}}{1}}}
\newcommand*{\uetwo}{\ensuremath{\msub{\widehat{\boldsymbol{e}}}{2}}}
\newcommand*{\uethree}{\ensuremath{\msub{\widehat{\boldsymbol{e}}}{3}}}
\newcommand*{\uefour}{\ensuremath{\msub{\widehat{\boldsymbol{e}}}{4}}}
\newcommand*{\uek}[1]{\ensuremath{\msub{\widehat{\boldsymbol{e}}}{#1}}}
\newcommand*{\ue}{\uek}
```

```
\newcommand*{\ezerozero}{\ek{00}}
\newcommand*{\ezeroone}{\ek{01}}
\newcommand*{\ezerotwo}{\ek{02}}
\newcommand*{\ezerothree}{\ek{03}}
\newcommand*{\ezerofour}{\ek{04}}
\newcommand*{\eoneone}{\ek{11}}
\newcommand*{\eonetwo}{\ek{12}}
\newcommand*{\eonethree}{\ek{13}}
\newcommand*{\eonefour}{\ek{14}}
\newcommand*{\etwoone}{\ek{21}}
\newcommand*{\etwotwo}{\ek{22}}
\newcommand*{\etwothree}{\ek{23}}
\newcommand*{\etwofour}{\ek{24}}
\newcommand*{\ethreeone}{\ek{31}}
\newcommand*{\ethreetwo}{\ek{32}}
\newcommand*{\ethreethree}{\ek{33}}
\newcommand*{\ethreefour}{\ek{34}}
\newcommand*{\efourone}{\ek{41}}
\newcommand*{\efourtwo}{\ek{42}}
\newcommand*{\efourthree}{\ek{43}}
\newcommand*{\efourfour}{\ek{44}}
\newcommand*{\euzero}{\ensuremath{\boldsymbol{e}^0}}
\newcommand*{\euone}{\ensuremath{\boldsymbol{e}^1}}
\newcommand*{\eutwo}{\ensuremath{\boldsymbol{e}^2}}
\newcommand*{\euthree}{\ensuremath{\boldsymbol{e}^3}}
\newcommand*{\eufour}{\ensuremath{\boldsymbol{e}^4}}
\newcommand*{\euk}[1]{\ensuremath{\boldsymbol{e}^{#1}}}
\newcommand*{\eu}{\euk}
\newcommand*{\euzerozero}{\euk{00}}
\newcommand*{\euzeroone}{\euk{01}}
\newcommand*{\euzerotwo}{\euk{02}}
\newcommand*{\euzerothree}{\euk{03}}
\newcommand*{\euzerofour}{\euk{04}}
\newcommand*{\euoneone}{\euk{11}}
\newcommand*{\euonetwo}{\euk{12}}
\newcommand*{\euonethree}{\euk{13}}
\newcommand*{\euonefour}{\euk{14}}
\newcommand*{\eutwoone}{\euk{21}}
\newcommand*{\eutwotwo}{\euk{22}}
\newcommand*{\eutwothree}{\euk{23}}
\newcommand*{\eutwofour}{\euk{24}}
\newcommand*{\euthreeone}{\euk{31}}
\newcommand*{\euthreetwo}{\euk{32}}
\newcommand*{\euthreethree}{\euk{33}}
\newcommand*{\euthreefour}{\euk{34}}
\newcommand*{\eufourone}{\euk{41}}
\newcommand*{\eufourtwo}{\euk{42}}
\newcommand*{\eufourthree}{\euk{43}}
\newcommand*{\eufourfour}{\euk{44}}
\newcommand*{\gzero}{\ensuremath{\msub{\boldsymbol{\gamma}}{0}}}
```

```
\newcommand*{\gone}{\ensuremath{\msub{\boldsymbol{\gamma}}{1}}}
\newcommand*{\gtwo}{\ensuremath{\msub{\boldsymbol{\gamma}}{2}}}
\newcommand*{\gthree}{\ensuremath{\msub{\boldsymbol{\gamma}}{3}}}
\newcommand*{\gfour}{\ensuremath{\msub{\boldsymbol{\gamma}}{4}}}
\newcommand*{\gk}[1]{\ensuremath{\msub{\boldsymbol{\gamma}}{#1}}}
\newcommand*{\g}{\gk}
\newcommand*{\gzerozero}{\gk{00}}
\newcommand*{\gzeroone}{\gk{01}}
\newcommand*{\gzerotwo}{\gk{02}}
\newcommand*{\gzerothree}{\gk{03}}
\newcommand*{\gzerofour}{\gk{04}}
\newcommand*{\goneone}{\gk{11}}
\newcommand*{\gonetwo}{\gk{12}}
\newcommand*{\gonethree}{\gk{13}}
\newcommand*{\gonefour}{\gk{14}}
\newcommand*{\gtwoone}{\gk{21}}
\newcommand*{\gtwotwo}{\gk{22}}
\newcommand*{\gtwothree}{\gk{23}}
\newcommand*{\gtwofour}{\gk{24}}
\newcommand*{\gthreeone}{\gk{31}}
\newcommand*{\gthreetwo}{\gk{32}}
\newcommand*{\gthreethree}{\gk{33}}
\newcommand*{\gthreefour}{\gk{34}}
\newcommand*{\gfourone}{\gk{41}}
\newcommand*{\gfourtwo}{\gk{42}}
\newcommand*{\gfourthree}{\gk{43}}
\newcommand*{\gfourfour}{\gk{44}}
\newcommand*{\guzero}{\ensuremath{\boldsymbol{\gamma}^0}}
\newcommand*{\guone}{\ensuremath{\boldsymbol{\gamma}^1}}
\newcommand*{\gutwo}{\ensuremath{\boldsymbol{\gamma}^2}}
\newcommand*{\guthree}{\ensuremath{\boldsymbol{\gamma}^3}}
\newcommand*{\gufour}{\ensuremath{\boldsymbol{\gamma}^4}}
\newcommand*{\guk}[1]{\ensuremath{\boldsymbol{\gamma}^{#1}}}
\newcommand*{\gu}{\guk}
\newcommand*{\guzerozero}{\guk{00}}
\newcommand*{\guzeroone}{\guk{01}}
\newcommand*{\guzerotwo}{\guk{02}}
\newcommand*{\guzerothree}{\guk{03}}
\newcommand*{\guzerofour}{\guk{04}}
\newcommand*{\guoneone}{\guk{11}}
\newcommand*{\guonetwo}{\guk{12}}
\newcommand*{\guonethree}{\guk{13}}
\newcommand*{\guonefour}{\guk{14}}
\newcommand*{\gutwoone}{\guk{21}}
\newcommand*{\gutwotwo}{\guk{22}}
\newcommand*{\gutwothree}{\guk{23}}
\newcommand*{\gutwofour}{\guk{24}}
\newcommand*{\guthreeone}{\guk{31}}
\newcommand*{\guthreetwo}{\guk{32}}
\newcommand*{\guthreethree}{\guk{33}}
```

```
\newcommand*{\guthreefour}{\guk{34}}
\newcommand*{\gufourone}{\guk{41}}
\newcommand*{\gufourtwo}{\guk{42}}
\newcommand*{\gufourthree}{\guk{43}}
\newcommand*{\gufourfour}{\guk{44}}
\ExplSyntaxOn % Vectors formated as in M\&I, written in LaTeX3
\NewDocumentCommand{\mivector}{ O{,} m o }%
 {%
   \mi_vector:nn { #1 } { #2 }
   \IfValueT{#3}{\;{#3}}
 }%
\seq_new:N \l__mi_list_seq
\cs_new_protected:Npn \mi_vector:nn #1 #2
{%
  \ensuremath{%
    \seq_set_split:Nnn \l__mi_list_seq { , } { #2 }
    \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \left\langle }
    \seq_use:Nnnn \l__mi_list_seq { #1 } { #1 } { #1 }
    \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \right\rangle }
  }%
}%
\ExplSyntaxOff
\ExplSyntaxOn % Column and row vectors, written in LaTeX3
\seq_new:N \l__vector_arg_seq
\cs_new_protected:Npn \vector_main:nnnn #1 #2 #3 #4
 {%
  \seq_set_split:Nnn \l__vector_arg_seq { #3 } { #4 }
  \begin{#1matrix}
    \seq_use:Nnnn \l__vector_arg_seq { #2 } { #2 } { #2 }
  \end{#1matrix}
 }%
\NewDocumentCommand{\rowvector}{ O{,} m }
 {%
  \ensuremath{
  \vector_main:nnnn { p } { \,\, } { #1 } { #2 }
  }%
 }%
\NewDocumentCommand{\colvector}{ O{,} m }
 {%
  \ensuremath{
  \vector_main:nnnn { p } { \\ } { #1 } { #2 }
  }%
 }%
\ExplSyntaxOff
\newcommandx{\scompscvect}[2][1,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
  {%
    \colvector{\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
  }%
  {%
```

