

The `mandi` package

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Change History

v2.0.0	No longer needs SIunits . It's deprecated	2	
General: First public release	2	v2.2.0	
v2.1.0	General: Completely reformatted documentation.	2	
General: Added more predefined quantities.	2	Many new physical quantities and constants.	2
Coexists with physymb . Load physymb before mandi	2	New commands, some deprecated in favor of mivector	2
Coexists with siunitx	2	Physical constants are given to three or four decimal places.	2
Improved vector operators.	2		

Possible Future Enhancements

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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. They 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 pdf \LaTeX , which creates PDF files as output, to build the documentation. I have not tested the build with standard \LaTeX , which creates DVI files.

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

3 Loading the Package

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

- **italicvectors** gives italic letters for the kernels of vector names. Otherwise, the letters are in Roman.
- **doubleabsbars** gives double bars in symbols for vector magnitudes. Otherwise, single bars are used. Double bars may be more familiar to students from their calculus courses.
- **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.
- **drvunits** causes all units to be displayed, when possible, in *drvunits* form, with SI derived units. Students may already be familiar with many of these derived units.
- If neither **baseunits** nor **drvunits** 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`.

`mandi` coexists with the `physymb` package, with which there are also functional overlaps and a few conflicts with identically named commands. If you wish to use `physymb` and `mandi` in the same document, be certain to load `physymb` first. `mandi` will detect its presence and behave accordingly.

4 Usage

So what does `mandi` allow you to do? 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

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

$$K \approx \frac{1}{2} (2 \text{ kg}) (2 \text{ m/s})^2$$

but `mandi` lets you do something more logical and more readable, like this

```
\[ K \approx \frac{1}{2} (\text{mass}) (\text{velocity})^2 \]
```

$$K \approx \frac{1}{2} (2 \text{ kg}) (2 \text{ m/s})^2$$

which produces the same output. In the second example, note that the units are abstracted so the user need not remember them.

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 $\langle 3, 2, 5 \rangle$ kg · 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.

If you want to save time in writing out the energy principle, just use

```
\energyprinciple
```

$$E_{\text{sys,f}} = E_{\text{sys,i}} + W_{\text{ext}} + Q$$

which, as you can see, takes fewer keystrokes and it's easier to remember.

This barely scratches the surface in describing `mandi` so continue reading this document to see everything this package 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

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 *drvunits* form.

5.3 Defining Physics Quantities

\newphysicsquantity{\<newname\>}{\<baseunits\>}[\<drvunits\>][\<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 `drvunits` and `tradunits` forms are not specified, they will be populated with the `baseunits` form.
- A command `\newnamebaseunit{⟨magnitude⟩}` is created that expresses the quantity and its units in `baseunits` form.
- A command `\newnamedrvdunit{⟨magnitude⟩}` is created that expresses the quantity and its units in `drvunits` form. This command is created whether or not the first optional argument is provided.
- A command `\newnametradunit{⟨magnitude⟩}` is created that expresses the quantity and its units in `tradunits` form. This command is created whether or not the first optional argument is provided.
- A command `\newnameonlybaseunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in `baseunits` form.
- A command `\newnameonlydrvunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in `drvunits` form.
- A command `\newnameonlytradunit{⟨magnitude⟩}` is created that expresses **only** the quantity's units in `tradunits` form.
- A command `\newnamevalue{⟨magnitude⟩}` is created that expresses **only** the quantity's numerical value.

5.3.1 Defining Vector Quantities

Nothing special is necessary for defining vector quantities, but a formatted vector is used when invoking the value of that quantity.

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

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

5.4 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.

5.4.1 Predefined Quantities

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

<code>\displacement{⟨magnitude⟩}</code>	Command for displacement.
-----------------------------------------	---------------------------

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

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

\mass{*magnitude*}

Command for mass.

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

a mass of 5 kg

\duration{*magnitude*}

Command for duration.

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

a duration of 5 s

\current{*magnitude*}

Command for current.

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

a current of 5 A

\temperature{*magnitude*}

Command for temperature.

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

a temperature of 5 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 rad

\solidangle{*magnitude*}

Command for solidangle.

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

a solid angle of 5 sr

\indegrees{*magnitude*}

Command for plane angle in degrees.

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

a plane angle of 5 °

\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.

a energy of \ineV{10.2}

an energy of 10.2 eV

\inMeVcs{*magnitude*}

Command for mass in MeV/c^2 .

a mass of \inMeVcs{0.511}

a mass of $0.511 \text{ MeV}/c^2$

\inMeVoc{*magnitude*}

Command for momentum in MeV/c .

a momentum of \inMeVoc{3.6}

a momentum of $3.6 \text{ MeV}/c$

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

\inpc{*magnitude*}

Command for displacement in parsecs.