```
    \colvector{\msub{#2}{0},\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
  }%
}%
\newcommandx{\scompsrvect}[2][1,usedefault]{%
  \ifthenelse{\equal{#1}{}}%
  {%
    \rowvector[,]{\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
  }%
  {%
    \rowvector[,]{\msub{#2}{0},\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
  }%
}%
\newphysicsconstant{oofpez}{\ensuremath{\frac{1}
{\phantom{_o}4\pi\epsilon_0}}}{\mi@p{9}{8.9876}\timestento{9}}
{\m\cubed\usk\kg\usk\reciprocalquartic\s\usk\A\reciprocalsquared}[\m\per\farad]
[\newton\usk\m\squared\per\coulomb\squared]
\newcommand*{\coulombconstant}{\oofpez}
\newphysicsconstant{oofpezcs}{\ensuremath{\frac{1}
{\phantom{_o}4\pi\epsilon_0 c^2\phantom{_o}}}}{\tento{-7}}
{\m\usk\kg\usk\s\reciprocalsquared\usk\A\reciprocalsquared}
[\T\usk\m\squared][\N\usk\s\squared\per\C\squared]
\newcommand*{\altcoulombconstant}{\oofpezcs}
\newphysicsconstant{vacuumpermittivity}{\ensuremath{\epsilon_0}}
{\mi@p{9.0}{8.8542}\timestento{-12}}
{\m\reciprocalcubed\usk\reciprocal\kg\usk\s\quarted\usk\A\squared}[\F\per\m]
[\C\squared\per\N\usk\m\squared]
\newphysicsconstant{mzofp}
{\ensuremath{\frac{\phantom{_oo}\mu_0\phantom{_o}}{4\pi}}}
{\tento{-7}}{\m\usk\kg\usk\s\reciprocalsquared\usk\A\reciprocalsquared}
[\henry\per\m][\tesla\usk\m\per\A]
\newcommand*{\biotsavartconstant}{\mzofp}
\newphysicsconstant{vacuumpermeability}{\ensuremath{\mu_0}}
{4\pi\timestento{-7}}{\m\usk\kg\usk\s\reciprocalsquared\usk\A\reciprocalsquared}
[\henry\per\m][\T\usk\m\per\A]
\newphysicsconstant{boltzmann}{\ensuremath{k_B}}
{\mi@p{1.4}{1.3806}\timestento{-23}}
{\m\squared\usk\kg\usk\reciprocalsquare\s\usk\reciprocal\K}[\joule\per\K][\J\per\K]
\newcommand*{\boltzmannconstant}{\boltzmann}
\newphysicsconstant{boltzmannineV}{\ensuremath{k_B}}
{\mi@p{8.6}{8.6173}\timestento{-5}}
{\eV\usk\reciprocal\K}[\eV\per\K][\eV\per\K]
\newphysicsconstant{stefanboltzmann}{\ensuremath{\sigma}}
{\mi@p{5.7}{5.6704}\timestento{-8}}
{\kg\usk\s\reciprocalcubed\usk\K\reciprocalquarted}[\W\per\m\squared\usk\K^4]
[\W\per\m\squared\usk\K\quarted]
\newcommand*{\stefanboltzmannconstant}{\stefanboltzmann}
\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]
\newcommand*{\planckconstant}{\planck}
\newphysicsconstant{planckineV}{\ensuremath{h}}{\mi@p{4.1}{4.1357}\timestento{-15}}
```

```
{\eV\usk\s}[\eV\usk\s][\eV\usk\s]
\newphysicsconstant{planckbar}{\ensuremath{\hslash}}{\mi@p{1.1}{1.0546}\timestento{-34}}
{\m\squared\usk\kg\usk\reciprocal\s}[\J\usk\s][\J\usk\s]
\newcommand*{\reducedplanckconstant}{\planckbar}
\newphysicsconstant{planckbarineV}{\ensuremath{\hslash}}
{\mi@p{6.6}{6.5821}\timestento{-16}}{\eV\usk\s}[\eV\usk\s][\eV\usk\s]
\newphysicsconstant{planckc}{\ensuremath{hc}}{\mi@p{2.0}{1.9864}\timestento{-25}}
{\m\cubed\usk\kg\usk\reciprocalsquare\s}[\J\usk\m][\J\usk\m]
\newcommand*{\planckconstanttimesc}{\planckc}
\newphysicsconstant{planckcineV}{\ensuremath{hc}}
{\mi@p{2.0}{1.9864}\timestento{-25}}{\eV\usk\text{n}\m}[\eV\usk\text{n}\m]
[\eV\usk\text{n}\m]
\newphysicsconstant{rydberg}{\ensuremath{\msub{R}{\infty}}}
{\mi@p{1.1}{1.0974}\timestento{7}}{\reciprocal\m}[\reciprocal\m][\reciprocal\m]
\newcommand*{\rydbergconstant}{\rydberg}
\newphysicsconstant{bohrradius}{\ensuremath{a_0}}{\mi@p{5.3}{5.2918}\timestento{-11}}
{\m}[\m][\m]
\newphysicsconstant{finestructure}{\ensuremath{\alpha}}
{\mi@p{\frac{1}{137}}{7.2974\timestento{-3}}}{\relax}
\newcommand*{\finestructureconstant}{\finestructure}
\newphysicsconstant{avogadro}{\ensuremath{N_A}}
{\mi@p{6.0}{6.0221}\timestento{23}}{\reciprocal\mol}[\reciprocal\mol][\reciprocal\mol]
\newcommand*{\avogadroconstant}{\avogadro}
\newphysicsconstant{universalgrav}{\ensuremath{G}}{\mi@p{6.7}{6.6738}\timestento{-11}}
{\m\cubed\usk\reciprocal\kg\usk\s\reciprocalsquared}[\J\usk\m\per\kg\squared]
[\N\usk\m\squared\per\kg\squared]
\newcommand*{\universalgravitationalconstant}{\universalgrav}
\newphysicsconstant{surfacegravfield}{\ensuremath{g}}{\mi@p{9.8}{9.80}}
{\m\usk\s\reciprocalsquared}[\N\per\kg][\N\per\kg]
\newcommand*{\earthssurfacegravitationalfield}{\surfacegravfield}
\newphysicsconstant{clight}{\ensuremath{c}}
{\mi@p{3}{2.9979}\timestento{8}}{\m\usk\reciprocal\s}[\m\per\s][\m\per\s]
\newcommand*{\photonconstant}{\clight}
\newphysicsconstant{clightinfeet}{\ensuremath{c}}{\mi@p{1}{0.9836}}
{\text{ft}\usk\reciprocal{\text{n}\s}}[\text{ft}\per\text{n}\s]
[\text{ft}\per\mathrm{n}\s]
\newphysicsconstant{Ratom}{\ensuremath{r_{\text{atom}}}}{\tento{-10}}{\m}[\m][\m]
\newphysicsconstant{Mproton}{\ensuremath{m_p}}
{\mi@p{1.7}{1.6726}\timestento{-27}}{\kg}[\kg][\kg]
\newphysicsconstant{Mneutron}{\ensuremath{m_n}}
{\mi@p{1.7}{1.6749}\timestento{-27}}{\kg}[\kg][\kg]
\newphysicsconstant{Mhydrogen}{\ensuremath{m_H}}
{\mi@p{1.7}{1.6737}\timestento{-27}}{\kg}[\kg][\kg]
\newphysicsconstant{Melectron}{\ensuremath{m_e}}
{\mi@p{9.1}{9.1094}\timestento{-31}}{\kg}[\kg][\kg]
\newphysicsconstant{echarge}{\ensuremath{e}}
{\mi@p{1.6}{1.6022}\timestento{-19}}{\A\usk\s}[\C][\C]
\newcommand*{\elementarycharge}{\echarge}
\newphysicsconstant{Qelectron}{\ensuremath{Q_e}}{-\echargevalue}
{\A\usk\s}[\C][\C]
```