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

a distance of 4.3 pc

\insolarL{\langle magnitude\rangle}

Command for luminosity in solar multiples.

```
a luminosity of \insolarL{4.3}
```

a luminosity of $4.3 L_{\odot}$

\insolarT{\langle magnitude\rangle}

Command for temperature in solar multiples.

```
a temperature of \insolarT{2}
```

a temperature of $2 T_{\odot}$

\insolarR{\langle magnitude\rangle}

Command for radius in solar multiples.

```
a radius of \insolarR{4.3}
```

a radius of $4.3 R_{\odot}$

\insolarM{\langle magnitude\rangle}

Command for mass in solar multiples.

```
a mass of \insolarM{4.3}
```

a mass of $4.3 M_{\odot}$

\insolarF{\langle magnitude\rangle}

Command for flux in solar multiples.

```
a flux of \insolarF{4.3}
```

a flux of $4.3 F_{\odot}$

\insolarf{\langle magnitude\rangle}

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 `\insular` 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 `\scin[]{}` to get scientific notation, with the mantissa as the optional first argument and the exponent as the required second argument. `\scin` has an optional third argument that specifies a unit, but that is not needed or used in the following examples.

`\velocityc{<magnitude>}`

Command for magnitude of velocity as a fraction of c .

a velocity of `\velocityc{0.9987} \\`
a velocity of `\velocityc{\mivector{0,0.9987,0}}`

a velocity of $0.9987c$
a velocity of $\langle 0, 0.9987, 0 \rangle c$

`\velocity{<magnitude>}`

Command for magnitude of velocity.

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

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

\lorentz{\langle magnitude \rangle}

Command for relativistic Lorentz factor.

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

a Lorentz factor of 2.34

\momentum{\langle magnitude \rangle}

Command for momentum.

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

a momentum of 2.34 kg · m/s
a momentum of $\langle 3, 2, -1 \rangle$ kg · m/s

\acceleration{\langle magnitude \rangle}

Command for acceleration.

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

an acceleration of 2.34 m/s²
an acceleration of $\langle 3, 2, -1 \rangle$ m/s²

\impulse{\langle magnitude \rangle}

Command for impulse.

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

an impulse of 2.34 kg · m/s
an impulse of $\langle 3, 2, -1 \rangle$ kg · m/s

\force{\langle magnitude \rangle}

Command for force.

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

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

\springstiffness{\langle magnitude \rangle}

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 m²

\volume{\(magnitude)}

Command for volume.

```
a volume of \volume{2.34}
```

a volume of 2.34 m³

\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/m²

\volumemassdensity{\(magnitude)}

Command for volume mass density.

```
a volume mass density of \volumemassdensity{2.34}
```

a volume mass density of 2.34 kg/m³

\youngsmodulus{\(magnitude)}

Command for Young's modulus.

```
a Young's modulus of  
  \youngsgmodulus{\scin[2.34]{9}}
```

a Young's modulus of 2.34×10^9 Pa

\work{*magnitude*}

Command for work.

```
an amount of work \work{2.34}
```

an amount of work 2.34 N · m

\energy{*magnitude*}

Command for energy. Work and energy have the same unit, but are conceptually different.

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

an amount of energy 2.34 N · m

\power{*magnitude*}

Command for power.

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

an amount of power 2.34 J/s

\angularvelocity{*magnitude*}

Command for angular velocity.

```
an angular velocity of \angularvelocity{2.34}
```

an angular velocity of 2.34 rad/s

\angularacceleration{*magnitude*}

Command for angular acceleration.

```
an angular acceleration of  
  \angularacceleration{2.34}
```

an angular acceleration of 2.34 rad/s²

\angularmomentum{*magnitude*}

Command for angular momentum.

```
an angular momentum of \angularmomentum{2.34}
```

an angular momentum of 2.34 kg · m²/s

\momentofinertia{*magnitude*}

Command for moment of inertia.

```
a moment of inertia of \momentofinertia{2.34}
```

a moment of inertia of $2.34 \text{ kg} \cdot \text{m}^2$

\torque{*magnitude*}

Command for torque.

```
a torque of \torque{2.34}
```

a torque of $2.34 \text{ N} \cdot \text{m}$

\entropy{*magnitude*}

Command for entropy.

```
an entropy of \entropy{2.34}
```

an entropy of 2.34 J/K

\wavelength{*magnitude*}

Command for wavelength.

```
a wavelength of \wavelength{\scin[4.00]{-7}}
```

a wavelength of $4.00 \times 10^{-7} \text{ m}$

\wavenumber{*magnitude*}

Command for wavenumber.

```
a wavenumber of \wavenumber{\scin[2.50]{6}}
```

a wavenumber of $2.50 \times 10^6 / \text{m}$

\frequency{*magnitude*}

Command for frequency.

```
a frequency of \frequency{\scin[7.50]{14}}
```

a frequency of $7.50 \times 10^{14} \text{ Hz}$

\angularfrequency{*magnitude*}

Command for angularfrequency.

```
an angular frequency of  
↳angularfrequency{\scin[4.70]{15}}
```

an angular frequency of 4.70×10^{15} 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.

5.5 Second Semester Physics

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

5.5.1 Predefined Quantities

\charge{⟨magnitude⟩}

Command for electric charge.

```
a charge of \charge{\scin[2]{-9}}
```

a charge of 2×10^{-9} C

\permittivity{⟨magnitude⟩}

Command for permittivity.

```
a permittivity of \permittivity{\scin[9]{-12}}
```

a permittivity of 9×10^{-12} C²/N · m²

\electricdipolemoment{⟨magnitude⟩}

Command for electric dipole moment.

```
an electric dipole moment of  
↳electricdipolemoment{\scin[2]{5}}
```

an electric dipole moment of 2×10^5 C · m

\permeability{⟨magnitude⟩}

Command for permeability.

```
a permeability of \permeability{\scin[4\pi]{-7}}
```

a permeability of $4\pi \times 10^{-7}$ T · m/A

\magneticfield{*magnitude*}

Command for magnetic field (also called magnetic induction).

```
a magnetic field of \magneticfield{1.25}
```

a magnetic field of $1.25 \text{ N/C} \cdot (\text{m/s})$

\cmagneticfield{*magnitude*}

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 N/C

\linearchargedensity{*magnitude*}

Command for linear charge density.

```
a linear charge density of >  
  \linearchargedensity{\scin[4.5]{-3}}
```

a linear charge density of $4.5 \times 10^{-3} \text{ C/m}$

\areachargedensity{*magnitude*}

Command for area charge density.

```
an area charge density of \areachargedensity{1.25}
```

an area charge density of 1.25 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 C/m^3

\mobility{*magnitude*}

Command for electron mobility.

```
a mobility of \areachargedensity{\scin[4.5]{-3}}
```

a mobility of $4.5 \times 10^{-3} \text{ C/m}^2$

\numberdensity{*magnitude*}

Command for electron number density.

```
a number density of \numberdensity{\scin[2]{18}}
```

a number density of $2 \times 10^{18} / \text{m}^3$

\polarizability{*magnitude*}

Command for polarizability.

```
a polarizability of \polarizability{\scin[1.96]{-40}}
```

a polarizability of $1.96 \times 10^{-40} \text{ C} \cdot \text{m} / (\text{N/C})$

\electricpotential{*magnitude*}

Command for electric potential.

```
an electric potential of \polarizability{1.5}
```

an electric potential of $1.5 \text{ C} \cdot \text{m} / (\text{N/C})$

\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

\electroncurrent{*magnitude*}

Command for electron current.

```
an electron current of >
\electroncurrent{\scin[2]{18}}
```

an electron current of $2 \times 10^{18} \text{ e/s}$

\conventionalcurrent{*magnitude*}

Command for conventional current.

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

a conventional current of 0.003 A

\magneticdipolemoment{*magnitude*}

Command for magnetic dipole moment.

```
a magnetic dipole moment of >
\magneticdipolemoment{1.25}
```

a magnetic dipole moment of $1.25 \text{ A} \cdot \text{m}^2$

\currentdensity{*magnitude*}

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

\magneticflux{*magnitude*}

Command for magnetic flux.

```
a magnetic flux of \magneticflux{1.25}
```

a magnetic flux of $1.25 \text{ T} \cdot \text{m}^2$

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

\conductivity{*magnitude*}

Command for conductivity.

```
a conductivity of \conductivity{1.25}
```

a conductivity of $1.25 (\text{A/m}^2) / (\text{V/m})$

\resistivity{*magnitude*}

Command for resistivity.

```
a resistivity of \resistivity{1.25}
```

a resistivity of $1.25 (\text{V/m}) / (\text{A/m}^2)$

\resistance{*magnitude*}

Command for resistance.

```
a resistance of \resistance{\scin[1]{6}}
```

a resistance of $1 \times 10^6 \Omega$

\conductance{*magnitude*}

Command for conductance.

```
a conductance of \conductance{\scin[1]{6}}
```

a conductance of 1×10^6 S

\magneticcharge{*magnitude*}

Command for magnetic charge, in case it actually exists.

```
a magnetic charge of \magneticcharge{1.25}
```

a magnetic charge of $1.25 \text{ m} \cdot \text{A}$

\energyflux{*magnitude*}

Command for energy flux.

```
an energy flux of \energyflux{\scin[4]{26}}
```

an energy flux of $4 \times 10^{26} \text{ W/m}^2$

5.6 Further Words on Units

As you recall, when a new scalar or vector is defined, a host of other commands is also automatically defined. Consider momentum. The following commands are defined:

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

The form of a quantity's unit can be changed on the fly regardless of the global format determined by **baseunits** and **drvunits**. 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 $3 \text{ m} \cdot \text{kg} \cdot \text{s}^{-1}$

\hereusedrvdunit{*magnitude*}

Command for using derived units in place.

```
a momentum of \hereusedrvdunit{\momentum{3}}
```

a momentum of $3 \text{ N} \cdot \text{s}$

\hereusetradunit{*magnitude*}

Command for using traditional units in place.

```
a momentum of \hereusetradunit{\momentum{3}}
```

a momentum of $3 \text{ kg} \cdot \text{m/s}$

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

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

Environment for using base units.

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

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

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

Environment for using derived units.

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

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

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

Environment for using traditional units.