```
\newphysicsconstant{qelectron}{\ensuremath{q_e}}{-\echargevalue}
{\A\usk\s}[\C][\C]
\newphysicsconstant{Qproton}{\ensuremath{Q_p}}{+\echargevalue}
{\A\usk\s}[\C][\C]
\newphysicsconstant{qproton}{\ensuremath{q_p}}{+\echargevalue}
{\A\usk\s}[\C][\C]
\newphysicsconstant{MEarth}{\ensuremath{M_{\text{Earth}}}}
{\mi@p{6.0}{5.9736}\timestento{24}}{\kg}[\kg][\kg]
\newphysicsconstant{MMoon}{\ensuremath{M_{\text{Moon}}}}
{\mi@p{7.3}{7.3459}\timestento{22}}{\kg}[\kg][\kg]
\newphysicsconstant{MSun}{\ensuremath{M_{\text{Sun}}}}
{\mi@p{2.0}{1.9891}\timestento{30}}
{\kg}[\kg][\kg]
\newphysicsconstant{REarth}{\ensuremath{R_{\text{Earth}}}}
{\mi@p{6.4}{6.3675}\timestento{6}}{\m}[\m][\m]
\newphysicsconstant{RMoon}{\ensuremath{R_{\text{Moon}}}}
{\mi@p{1.7}{1.7375}\timestento{6}}{\m}[\m][\m]
\newphysicsconstant{RSun}{\ensuremath{R_{\text{Sun}}}}{\mi@p{7.0}{6.9634}\timestento{8}}
{\m}[\m][\m]
\newphysicsconstant{ESdist}{\magvectsub{r}{ES}}{\mi@p{1.5}{1.4960}\timestento{11}}{\m}
[\m][\m]
\newphysicsconstant{SEdist}{\magvectsub{r}{SE}}{\mi@p{1.5}{1.4960}\timestento{11}}{\m}
[\m][\m]
\newcommand*{\EarthSundistance}{\ESdist}
\newcommand*{\SunEarthdistance}{\SEdist}
\newphysicsconstant{EMdist}{\magvectsub{r}{EM}}
{\mi@p{3.8}{3.8440}\timestento{8}}{\m}[\m][\m]
\newphysicsconstant{MEdist}{\magvectsub{r}{ME}}
{\mi@p{3.8}{3.8440}\timestento{8}}{\m}[\m][\m]
\newcommand*{\EarthMoondistance}{\ESdist}
\newcommand*{\MoonEarthdistance}{\SEdist}
\newphysicsconstant{LSun}{\ensuremath{L_{\text{Sun}}}}
{\mi@p{3.8}{3.8460}\timestento{26}}{\m\squared\usk\kg\usk\s\reciprocalcubed}[\W]
[\J\per\s]
\newphysicsconstant{TSun}{\ensuremath{T_{\text{Sun}}}}{\mi@p{5800}{5778}}{\K}[\K][\K]
\newphysicsconstant{MagSun}{\ensuremath{M_{\text{Sun}}}}{+4.83}{}[][]
\newphysicsconstant{magSun}{\ensuremath{m_{\text{Sun}}}}{-26.74}{}[][]
\newcommand*{\Lstar}[1][\(\star\)]{\ensuremath{L_{\text{#1}}}\xspace}
\newcommand*{\Lsolar}{\ensuremath{\Lstar[\(\odot\)]}\xspace}
\newcommand*{\Tstar}[1][\(\star\)]{\ensuremath{T_{\text{#1}}}\xspace}
\newcommand*{\Tsolar}{\ensuremath{\Tstar[\(\odot\)]}\xspace}
\newcommand*{\Rstar}[1][\(\star\)]{\ensuremath{R_{\text{#1}}}\xspace}
\newcommand*{\Rsolar}{\ensuremath{\Rstar[\(\odot\)]}\xspace}
\newcommand*{\Mstar}[1][\(\star\)]{\ensuremath{M_{\text{#1}}}\xspace}
\newcommand*{\Msolar}{\ensuremath{\Mstar[\(\odot\)]}\xspace}
\newcommand*{\Fstar}[1][\(\star\)]{\ensuremath{F_{\text{#1}}}\xspace}
\newcommand*{\fstar}[1][\(\star\)]{\ensuremath{f_{\text{#1}}}\xspace}
\newcommand*{\Fsolar}{\ensuremath{\Fstar[\(\odot\)]}\xspace}
\newcommand*{\fsolar}{\ensuremath{\fstar[\(\odot\)]}\xspace}
\newcommand*{\Magstar}[1][\(\star\)]{\ensuremath{M_{\text{#1}}}\xspace}
```

```
\newcommand*{\magstar}[1][\(\star\)]{\ensuremath{m_{\text{#1}}}\xspace}
\newcommand*{\Magsolar}{\ensuremath{\Magstar[\(\odot\)]}\xspace}
\newcommand*{\magsolar}{\ensuremath{\magstar[\(\odot\)]}\xspace}
\newcommand*{\Dstar}[1][\(\star\)]{\ensuremath{D_{\text{#1}}}\xspace}
\newcommand*{\dstar}[1][\(\star\)]{\ensuremath{d_{\text{#1}}}\xspace}
\newcommand*{\Dsolar}{\ensuremath{\Dstar[\(\odot\)]}\xspace}
\newcommand*{\dsolar}{\ensuremath{\dstar[\(\odot\)]}\xspace}
\newcommand*{\onehalf}{\ensuremath{\frac{1}{2}}\xspace}
\newcommand*{\onethird}{\ensuremath{\frac{1}{3}}\xspace}
\newcommand*{\onefourth}{\ensuremath{\frac{1}{4}}\xspace}
\newcommand*{\onefifth}{\ensuremath{\frac{1}{5}}\xspace}
\newcommand*{\onesixth}{\ensuremath{\frac{1}{6}}\xspace}
\newcommand*{\oneseventh}{\ensuremath{\frac{1}{7}}\xspace}
\newcommand*{\oneeighth}{\ensuremath{\frac{1}{8}}\xspace}
\newcommand*{\oneninth}{\ensuremath{\frac{1}{9}}\xspace}
\newcommand*{\onetenth}{\ensuremath{\frac{1}{10}}\xspace}
\newcommand*{\twooneths}{\ensuremath{\frac{2}{1}}\xspace}
\newcommand*{\twohalves}{\ensuremath{\frac{2}{2}}\xspace}
\newcommand*{\twothirds}{\ensuremath{\frac{2}{3}}\xspace}
\newcommand*{\twofourths}{\ensuremath{\frac{2}{4}}\xspace}
\newcommand*{\twofifths}{\ensuremath{\frac{2}{5}}\xspace}
\newcommand*{\twosixths}{\ensuremath{\frac{2}{6}}\xspace}
\newcommand*{\twosevenths}{\ensuremath{\frac{2}{7}}\xspace}
\newcommand*{\twoeighths}{\ensuremath{\frac{2}{8}}\xspace}
\newcommand*{\twoninths}{\ensuremath{\frac{2}{9}}\xspace}
\newcommand*{\twotenths}{\ensuremath{\frac{2}{10}}\xspace}
\newcommand*{\threeoneths}{\ensuremath{\frac{3}{1}}\xspace}
\newcommand*{\threehalves}{\ensuremath{\frac{3}{2}}\xspace}
\newcommand*{\threethirds}{\ensuremath{\frac{3}{3}}\xspace}
\newcommand*{\threefourths}{\ensuremath{\frac{3}{4}}\xspace}
\newcommand*{\threefifths}{\ensuremath{\frac{3}{5}}\xspace}
\newcommand*{\threesixths}{\ensuremath{\frac{3}{6}}\xspace}
\newcommand*{\threesevenths}{\ensuremath{\frac{3}{7}}\xspace}
\newcommand*{\threeeighths}{\ensuremath{\frac{3}{8}}\xspace}
\newcommand*{\threeninths}{\ensuremath{\frac{3}{9}}\xspace}
\newcommand*{\threetenths}{\ensuremath{\frac{3}{10}}\xspace}
\newcommand*{\fouroneths}{\ensuremath{\frac{4}{1}}\xspace}
\newcommand*{\fourhalves}{\ensuremath{\frac{4}{2}}\xspace}
\newcommand*{\fourthirds}{\ensuremath{\frac{4}{3}}\xspace}
\newcommand*{\fourfourths}{\ensuremath{\frac{4}{4}}\xspace}
\newcommand*{\fourfifths}{\ensuremath{\frac{4}{5}}\xspace}
\newcommand*{\foursixths}{\ensuremath{\frac{4}{6}}\xspace}
\newcommand*{\foursevenths}{\ensuremath{\frac{4}{7}}\xspace}
\newcommand*{\foureighths}{\ensuremath{\frac{4}{8}}\xspace}
\newcommand*{\fourninths}{\ensuremath{\frac{4}{9}}\xspace}
\newcommand*{\fourtenths}{\ensuremath{\frac{4}{10}}\xspace}
\newcommand*{\sumoverall}[1]{\ensuremath{\displaystyle\sum_{\substack{\text{\tiny{all }}
  \text{\tiny{{#1}}}}}}}
\newcommand*{\dx}[1]{\ensuremath{\,\mathrm{d}{#1}}}
\newcommand*{\evalfromto}[3]{\ensuremath{\Bigg.{#1}\Bigg\rvert_{#2}^{#3}}}
```