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

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

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{\langle magnitude \rangle}`

Command for perpetually using derived units..

`\perpusetradunit{\langle magnitude \rangle}`

Command for perpetually using traditional units..

5.7 Symbolic Expressions with Vectors

5.7.1 Basic Vectors

`\vect{\langle kernel \rangle}`

Symbol for a vector quantity.

`\vect{p}`

\vec{p}

`\magvect{\langle kernel \rangle}`

Symbol for magnitude of a vector quantity.

`\magvect{p}`

$|\vec{p}|$

`\dirvect{\langle kernel \rangle}`

Symbol for direction of a vector quantity.

`\dirvect{p}`

\hat{p}

`\mivector[\langle printed delimiter \rangle]{\langle command limited list of comps \rangle}[\langle unit \rangle]`

Generic workhorse command for vectors formatted as in *Matter & Interactions*.

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

$$u_\mu = \langle \mathbf{e}_0, \mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3 \rangle$$

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

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

\ncompszerovect

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

`\ncompszerovect` $\langle 0, 0, 0 \rangle$ **\symvect{listofcomps}**

Command for a vector with symbolic components. Deprecated. Use `\mivector` instead.

`\symvect{\magvect{E}\cos\theta, \magvect{E}\sin\theta, 0}` $\langle |\vec{E}| \cos \theta, |\vec{E}| \sin \theta, 0 \rangle$ **\ncompsvect{listofcomps}[unit]**

Command for a vector with numerical components and an optional unit. Deprecated. Use `\mivector` instead.

`\ncompsvect{3,4,6}[\velocityonlytradunit]` $\langle 3, 4, 6 \rangle \text{ m/s}$ **\magvect\ncomps{listofcomps}[unit]**

Expression for a vector's magnitude with numerical components and an optional unit.

`\magvect\ncomps{3.12,4.04,6.73}[\velocityonlytradunit]`
$$\sqrt{(3.12 \text{ m/s})^2 + (4.04 \text{ m/s})^2 + (6.73 \text{ m/s})^2}$$
\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 **\magvect\scomps{kernel}**

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

`\magvect\scomps{B}`
$$\sqrt{B_x^2 + B_y^2 + B_z^2}$$

5.7.2 Position Vectors

`\scompspos`

Expression for a position vector's traditional symbolic components.

`\scompspos`

$\langle x, y, z \rangle$

`\comppos{\langle component \rangle}`

Isolates one symbolic component of a position vector.

`\comppos{z}`

z

5.7.3 Differentials and Derivatives of Vectors

`\dvect{\langle kernel \rangle}`

Symbol for the differential of a vector.

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

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

`\Dvect{\langle kernel \rangle}`

Identical to `\dvect` but uses Δ .

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

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

`\dirdvect{\langle kernel \rangle}`

Symbol for the direction of a vector's differential.

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

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

`\dirDvect{\langle kernel \rangle}`

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.

the change \ddirvect{E} in the direction

the change $d\hat{E}$ in the direction

\Ddirvect{<kernel>}

Identical to \ddirvect but uses Δ .

the direction \Ddirvect{E} of the change

the direction $\Delta\hat{E}$ of the change

\magdvect{<kernel>}

Symbol for the magnitude of a vector's differential.

the magnitude \magdvect{E} of the change

the magnitude $|d\vec{E}|$ of the change

\magDvect{<kernel>}

Identical to \magdvect but uses Δ .

the magnitude \magDvect{E} of the change

the magnitude $|\Delta\vec{E}|$ of the change

\dmagvect{<kernel>}

Symbol for the differential of a vector's magnitude.

the change \dmagvect{E} in the magnitude

the change $d|\vec{E}|$ in the magnitude

\Dmagvect{<kernel>}

Identical to \dmagvect but uses Δ .

the change \Dmagvect{E} in the magnitude

the change $\Delta|\vec{E}|$ in the magnitude

\scompsdvect{<kernel>}

Symbolic components of a vector.

the vector `\scompsdvect{E}`

the vector $\langle dE_x, dE_y, dE_z \rangle$

`\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 dE_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

`\scompsdpos`

Symbolic components of a position vector.

the change in position `\scompsdpos`

the change in position $\langle dx, dy, dz \rangle$

`\scompsDpos`

Identical to `\scompsdpos` but uses Δ .

the change in position `\scompsDpos`

the change in position $\langle \Delta x, \Delta y, \Delta z \rangle$

`\compdpos{<component>}`

Isolates one component of a position vector's differential.

the component `\compdpos{z}` of the change

the component dz of the change

`\compDpos{<component>}`

Identical to `\compdpos` but uses Δ .

the component `\compDpos{z}` of the change

the component Δz 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 $\frac{d\vec{E}}{dt}$

`\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 $\frac{d|\vec{E}|}{dt}$

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

Identical to `\dermagvect` but uses Δ .