```
\newcommand*{\evalat}[2]{\ensuremath{\Bigg.{#1}\Bigg\rvert_{#2}}}
\newcommand*{\evaluatedat}[1]{\ensuremath{\Bigg.\Bigg\rvert_{#1}}}
\newcommandx{\integral}[4][1,2,usedefault]{\ensuremath{%
  \int_{\ifthenelse{\equal{#1}{}}{}{#4=#1}}^{\ifthenelse{\equal{#2}{}}{}{#4=#2}}
  {#3}\dx{#4}}
\newcommand*{\opensurfaceintegral}[2]{\ensuremath{%
  \iint\nolimits_{#1}\vectdotvect{#2}{\dirvect{n}}\dx{A}}}
\newcommand*{\closedsurfaceintegral}[2]{\ensuremath{%
  \varoiint\nolimits_{#1}\vectdotvect{#2}{\dirvect{n}}\dx{A}}}
\newcommand*{\openlineintegral}[2]{\ensuremath{%
  \int\nolimits_{#1}\vectdotvect{#2}{\dirvect{t}}\dx{\ell}}}
\newcommand*{\closedlineintegral}[2]{\ensuremath{%
  \oint\nolimits_{#1}\vectdotvect{#2}{\dirvect{t}}\dx{\ell}}}
\newcommand*{\volumeintegral}[2]{\ensuremath{\iiint\nolimits_{#1}{#2}\dx{V}}}
\newcommandx{\dbydt}[1][1]{\ensuremath{\frac{\mathrm{d}{#1}}{\mathrm{d}t}}}
\newcommandx{\DbyDt}[1][1]{\ensuremath{\frac{\Delta{#1}}{\Delta t}}}
\newcommandx{\ddbydt}[1][1]{\ensuremath{\frac{\mathrm{d}^{2}{#1}}{\mathrm{d}t^{2}}}}
\newcommandx{\DDbyDt}[1][1]{\ensuremath{\frac{\Delta^{2}{#1}}{\Delta t^{2}}}}
\newcommandx{\pbypt}[1][1]{\ensuremath{\frac{\partial{#1}}{\partial t}}}
\newcommandx{\ppbypt}[1][1]{\ensuremath{\frac{\partial^{2}{#1}}{\partial t^{2}}}}
\newcommand*{\dbyd}[2]{\ensuremath{\frac{\mathrm{d}{#1}}{\mathrm{d}{#2}}}}
\newcommand*{\DbyD}[2]{\ensuremath{\frac{\Delta{#1}}{\Delta{#2}}}}
\newcommand*{\ddbyd}[2]{\ensuremath{\frac{\mathrm{d}^{2}{#1}}{\mathrm{d}{#2}^{2}}}}
\newcommand*{\DDbyD}[2]{\ensuremath{\frac{\Delta^{2}{#1}}{\Delta{#2}^{2}}}}
\newcommand*{\pbyp}[2]{\ensuremath{\frac{\partial{#1}}{\partial{#2}}}}
\newcommand*{\ppbyp}[2]{\ensuremath{\frac{\partial^{2}{#1}}{\partial{#2}^{2}}}}
\newcommand*{\seriesfofx}{\ensuremath{%
f(x) \approx f(a) + \frac{f^\prime (a)}{1!}(x-a) + \frac{f^{\prime\prime}(a)}{2!}(x-a)^2
+ \frac{f^{\prime\prime\prime}(a)}{3!}(x-a)^3 + \ldots}\xspace}
\newcommand*{\seriesexpx}{\ensuremath{%
e^x \approx 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \ldots}\xspace}
\newcommand*{\seriessinx}{\ensuremath{%
\sin x \approx x - \frac{x^3}{3!} + \frac{x^5}{5!} - \ldots}\xspace}
\newcommand*{\seriescosx}{\ensuremath{%
\cos x \approx 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \ldots}\xspace}
\newcommand*{\seriestanx}{\ensuremath{%
\tan x \approx x + \frac{x^3}{3} + \frac{2x^5}{15} + \ldots}\xspace}
\newcommand*{\seriesatox}{\ensuremath{%
a^x \approx 1 + x \ln{a} + \frac{(x \ln a)^2}{2!} + \frac{(x \ln a)^3}{3!} + \ldots}
\xspace}
\newcommand*{\serieslnoneplusx}{\ensuremath{%
\ln(1 \pm x) \approx \pm\; x - \frac{x^2}{2} \pm \frac{x^3}{3} - \frac{x^4}{4} \pm
\ldots}\xspace}
\newcommand*{\binomialseries}{\ensuremath{%
(1 + x)^n \approx 1 + nx + \frac{n(n-1)}{2!}x^2 + \ldots}\xspace}
\newcommand*{\gradient}{\ensuremath{\boldsymbol{\nabla}}}
\newcommand*{\divergence}{\ensuremath{\boldsymbol{\nabla}\bullet}}
\newcommand*{\curl}{\ensuremath{\boldsymbol{\nabla\times}}}
\newcommand*{\laplacian}{\ensuremath{\boldsymbol{\nabla}^2}}
\newcommand*{\dalembertian}{\ensuremath{\boldsymbol{\Box}}}
```

```
\newcommand*{\diracdelta}[1]{\ensuremath{\delta}(#1)}
\newcommand*{\orderof}[1]{\ensuremath{\mathcal{O}(#1)}}
\DeclareMathOperator{\asin}{\sin^{-1}}
\DeclareMathOperator{\acos}{\cos^{-1}}
\DeclareMathOperator{\atan}{\tan^{-1}}
\DeclareMathOperator{\asec}{\sec^{-1}}
\DeclareMathOperator{\acsc}{\csc^{-1}}
\DeclareMathOperator{\acot}{\cot^{-1}}
\DeclareMathOperator{\sech}{sech}
\DeclareMathOperator{\csch}{csch}
\DeclareMathOperator{\asinh}{\sinh^{-1}}
\DeclareMathOperator{\acosh}{\cosh^{-1}}
\DeclareMathOperator{\atanh}{\tanh^{-1}}
\DeclareMathOperator{\asech}{\sech^{-1}}
\DeclareMathOperator{\acsch}{\csch^{-1}}
\DeclareMathOperator{\acoth}{\coth^{-1}}
\DeclareMathOperator{\sgn}{sgn}
\DeclareMathOperator{\dex}{dex}
\newcommand*{\logb}[1][\relax]{\ensuremath{\log_{#1}}}
\ifthenelse{\boolean{@optboldvectors}}
  {\newcommand*{\cB}{\ensuremath{\boldsymbol{c\mskip -3.00mu B}}}}
  {\ifthenelse{\boolean{@optromanvectors}}
   {\newcommand*{\cB}{\ensuremath{\textsf{c}\mskip -3.00mu\mathrm{B}}}}
   {\newcommand*{\cB}{\ensuremath{c\mskip -3.00mu B}}}}
\newcommand*{\newpi}{\ensuremath{\pi\mskip -7.8mu\pi}}
\newcommand*{\scripty}[1]{\ensuremath{\mathcalligra{#1}}}
\newcommandx{\flux}[1][1]{\ensuremath{\ssub{\Phi}{#1}}}
\@ifpackageloaded{commath}{%
  \typeout{mandi: Package commath detected. Its \protect\abs\space command will
  be used.}
}{%
  \typeout{mandi: Package commath not detected. mandi’s \protect\abs\space command
  will be used.}
  \newcommand*{\abs}[1]{\ensuremath{\left\lvert{#1}\right\rvert}}
}%
\newcommand*{\magof}[1]{\ensuremath{\left\lVert{#1}\right\rVert}}
\newcommand*{\dimsof}[1]{\ensuremath{\left[{#1}\right]}}
\newcommand*{\unitsof}[1]{\ensuremath{\left[{#1}\right]_u}}
\newcommand*{\changein}[1]{\ensuremath{\delta{#1}}}
\newcommand*{\Changein}[1]{\ensuremath{\Delta{#1}}}
\newcommandx{\scin}[3][1,3=\!\!,usedefault]{\ensuremath{%
  \ifthenelse{\equal{#1}{}}
    {\unit{10^{#2}}{#3}}
    {\unit{{#1}\times 10^{#2}}{#3}}}}
\newcommandx{\timestento}[2][2=\!\!,usedefault]{\ensuremath{%
  \ifthenelse{\equal{#2}{}}
    {\unit{\;\times\;10^{#1}}{}}
    {\unit{\;\times\;10^{#1}}{#2}}}}
\newcommand*{\xtento}{\timestento}
\newcommandx{\tento}[2][2=\!\!,usedefault]{\ensuremath{%
```