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

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

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

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

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

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

\scompsDervect{<kernel>}{<indvar>}

Identical to \scompsdervect but uses Δ .

the derivative \scompsdervect{E}{t}

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

\compdervect{<kernel>}{<component>}{<indvar>}

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

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

$$\text{the derivative } \frac{dE_y}{dt}$$

\compDervect{<kernel>}{<component>}{<indvar>}

Identical to \compdervect but uses Δ .

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

$$\text{the derivative } \frac{\Delta E_y}{\Delta t}$$

\magdervect{<kernel>}{<indvar>}

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

the derivative \magdervect{E}{t}

$$\text{the derivative } \left| \frac{d\vec{E}}{dt} \right|$$

\magDervect{<kernel>}{<indvar>}

Identical to \magdervect but uses Δ .

the derivative \magDervect{E}{t}

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

\scompsderpos{<indvar>}

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

the derivative \scompsderpos{t}

$$\text{the derivative } \left\langle \frac{dx}{dt}, \frac{dy}{dt}, \frac{dz}{dt} \right\rangle$$

`\scompsDerpos{\langle indvar \rangle}`

Identical to `\scompsderpos` but uses Δ .

the derivative `\scompsDerpos{t}`

the derivative $\left\langle \frac{\Delta x}{\Delta t}, \frac{\Delta y}{\Delta t}, \frac{\Delta z}{\Delta t} \right\rangle$

`\compderpos{\langle component \rangle}{\langle indvar \rangle}`

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

the derivative `\compderpos{z}{t}`

the derivative $\frac{dz}{dt}$

`\compDerpos{\langle component \rangle}{\langle indvar \rangle}`

Identical to `\compderpos` but uses Δ .

the derivative `\compDerpos{z}{t}`

the derivative $\frac{\Delta z}{\Delta t}$

5.7.4 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.

5.7.5 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` and `pos` becomes `possub`. 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.

`\vectsub{\langle kernel \rangle}{\langle sub \rangle}`

Symbol for a subscripted vector.

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

the vector \vec{p}_{ball}

`\magvectsub{\langle kernel \rangle}{\langle sub \rangle}`

Symbol for a subscripted vector's direction.

the direction `\dirvectsub{p}{ball}`

the direction \hat{p}_{ball}

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

Symbol for a subscripted vector's magnitude.

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

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

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

Symbolic components of a subscripted vector.

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

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

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

Isolates one component of a subscripted vector.

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

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

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

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

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

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

`\scompspossub{<sub>}`

Symbolic components of a subscripted position vector.

the vector `\scompspossub{ball}`

the vector $\langle x_{\text{ball}}, y_{\text{ball}}, z_{\text{ball}} \rangle$

`\comppossub{<component>}{<sub>}`

Isolates one component of a subscripted position vector.

the component `\comppossub{x}{ball}`

the component x_{ball}

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

Differential of a subscripted vector.

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

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

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

Identical to `\dvectsub` but uses Δ .

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

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

\scomsdvectsub{<kernel>}{<sub>}

Symbolic components of a subscripted vector's differential.

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

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

\scomsDvectsub{<kernel>}{<sub>}

Identical to `\scomsdvectsub` but uses Δ .

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

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

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

Isolates one component of a subscripted vector's differential.

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

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

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

Identical to `\compdvectsub` but uses Δ .

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

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

\scompsdpossub{<sub>}

Symbolic components of a subscripted position vector's differential.

the vector `\scopmsdpossub{ball}`

the vector $\langle dx_{\text{ball}}, dy_{\text{ball}}, dz_{\text{ball}} \rangle$

\scopmsDpossub{*sub*}

Identical to `\scopmsdpossub` but uses Δ .

the vector `\scopmsDpossub{ball}`

the vector $\langle \Delta x_{\text{ball}}, \Delta y_{\text{ball}}, \Delta z_{\text{ball}} \rangle$

\compdpossub{*component*} {*sub*}

Isolates one component of a subscripted position vector's differential.

the component `\compdpossub{x}{ball}`

the component dx_{ball}

\compDpossub{*component*} {*sub*}

Identical to `\compdpossub` but uses Δ .

the component `\compDpossub{x}{ball}`

the component Δx_{ball}

\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 $\frac{d\vec{p}_{\text{ball}}}{dt}$

\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 $\frac{d|\vec{E}_{\text{ball}}|}{dt}$

\Dermagvectsub{<kernel>}{<sub>}{<indvar>}

Identical to \dermagvectsub but uses Δ .

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

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

\scompsdervectsub{<kernel>}{<sub>}{<indvar>}

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

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

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

\scompsDervectsub{<kernel>}{<sub>}{<indvar>}

Identical to \scompsdervectsub but uses Δ .

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

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

\compdervectsub{<kernel>}{<component>}{<sub>}{<indvar>}

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

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

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

\compDervectsub{<kernel>}{<component>}{<sub>}{<indvar>}

Identical to \compdervectsub but uses Δ .

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

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

\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}

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

`\magDerVectSub{<kernel>}{{<sub>}{<indvar>}}`

Identical to `\magDerVectSub` but uses Δ .

the derivative `\magDerVectSub{p}{ball}{t}`

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

`\scompsDerPosSub{<sub>}{{<indvar>}}`

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

the vector `\scompsDerPosSub{ball}{t}`

$$\text{the vector } \left\langle \frac{dx_{\text{ball}}}{dt}, \frac{dy_{\text{ball}}}{dt}, \frac{dz_{\text{ball}}}{dt} \right\rangle$$

`\scompsDerPosSub{<sub>}{{<indvar>}}`

Identical to `\scompsDerPosSub` but uses Δ .

the vector `\scompsDerPosSub{ball}{t}`

$$\text{the vector } \left\langle \frac{\Delta x_{\text{ball}}}{\Delta t}, \frac{\Delta y_{\text{ball}}}{\Delta t}, \frac{\Delta z_{\text{ball}}}{\Delta t} \right\rangle$$

`\compDerPosSub{<component>}{{<sub>}{{<indvar>}}}`

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

the component `\compDerPosSub{y}{ball}{t}`

$$\text{the component } \frac{dy_{\text{ball}}}{dt}$$

`\compDerPosSub{<component>}{{<sub>}{{<indvar>}}}`

Identical to `\compDerPosSub` but uses Δ .

the component `\compDerPosSub{y}{ball}{t}`

$$\text{the component } \frac{\Delta y_{\text{ball}}}{\Delta t}$$

5.7.6 Relative Vectors

Sometimes it's convenient to think of the position, velocity, momentum, or force of/on one thing relative to/due to another thing.

`\relPos{<sub>}`

Symbol for relative position.

the vector `\relpos{12}`

the vector \vec{r}_{12}

\relvel{*sub*}

Symbol for relative velocity.

the vector `\relvel{12}`

the vector \vec{v}_{12}

\relmom{*sub*}

Symbol for relative momentum.

the vector `\relmom{12}`

the vector \vec{p}_{12}

\relfor{*sub*}

Symbol for relative force.

the vector `\relfor{12}`

the vector \vec{F}_{12}

5.7.7 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}`

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

`\vectdot{vect}{kernel1}{kernel2}`

Symbol for dot of two vectors as an expanded sum.

`\vectdot{vect}{F}{v}`

$$F_x v_x + F_y v_y + F_z v_z$$

`\vectdot{pos}{kernel}`

Dot of a vector and a position vector with symbolic components.

`\vectdot{pos}{F}`

$$\langle F_x, F_y, F_z \rangle \bullet \langle x, y, z \rangle$$

`\vectdot{pos}{kernel}`

Dot of a vector and a position vector as an expanded sum.

`\vectdot{pos}{F}`

$$F_x x + F_y y + F_z z$$

`\vectdot{sdvect}{kernel1}{kernel2}`

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

`\vectdot{sdvect}{F}{r}`

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

`\vectdot{Dvect}{kernel1}{kernel2}`

Identical to `\vectdot{sdvect}` but uses Δ .

`\vectdot{Dvect}{F}{r}`

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

`\vectdot{edvect}{kernel1}{kernel2}`

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

`\vectdot{edvect}{F}{r}`

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

`\vectdot{eDvect}{kernel1}{kernel2}`

Identical to `\vectdot{edvect}` but uses Δ .

```
\vectdotDvect{F}{r}
```

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

\vectdotsdpos{<kernel>}

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

```
\vectdotsdpos{F}
```

$$\langle F_x, F_y, F_z \rangle \bullet \langle dx, dy, dz \rangle$$

\vectdotsDpos{<kernel>}

Identical to `\vectdotsdpos` but uses Δ .

```
\vectdotsDpos{F}
```

$$\langle F_x, F_y, F_z \rangle \bullet \langle \Delta x, \Delta y, \Delta z \rangle$$

\vectdottedpos{<kernel>}

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

```
\vectdottedpos{F}
```

$$F_x dx + F_y dy + F_z dz$$

\vectdotDpos{<kernel>}

Identical to `\vectdottedpos` but uses Δ .

```
\vectdotDpos{F}
```

$$F_x \Delta x + F_y \Delta y + F_z \Delta z$$

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

Dot of two subscripted vectors with symbolic components.

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

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

\vectsubdotvectsub{<kernel1>}{<sub1>} {<kernel2>}{<sub2>}

Dot of two subscripted vectors as an expanded sum.

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

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

\vectsubdotsdvectsub{*kernel1*}{{*sub1*}}{*kernel2*}{{*sub2*}}

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

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

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

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

Identical to **\vectsubdotsdvectsub** but uses Δ .

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

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

\vectsubdottedvectsub{*kernel1*}{{*sub1*}}{*kernel2*}{{*sub2*}}

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

```
\vectsubdottedvectsub{A}{ball}{B}{car}
```

$$A_{x,ball} dB_{x,car} + A_{y,ball} dB_{y,car} + A_{z,ball} dB_{z,car}$$

\vectsubdoteDvectsub{*kernel1*}{{*sub1*}}{*kernel2*}{{*sub2*}}

Identical to **\vectsubdottedvectsub** but uses Δ .