```
  \ifthenelse{\equal{#2}{}}
    {\unit{10^{#1}}{}}
    {\unit{10^{#1}}{#2}}}}
\newcommand*{\ee}[2]{\texttt{{#1}e{#2}}}
\newcommand*{\EE}[2]{\texttt{{#1}E{#2}}}
\newcommand*{\dms}[3]{\ensuremath{\indegrees{#1}\inarcminutes{#2}\inarcseconds{#3}}}
\newcommand*{\hms}[3]{\ensuremath{{#1}^{\hour}{#2}^{\mathrm{m}}{#3}^{\s}}}
\newcommand*{\clockreading}{\hms}
\newcommand*{\latitude}[1]{\unit{#1}{\degree}}
\newcommand*{\latitudeN}[1]{\unit{#1}{\degree\;\mathrm{N}}}
\newcommand*{\latitudeS}[1]{\unit{#1}{\degree\;\mathrm{S}}}
\newcommand*{\longitude}[1]{\unit{#1}{\degree}}
\newcommand*{\longitudeE}[1]{\unit{#1}{\degree\;\mathrm{E}}}
\newcommand*{\longitudeW}[1]{\unit{#1}{\degree\;\mathrm{W}}}
\newcommand*{\ssub}[2]{\ensuremath{#1_{\text{#2}}}}
\newcommand*{\ssup}[2]{\ensuremath{#1^{\text{#2}}}}
\newcommand*{\ssud}[3]{\ensuremath{#1^{\text{#2}}_{\text{#3}}}}
\newcommand*{\msub}[2]{\ensuremath{#1_{#2}}}
\newcommand*{\msup}[2]{\ensuremath{#1^{#2}}}
\newcommand*{\msud}[3]{\ensuremath{#1^{#2}_{#3}}}
\newcommand*{\levicivita}[1]{\ensuremath{\varepsilon_{\scriptscriptstyle{#1}}}}
\newcommand*{\kronecker}[1]{\ensuremath{\delta_{\scriptscriptstyle{#1}}}}
\newcommand*{\xaxis}{\ensuremath{x\text{-axis}}\xspace}
\newcommand*{\yaxis}{\ensuremath{y\text{-axis}}\xspace}
\newcommand*{\zaxis}{\ensuremath{z\text{-axis}}\xspace}
\newcommand*{\naxis}[1]{\ensuremath{{#1}\text{-axis}}\xspace}
\newcommand*{\axis}{\ensuremath{\text{-axis}}\xspace}
\newcommand*{\xyplane}{\ensuremath{xy\text{-plane}}\xspace}
\newcommand*{\yzplane}{\ensuremath{yz\text{-plane}}\xspace}
\newcommand*{\zxplane}{\ensuremath{zx\text{-plane}}\xspace}
\newcommand*{\yxplane}{\ensuremath{yx\text{-plane}}\xspace}
\newcommand*{\zyplane}{\ensuremath{zy\text{-plane}}\xspace}
\newcommand*{\xzplane}{\ensuremath{xz\text{-plane}}\xspace}
\newcommand*{\plane}{\ensuremath{\text{-plane}}\xspace}
% Frequently used roots. Prepend |f| for fractional exponents.
\newcommand*{\cuberoot}[1]{\ensuremath{\sqrt[3]{#1}}}
\newcommand*{\fourthroot}[1]{\ensuremath{\sqrt[4]{#1}}}
\newcommand*{\fifthroot}[1]{\ensuremath{\sqrt[5]{#1}}}
\newcommand*{\fsqrt}[1]{\ensuremath{{#1}^\onehalf}}
\newcommand*{\fcuberoot}[1]{\ensuremath{{#1}^\onethird}}
\newcommand*{\ffourthroot}[1]{\ensuremath{{#1}^\onefourth}}
\newcommand*{\ffifthroot}[1]{\ensuremath{{#1}^\onefifth}}
\newcommand*{\relgamma}[1]{\ensuremath{%
  \frac{1}{\sqrt{1-(\frac{#1}{c})\squared}}}}
\newcommand*{\frelgamma}[1]{\ensuremath{%
  (1-\frac{{#1}\squared}{c\squared})^{-\onehalf}}}
\newcommand*{\oosqrtomxs}[1]{\ensuremath{\frac{1}{\sqrt{1-{#1}\squared}}}}
\newcommand*{\oosqrtomx}[1]{\ensuremath{\frac{1}{\sqrt{1-{#1}}}}}
\newcommand*{\ooomx}[1]{\ensuremath{\frac{1}{1-{#1}}}}
\newcommand*{\ooopx}[1]{\ensuremath{\frac{1}{1+{#1}}}}
```

```
\newcommand*{\isequals}{\wordoperator{?}{=}\xspace}
\newcommand*{\wordoperator}[2]{\ensuremath{%
  \mathrel{\vcenter{\offinterlineskip
  \halign{\hfil\tiny\upshape##\hfil\cr\noalign{\vskip-.5ex}
    {#1}\cr\noalign{\vskip.5ex}{#2}\cr}}}}}
\newcommand*{\definedas}{\wordoperator{defined}{as}\xspace}
\newcommand*{\associated}{\wordoperator{associated}{with}\xspace}
\newcommand*{\adjustedby}{\wordoperator{adjusted}{by}\xspace}
\newcommand*{\earlierthan}{\wordoperator{earlier}{than}\xspace}
\newcommand*{\laterthan}{\wordoperator{later}{than}\xspace}
\newcommand*{\forevery}{\wordoperator{for}{every}\xspace}
\newcommand*{\pwordoperator}[2]{\ensuremath{\left(%
  \mathrel{\vcenter{\offinterlineskip%
  \halign{\hfil\tiny\upshape##\hfil\cr\noalign{\vskip-.5ex}%
    {#1}\cr\noalign{\vskip.5ex}{#2}\cr}}}\right)}}%
\newcommand*{\pdefinedas}{\pwordoperator{defined}{as}\xspace}
\newcommand*{\passociated}{\pwordoperator{associated}{with}\xspace}
\newcommand*{\padjustedby}{\pwordoperator{adjusted}{by}\xspace}
\newcommand*{\pearlierthan}{\pwordoperator{earlier}{than}\xspace}
\newcommand*{\platerthan}{\pwordoperator{later}{than}\xspace}
\newcommand*{\pforevery}{\pwordoperator{for}{every}\xspace}
\newcommand*{\defines}{\ensuremath{\stackrel{\text{\tiny{def}}}{=}}\xspace}
\newcommand*{\inframe}[1][\relax]{\ensuremath{\xrightarrow[\text\tiny{\mathcal #1}]{}}
  \xspace}
\newcommand*{\associates}{\ensuremath{\xrightarrow{\text{\tiny{assoc}}}}\xspace}
\newcommand*{\becomes}{\ensuremath{\xrightarrow{\text{\tiny{becomes}}}}\xspace}
\newcommand*{\rrelatedto}[1]{\ensuremath{\xLongrightarrow{\text{\tiny{#1}}}}}
\newcommand*{\lrelatedto}[1]{\ensuremath{\xLongleftarrow[\text{\tiny{#1}}]{}}}
\newcommand*{\brelatedto}[2]{\ensuremath{%
  \xLongleftrightarrow[\text{\tiny{#1}}]{\text{\tiny{#2}}}}}
\newcommand*{\momentumprinciple}{\ensuremath{%
  \vectsub{p}{sys,final}=\vectsub{p}{sys,initial}+\Fnetsys\Delta t}}
\newcommand*{\LHSmomentumprinciple}{\ensuremath{\vectsub{p}{sys,final}}}
\newcommand*{\RHSmomentumprinciple}{\ensuremath{\vectsub{p}{sys,initial}+\Fnetsys
  \Delta t}}
\newcommand*{\momentumprinciplediff}{\ensuremath{\Dvectsub{p}{sys}=\Fnetsys\Delta t}}
\newcommand*{\energyprinciple}{\ensuremath{\ssub{E}{sys,final}=\ssub{E}{sys,initial}+W
  +Q}}
\newcommand*{\LHSenergyprinciple}{\ensuremath{\ssub{E}{sys,final}}}
\newcommand*{\RHSenergyprinciple}{\ensuremath{\ssub{E}{sys,initial}+W+Q}}
\newcommand*{\energyprinciplediff}{\ensuremath{\Delta\ssub{E}{sys}=W+Q}}
\newcommand*{\angularmomentumprinciple}{\ensuremath{\vectsub{L}{\(A\),sys,final}=
  \vectsub{L}{\(A\),sys,initial}+\Tsub{net}\Delta t}}
\newcommand*{\LHSangularmomentumprinciple}{\ensuremath{\vectsub{L}{\(A\),sys,final}}}
\newcommand*{\RHSangularmomentumprinciple}{\ensuremath{\vectsub{L}{\(A\),sys,initial}+
  \Tsub{net}\Delta t}}
\newcommand*{\angularmomentumprinciplediff}{\ensuremath{\Dvectsub{L}{\(A\),sys}=
  \Tsub{net}\Delta t}}
\newcommand*{\gravitationalinteraction}{\ensuremath{%
  \universalgravmathsymbol\frac{\msub{M}{1}\msub{M}{2}}{\magvectsub{r}{12}\squared}
```

```
  (-\dirvectsub{r}{12})}}
\newcommand*{\electricinteraction}{\ensuremath{%
  \oofpezmathsymbol\frac{\msub{Q}{1}\msub{Q}{2}}{\magvectsub{r}{12}\squared}
  \dirvectsub{r}{12}}}
\newcommand*{\springinteraction}{\ensuremath{\ks\magvect{s}(-\dirvect{s})}}
\newcommand*{\Bfieldofparticle}{\ensuremath{%
  \mzofpmathsymbol\frac{Q\magvect{v}}{\magvect{r}\squared}\dirvect{v}\times\dirvect{r}}}
\newcommand*{\Efieldofparticle}{\ensuremath{%
  \oofpezmathsymbol\frac{Q}{\magvect{r}\squared}\dirvect{r}}}
\newcommandx{\Esys}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{sys}}{\ssub{E}{sys,#1}}}
\newcommandx{\Us}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{U}{\(s\)}}{\ssub{U}{\(s\),#1}}}
\newcommandx{\Ug}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{U}{\(g\)}}{\ssub{U}{\(g\),#1}}}
\newcommandx{\Ue}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{U}{\(e\)}}{\ssub{U}{\(e\),#1}}}
\newcommandx{\Ktrans}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{K}{trans}}
  {\ssub{K}{trans,#1}}}
\newcommandx{\Krot}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{K}{rot}}{\ssub{K}{rot,#1}}}
\newcommandx{\Kvib}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{K}{vib}}{\ssub{K}{vib,#1}}}
\newcommandx{\Eparticle}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{particle}}
  {\ssub{E}{particle,#1}}}
\newcommandx{\Einternal}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{internal}}
  {\ssub{E}{internal,#1}}}
\newcommandx{\Erest}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{rest}}{\ssub{E}{rest,#1}}}
\newcommandx{\Echem}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{chem}}{\ssub{E}{chem,#1}}}
\newcommandx{\Etherm}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{therm}}
  {\ssub{E}{therm,#1}}}
\newcommandx{\Evib}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{vib}}{\ssub{E}{vib,#1}}}
\newcommandx{\Ephoton}[1][1]{\ifthenelse{\equal{#1}{}}{\ssub{E}{photon}}
  {\ssub{E}{photon,#1}}}
\newcommand*{\DEsys}{\Changein\Esys}
\newcommand*{\DUs}{\Changein\Us}
\newcommand*{\DUg}{\Changein\Ug}
\newcommand*{\DUe}{\Changein\Ue}
\newcommand*{\DKtrans}{\Changein\Ktrans}
\newcommand*{\DKrot}{\Changein\Krot}
\newcommand*{\DKvib}{\Changein\Kvib}
\newcommand*{\DEparticle}{\Changein\Eparticle}
\newcommand*{\DEinternal}{\Changein\Einternal}
\newcommand*{\DErest}{\Changein\Erest}
\newcommand*{\DEchem}{\Changein\Echem}
\newcommand*{\DEtherm}{\Changein\Etherm}
\newcommand*{\DEvib}{\Changein\Evib}
\newcommand*{\DEphoton}{\Changein\Ephoton}
\newcommand*{\springpotentialenergy}{\onehalf\ks\magsquaredvect{s}}
\newcommand*{\finalspringpotentialenergy}
  {\ssub{\left(\springpotentialenergy\right)}{\!\!final}}
\newcommand*{\initialspringpotentialenergy}
  {\ssub{\left(\springpotentialenergy\right)}{\!\!initial}}
\newcommand*{\gravitationalpotentialenergy}{\ensuremath{%
  -G\frac{\msub{M}{1}\msub{M}{2}}{\magvectsub{r}{12}}}}
\newcommand*{\finalgravitationalpotentialenergy}
```