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

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

\vectsubdotsdvect{*kernel1*}{{*sub1*}}{*kernel2*}

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

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

$$\langle A_{x,ball}, A_{y,ball}, A_{z,ball} \rangle \bullet \langle dB_x, dB_y, dB_z \rangle$$

\vectsubdotsDvect{*kernel1*}{{*sub1*}}{*kernel2*}

Identical to **\vectsubdotsdvect** but uses Δ .

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

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

\vectsubdottedvect{*kernel1*}{{*sub1*}}{*kernel2*}

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

```
\vectsubdottedvect{A}{ball}{B}
```

$$A_{x,\text{ball}} dx_B + A_{y,\text{ball}} dy_B + A_{z,\text{ball}} dz_B$$

\vectsubdoteDvect{*kernel1*}{{*sub1*}}{{*kernel2*}}

Identical to **\vectsubdottedvect** but uses Δ .

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

$$A_{x,\text{ball}} \Delta x_B + A_{y,\text{ball}} \Delta y_B + A_{z,\text{ball}} \Delta z_B$$

\vectsubdotsdpos{*kernel*}{{*sub*}}

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

```
\vectsubdotsdpos{A}{ball}
```

$$\langle A_{x,\text{ball}}, A_{y,\text{ball}}, A_{z,\text{ball}} \rangle \bullet \langle dx, dy, dz \rangle$$

\vectsubdotsDpos{*kernel*}{{*sub*}}

Identical to **\vectsubdotsdpos** but uses Δ .

```
\vectsubdotsDpos{A}{ball}
```

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

\vectsubdotedpos{*kernel*}{{*sub*}}

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

```
\vectsubdotedpos{A}{ball}
```

$$A_{x,\text{ball}} dx + A_{y,\text{ball}} dy + A_{z,\text{ball}} dz$$

\vectsubdoteDpos{*kernel*}{{*sub*}}

Identical to **\vectsubdotedpos** but uses Δ .

```
\vectsubdoteDpos{A}{ball}
```

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

\dervectdotsvect{*kernel1*}{{*indvar*}}{{*kernel2*}}

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

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

$$\left\langle \frac{dA_x}{dt}, \frac{dA_y}{dt}, \frac{dA_z}{dt} \right\rangle \bullet \langle B_x, B_y, B_z \rangle$$

\Dervectdotsvect{*kernel1*}{{*indvar*}}{*kernel2*}

Identical to **\dervectdotsvect** but uses Δ .

\Dervectdotsvect{A}{t}{B}

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

\dervectdotvect{*kernel1*}{{*indvar*}}{*kernel2*}

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

\dervectdotvect{A}{t}{B}

$$\frac{dA_x}{dt}x_B + \frac{dA_y}{dt}y_B + \frac{dA_z}{dt}z_B$$

\Dervectdotvect{*kernel1*}{{*indvar*}}{*kernel2*}

Identical to **\dervectdotvect** but uses Δ .

\Dervectdotvect{A}{t}{B}

$$\frac{\Delta A_x}{\Delta t}x_B + \frac{\Delta A_y}{\Delta t}y_B + \frac{\Delta A_z}{\Delta t}z_B$$

\vectdotsderivect{*kernel1*}{{*kernel2*}}{*indvar*}

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

\vectdotsderivect{A}{B}{t}

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

\vectdotsDervect{*kernel1*}{{*kernel2*}}{*indvar*}

Identical to **\vectdotsderivect** but uses Δ .

\vectdotsDervect{A}{B}{t}

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

\vectdottedderivect{*kernel1*}{{*kernel2*}}{*indvar*}

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

\vectdottedderivect{A}{B}{t}

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

\vectdotDerivect{*kernel1*}{{*kernel2*}}{*indvar*}

Identical to **\vectdotedervect** but uses Δ .

\vectdotDerivect{A}{B}{t}

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

\dervectdotpos{*kernel*}{{*indvar*}}

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

\dervectdotpos{A}{t}

$$\left\langle \frac{dA_x}{dt}, \frac{dA_y}{dt}, \frac{dA_z}{dt} \right\rangle \bullet \langle x, y, z \rangle$$

\Dervectdotpos{*kernel*}{{*indvar*}}

Identical to **\dervectdotpos** but uses Δ .

\Dervectdotpos{A}{t}

$$\left\langle \frac{\Delta A_x}{\Delta t}, \frac{\Delta A_y}{\Delta t}, \frac{\Delta A_z}{\Delta t} \right\rangle \bullet \langle x, y, z \rangle$$

\dervectdotpos{*kernel*}{{*indvar*}}

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

\dervectdotpos{A}{t}

$$\frac{dA_x}{dt}x + \frac{dA_y}{dt}y + \frac{dA_z}{dt}z$$

\Dervectdotpos{*kernel*}{{*indvar*}}

Identical to **\dervectdotpos** but uses Δ .

\Dervectdotpos{A}{t}

$$\frac{\Delta A_x}{\Delta t}x + \frac{\Delta A_y}{\Delta t}y + \frac{\Delta A_z}{\Delta t}z$$

\dervectdotsdvect{*kernel1*}{{*indvar*}}{*kernel2*}

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

\dervectdotsdvect{A}{t}{B}

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

\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}

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

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

Identical to **\dervectdotedvect** but uses Δ .