```
  {\ssub{\left(\gravitationalpotentialenergy\right)}{\!\!final}}
\newcommand*{\initialgravitationalpotentialenergy}
  {\ssub{\left(\gravitationalpotentialenergy\right)}{\!\!initial}}
\newcommand*{\electricpotentialenergy}{\ensuremath{%
  \oofpezmathsymbol\frac{\ssub{Q}{1}\ssub{Q}{2}}{\magvectsub{r}{12}}}}
\newcommand*{\finalelectricpotentialenergy}
  {\ssub{\left(\electricpotentialenergy\right)}{\!\!final}}
\newcommand*{\initialelectricpotentialenergy}
  {\ssub{\left(\electricpotentialenergy\right)}{\!\!initial}}
\newcommand*{\ks}{\msub{k}{s}}
\newcommand*{\Fnet}{\ensuremath{\vectsub{F}{net}}}
\newcommand*{\Fnetext}{\ensuremath{\vectsub{F}{net,ext}}}
\newcommand*{\Fnetsys}{\ensuremath{\vectsub{F}{net,sys}}}
\newcommand*{\Fsub}[1]{\ensuremath{\vectsub{F}{#1}}}
\newcommand*{\Ltotal}{\ensuremath{\vectsub{L}{\(A\),total}}}
\newcommand*{\Lsys}{\ensuremath{\vectsub{L}{\(A\),sys}}}
\newcommand*{\Lsub}[1]{\ensuremath{\vectsub{L}{\(A\),{#1}}}}
\newcommand*{\Tnet}{\ensuremath{\vectsub{\tau}{\(A\),net}}}
\newcommand*{\Tnetext}{\ensuremath{\vectsub{\tau}{\(A\),net,ext}}}
\newcommand*{\Tnetsys}{\ensuremath{\vectsub{\tau}{\(A\),net,sys}}}
\newcommand*{\Tsub}[1]{\ensuremath{\vectsub{\tau}{\(A\),#1}}}
\newcommand*{\LHSmaxwelliint}[1][\partial V]{\ensuremath{%
  \closedsurfaceintegral{#1}{\vect{E}}}}
\newcommand*{\RHSmaxwelliint}{\ensuremath{\frac{\ssub{Q}{\(e\),net}}%
  {\vacuumpermittivitymathsymbol}}}
\newcommand*{\RHSmaxwelliinta}[1][V]{\ensuremath{%
  \frac{1}{\vacuumpermittivitymathsymbol}\volumeintegral{#1}{\msub{\rho}{e}}}}
\newcommand*{\RHSmaxwelliintfree}{\ensuremath{0}}
\newcommand*{\maxwelliint}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliint[#1]=\RHSmaxwelliint}}
\newcommandx*{\maxwelliinta}[2][1={\partial V},2={V},usedefault]{\ensuremath{%
  \LHSmaxwelliint[#1]=\RHSmaxwelliinta[#2]}}
\newcommand*{\maxwelliintfree}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliint[#1]=\RHSmaxwelliintfree}}
\newcommand*{\LHSmaxwelliiint}[1][\partial V]{\ensuremath{%
  \closedsurfaceintegral{#1}{\vect{B}}}}
\newcommand*{\RHSmaxwelliiint}{\ensuremath{0}}
\newcommand*{\RHSmaxwelliiintm}{\ensuremath{%
  \vacuumpermeabilitymathsymbol\ssub{Q}{\(m\),net}}}
\newcommand*{\RHSmaxwelliiintma}[1][V]{\ensuremath{%
  \vacuumpermeabilitymathsymbol\volumeintegral{#1}{\msub{\rho}{m}}}}
\newcommand*{\RHSmaxwelliiintfree}{\ensuremath{0}}
\newcommand*{\maxwelliiint}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliiint[#1]=\RHSmaxwelliiint}}
\newcommand*{\maxwelliiintm}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliiint[#1]=\RHSmaxwelliiintm}}
\newcommandx*{\maxwelliiintma}[2][1={\partial V},2={V},usedefault]{\ensuremath{%
  \LHSmaxwelliiint[#1]=\RHSmaxwelliiintma[#2]}}
\newcommand*{\maxwelliiintfree}[1][\partial V]{\ensuremath{%
  \LHSmaxwelliiint[#1]=\RHSmaxwelliiintfree}}
```

```
\newcommand*{\LHSmaxwelliiiint}[1][\partial\Omega]{\ensuremath{%
  \closedlineintegral{#1}{\vect{E}}}}
\newcommand*{\RHSmaxwelliiiint}[1][\Omega]{\ensuremath{%
  -\dbydt\opensurfaceintegral{#1}{\vect{B}}}}
\newcommand*{\RHSmaxwelliiiintm}[1][\Omega]{\ensuremath{%
  -\dbydt\opensurfaceintegral{#1}{\vect{B}}%
  -\vacuumpermeabilitymathsymbol\ssub{I}{\(m\),net}}}
\newcommand*{\RHSmaxwelliiiintma}[1][\Omega]{\ensuremath{%
  -\dbydt\opensurfaceintegral{#1}{\vect{B}}%
  -\vacuumpermeabilitymathsymbol\opensurfaceintegral{#1}{\vectsub{J}{\(m\)}}}}
\newcommand*{\RHSmaxwelliiiintfree}{\RHSmaxwelliiiint}
\newcommandx*{\maxwelliiiint}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwelliiiint[#1]=\RHSmaxwelliiiint[#2]}}
\newcommandx*{\maxwelliiiintm}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwelliiiint[#1]=\RHSmaxwelliiiintm[#2]}}
\newcommandx*{\maxwelliiiintma}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwelliiiint[#1]=\RHSmaxwelliiiintma[#2]}}
\newcommand*{\maxwelliiiintfree}{\maxwelliiiint}
\newcommand*{\LHSmaxwellivint}[1][\partial\Omega]{\ensuremath{%
  \closedlineintegral{#1}{\vect{B}}}}
\newcommand*{\RHSmaxwellivint}[1][\Omega]{\ensuremath{%
  \vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol%
  \dbydt\opensurfaceintegral{#1}{\vect{E}}+%
  \vacuumpermeabilitymathsymbol\ssub{I}{\(e\),net}}}
\newcommand*{\RHSmaxwellivinta}[1][\Omega]{\ensuremath{%
  \vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol%
  \dbydt\opensurfaceintegral{#1}{\vect{E}}+%
  \vacuumpermeabilitymathsymbol\opensurfaceintegral{#1}{\vectsub{J}{\(e\)}}}}
\newcommand*{\RHSmaxwellivintfree}[1][\Omega]{\ensuremath{%
  \vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol%
  \dbydt\opensurfaceintegral{#1}{\vect{E}}}}
\newcommandx*{\maxwellivint}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwellivint[#1]=\RHSmaxwellivint[#2]}}
\newcommandx*{\maxwellivinta}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwellivint[#1]=\RHSmaxwellivinta[#2]}}
\newcommandx*{\maxwellivintfree}[2][1={\partial\Omega},2={\Omega},usedefault]%
  {\ensuremath{\LHSmaxwellivint[#1]=\RHSmaxwellivintfree[#2]}}
\newcommand*{\LHSmaxwellidif}{\ensuremath{\divergence{\vect{E}}}}
\newcommand*{\RHSmaxwellidif}{\ensuremath{\frac{\msub{\rho}{e}}
  {\vacuumpermittivitymathsymbol}}}
\newcommand*{\RHSmaxwellidiffree}{\ensuremath{0}}
\newcommand*{\maxwellidif}{\ensuremath{\LHSmaxwellidif=\RHSmaxwellidif}}
\newcommand*{\maxwellidiffree}{\ensuremath{\LHSmaxwellidif=\RHSmaxwellidiffree}}
\newcommand*{\LHSmaxwelliidif}{\ensuremath{\divergence{\vect{B}}}}
\newcommand*{\RHSmaxwelliidif}{\ensuremath{0}}
\newcommand*{\RHSmaxwelliidifm}{\ensuremath{\vacuumpermeabilitymathsymbol%
  \msub{\rho}{m}}}
\newcommand*{\RHSmaxwelliidiffree}{\ensuremath{0}}
\newcommand*{\maxwelliidif}{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidif}}
\newcommand*{\maxwelliidifm}{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidifm}}
```

```
\newcommand*{\maxwelliidiffree}{\ensuremath{\LHSmaxwelliidif=\RHSmaxwelliidiffree}}
\newcommand*{\LHSmaxwelliiidif}{\ensuremath{\curl{\vect{E}}}}
\newcommand*{\RHSmaxwelliiidif}{\ensuremath{-\pbypt[\vect{B}]}}
\newcommand*{\RHSmaxwelliiidifm}{\ensuremath{-\pbypt[\vect{B}]-%
  \vacuumpermeabilitymathsymbol\vectsub{J}{\(m\)}}}
\newcommand*{\RHSmaxwelliiidiffree}{\RHSmaxwelliiidif}
\newcommand*{\maxwelliiidif}{\ensuremath{\LHSmaxwelliiidif=\RHSmaxwelliiidif}}
\newcommand*{\maxwelliiidifm}{\ensuremath{\LHSmaxwelliiidif=\RHSmaxwelliiidifm}}
\newcommand*{\maxwelliiidiffree}{\ensuremath{\LHSmaxwelliiidif=\RHSmaxwelliiidif}}
\newcommand*{\LHSmaxwellivdif}{\ensuremath{\curl{\vect{B}}}}
\newcommand*{\RHSmaxwellivdif}{\ensuremath{\vacuumpermeabilitymathsymbol%
  \vacuumpermittivitymathsymbol\pbypt[\vect{E}]+%
  \vacuumpermeabilitymathsymbol\vectsub{J}{\(e\)}}}
\newcommand*{\RHSmaxwellivdiffree}{\ensuremath{\vacuumpermeabilitymathsymbol\vacuumpermittivitymathsymbol\pbypt[\vect
\newcommand*{\maxwellivdif}{\ensuremath{\LHSmaxwellivdif=\RHSmaxwellivdif}}
\newcommand*{\maxwellivdiffree}{\ensuremath{\LHSmaxwellivdif=\RHSmaxwellivdiffree}}
\newcommand*{\RHSlorentzforce}{\ensuremath{\msub{q}{e}\left(\vect{E}+%
  \vectcrossvect{\vect{v}}{\vect{B}}\right)}}
\newcommand*{\RHSlorentzforcem}{\ensuremath{\RHSlorentzforce+\msub{q}{m}\left(%
  \vect{B}-\vectcrossvect{\vect{v}}{\frac{\vect{E}}{c^2}}\right)}}
\newcommand*{\vpythonline}{\lstinline[style=vpython]}
\lstnewenvironment{vpythonblock}{\lstset{style=vpython}}{}
\newcommand*{\vpythonfile}{\lstinputlisting[style=vpython]}
\newcommandx{\emptyanswer}[2][1=0.80,2=0.1,usedefault]
  {\begin{minipage}{#1\textwidth}\hfill\vspace{#2\textheight}\end{minipage}}
\newenvironmentx{activityanswer}[5][1=white,2=black,3=black,4=0.90,5=0.10,usedefault]{%
  \def\skipper{#5}%
  \def\response@fbox{\fcolorbox{#2}{#1}}%
  \begin{center}%
    \begin{lrbox}{\@tempboxa}%
      \begin{minipage}[c][#5\textheight][c]{#4\textwidth}\color{#3}%
        \vspace{#5\textheight}}{%
        \vspace{\skipper\textheight}%
      \end{minipage}%
    \end{lrbox}%
    \response@fbox{\usebox{\@tempboxa}}%
  \end{center}%
}%
\newenvironmentx{adjactivityanswer}[5][1=white,2=black,3=black,4=0.90,5=0.00,%
  usedefault]{%
  \def\skipper{#5}%
  \def\response@fbox{\fcolorbox{#2}{#1}}%
  \begin{center}%
    \begin{lrbox}{\@tempboxa}%
      \begin{minipage}[c]{#4\textwidth}\color{#3}%
        \vspace{#5\textheight}}{%
        \vspace{\skipper\textheight}%
      \end{minipage}%
    \end{lrbox}%
    \response@fbox{\usebox{\@tempboxa}}%
```

```
  \end{center}%
}%
\newcommandx{\emptybox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.10,usedefault]
  {\begin{center}%
     \fcolorbox{#3}{#2}{%
       \begin{minipage}[c][#6\textheight][c]{#5\textwidth}\color{#4}%
         {#1}%
       \end{minipage}}%
     \vspace{\baselineskip}%
   \end{center}%
}%
\newcommandx{\adjemptybox}[7][1=\hfill,2=white,3=black,4=black,5=0.90,6=,
7=0.0,usedefault]
  {\begin{center}%
     \fcolorbox{#3}{#2}{%
       \begin{minipage}[c]{#5\textwidth}\color{#4}%
         \vspace{#7\textheight}%
           {#1}%
         \vspace{#7\textheight}%
       \end{minipage}}%
     \vspace{\baselineskip}%
   \end{center}%
}%
\newcommandx{\answerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.1,usedefault]
  {\ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\adjanswerbox}[7][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.1,7=0.0,%
  usedefault]%
  {\ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\adjemptybox[#1][#2][#3][#4][#5][#6][#7]}%
}%
\newcommandx{\smallanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.10,%
  usedefault]%
  {\ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
```

```
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\mediumanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.20,%
  usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\largeanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.25,%
  usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\largeranswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.33,%
  usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\hugeanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.50,%
  usedefault]{%
  \ifthenelse{\equal{#1}{}}
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\hugeranswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.75,%
  usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
```

```
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\newcommandx{\fullpageanswerbox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=1.00,%
  usedefault]{%
  \ifthenelse{\equal{#1}{}}%
    {\begin{center}%
       \fcolorbox{#3}{#2}{%
         \emptyanswer[#5][#6]}%
     \vspace{\baselineskip}%
     \end{center}}%
    {\emptybox[#1][#2][#3][#4][#5][#6]}%
}%
\mdfdefinestyle{miinstructornotestyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    frametitle={INSTRUCTOR NOTE},
    frametitlebackgroundcolor=cyan!60,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=cyan!25,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{miinstructornote}{%
  \begin{mdframed}[style=miinstructornotestyle]
    \begin{adjactivityanswer}[cyan!25][cyan!25][black]
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
\mdfdefinestyle{mistudentnotestyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    frametitle={STUDENT NOTE},
    frametitlebackgroundcolor=cyan!60,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=cyan!25,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{mistudentnote}{%
  \begin{mdframed}[style=mistudentnotestyle]
    \begin{adjactivityanswer}[cyan!25][cyan!25][black]
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
\mdfdefinestyle{miderivationstyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=0pt,rightmargin=0pt,linewidth=1,roundcorner=10,
    frametitle={DERIVATION},
    frametitlebackgroundcolor=orange!60,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=orange!25,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{miderivation}{%
  \begin{mdframed}[style=miderivationstyle]
  \setcounter{equation}{0}
```

```
    \begin{align*}
      \BODY
    \end{align*}
  \end{mdframed}
}%
\mdfdefinestyle{bwinstructornotestyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    frametitle={INSTRUCTOR NOTE},
    frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=gray!20,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{bwinstructornote}{%
  \begin{mdframed}[style=bwinstructornotestyle]
    \begin{adjactivityanswer}[gray!20][gray!20][black]
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
\mdfdefinestyle{bwstudentnotestyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=40pt,rightmargin=40pt,linewidth=1,roundcorner=10,
    frametitle={STUDENT NOTE},
    frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=gray!20,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{bwstudentnote}{%
  \begin{mdframed}[style=bwstudentnotestyle]
    \begin{adjactivityanswer}[gray!20][gray!20][black]
      \BODY
    \end{adjactivityanswer}
  \end{mdframed}
}%
\mdfdefinestyle{bwderivationstyle}{%
    hidealllines=false,skipbelow=\baselineskip,skipabove=\baselineskip,
    leftmargin=0pt,rightmargin=0pt,linewidth=1,roundcorner=10,
    frametitle={DERIVATION},
    frametitlebackgroundcolor=gray!50,frametitlerule=true,frametitlerulewidth=1,
    backgroundcolor=gray!20,
    linecolor=black,fontcolor=black,shadow=true}
\NewEnviron{bwderivation}{%
  \begin{mdframed}[style=bwderivationstyle]
  \setcounter{equation}{0}
    \begin{align*}
      \BODY
    \end{align*}
  \end{mdframed}
}%
\NewEnviron{mysolution}{%
  \begin{align*}
```

```
    \BODY
  \end{align*}
}%
\newcommand*{\checkpoint}{%
  \vspace{1cm}\begin{center}|--------- CHECKPOINT ---------|\end{center}}%
\newcommand*{\image}[2]{%
  \begin{figure}[h!]
    \begin{center}%
      \includegraphics[scale=1]{#1}%
      \caption{#2}%
      \label{#1}%
    \end{center}%
  \end{figure}}
\newcommand*{\sneakyone}[1]{\ensuremath{\cancelto{1}{\frac{#1}{#1}}}}
% undocumented diagnostic command
\newcommand*{\chkquantity}[1]{%
  \begin{center}
    \begin{tabular}{C{4.5cm} C{4cm} C{4cm} C{4cm}}
      name    & baseunit & drvdunit & tradunit \tabularnewline
      \cs{#1} & \csname #1onlybaseunit\endcsname & \csname #1onlydrvdunit\endcsname &
        \csname #1onlytradunit\endcsname
    \end{tabular}
  \end{center}
}%
% undocumented diagnostic command
\newcommand*{\chkconstant}[1]{%
  \begin{center}
    \begin{tabular}{C{4cm} C{2cm} C{3cm} C{3cm} C{3cm} C{3cm}}
      name    & symbol & value & baseunit & drvdunit & tradunit \tabularnewline
      \cs{#1} & \csname #1mathsymbol\endcsname & \csname #1value\endcsname &
        \csname #1onlybaseunit\endcsname & \csname #1onlydrvdunit\endcsname &
        \csname #1onlytradunit\endcsname
    \end{tabular}
  \end{center}
}%
```

7 Acknowledgements

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8 Index

Page numbers refer to page where the corresponding entry is described. Not every command defined in the package is indexed. There may be commands similar to indexed commands described in relevant parts of the documentation.

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