\DervectdoteDvect{A}{t}{B}

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

\dervectdotdpos{*kernel*}{{*indvar*}}

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

\dervectdotdpos{A}{t}

$$\left\langle \frac{dA_x}{dt}, \frac{dA_y}{dt}, \frac{dA_z}{dt} \right\rangle \bullet \langle dx, dy, dz \rangle$$

\DervectdotsDpos{*kernel*}{{*indvar*}}

Identical to **\dervectdotdpos** but uses Δ .

\DervectdotsDpos{A}{t}

$$\left\langle \frac{\Delta A_x}{\Delta t}, \frac{\Delta A_y}{\Delta t}, \frac{\Delta A_z}{\Delta t} \right\rangle \bullet \langle \Delta x, \Delta y, \Delta z \rangle$$

\dervectdotedpos{*kernel*}{{*indvar*}}

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

\dervectdotedpos{A}{t}

$$\frac{dA_x}{dt} dx + \frac{dA_y}{dt} dy + \frac{dA_z}{dt} dz$$

\DervectdotDpos{<kernel>}{<indvar>}

Identical to **\dervectdotedpos** but uses Δ .

\DervectdotDpos{A}{t}

$$\frac{\Delta A_x}{\Delta t} \Delta x + \frac{\Delta A_y}{\Delta t} \Delta y + \frac{\Delta A_z}{\Delta t} \Delta z$$

5.7.8 Expressions Containing Crosses

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

\vectcrossvect{<kernel1>}{<kernel2>}

Cross of two vectors.

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

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

\ltriplecross{<kernel1>}{<kernel2>}{<kernel3>}

Symbol for left associated triple cross product.

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

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

\rtriplecross{<kernel1>}{<kernel2>}{<kernel3>}

Symbol for right associated triple cross product.

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

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

\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}}

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

5.7.9 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
```

 $e_0 e_1 e_2 e_3 e_4$

\uezero

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

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

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

\ezerozero

Symbols for basis bivectors with lower indices up to 4.

```
\ezerozero \ezeroone \ezerotwo \ezerothree \ezerofour  
↳ \ezerofour up to \efourfour
```

 $e_{00} e_{01} e_{02} e_{03} e_{04}$ up to e_{44}

\euzero

Symbols for basis vectors with upper indices up to 4.

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

 $e^0 e^1 e^2 e^3 e^4$

\euzerozero

Symbols for basis bivectors with upper indices up to 4.

```
\euzerozero \euzeroone \euzerotwo \euzerothree \euzerofour  
↳ \euzerofour up to \eufourfour
```

 $e^{00} e^{01} e^{02} e^{03} e^{04}$ up to e^{44}

\gzero

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

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

 $\gamma_0 \gamma_1 \gamma_2 \gamma_3 \gamma_4$

\gzero

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

```
\gzero \guone \gutwo \guthree \gufour
```

$$\gamma^0 \gamma^1 \gamma^2 \gamma^3 \gamma^4$$

\gzerzero

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

```
\gzerzero \gzerone \gzerotwo \gzerothree >  
\\gzerofour up to \gfourfour
```

$$\gamma_{00} \gamma_{01} \gamma_{02} \gamma_{03} \gamma_{04} \text{ up to } \gamma_{44}$$

\gzerozero

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

```
\gzerozero \gzerone \gzerotwo \gzerothree >  
\\gzerofour up to \gfourfour
```

$$\gamma^{00} \gamma^{01} \gamma^{02} \gamma^{03} \gamma^{04} \text{ up to } \gamma^{44}$$

\colvector{\langle command delimited list of comps \rangle}

Typesets column vectors.

```
\colvector{\msup{x}{0}, \msup{x}{1}, \msup{x}{2},  
\\msup{x}{3}}
```

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

\rowvector{\langle command delimited list of comps \rangle}

Typesets row vectors.

```
\rowvector{\msup{x}{0}, \msup{x}{1}, \msup{x}{2},  
\\msup{x}{3}}
```

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

\scmpscvect[\langle any nonzero \rangle]{\langle kernel \rangle}

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

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

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

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

\textbf{scompsrvect} [*any nonzero*] {*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*}
\text{\textbf{vect}}\{p\} &= \text{\textbf{scompsrvect}}\{p\} \\
\text{\textbf{vect}}\{p\} &= \text{\textbf{scompsrvect}}[4]\{p\}
\end{align*}
```

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

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

5.8 Physical Constants

5.8.1 Defining Physical Constants

\textbf{newphysicsconstant} {*newname*} {*symbol*} {*value*} {*baseunits*} [*drvunits*] [*tradunits*]

Defines a new physical constant.

Here is how \oofpez (the Coulomb constant) is defined internally.

```
\newphysicsconstant{oofpez}
{\ensuremath{\frac{1}{4\pi\epsilon_0}}}
{\scin[9]{9}}
{\ensuremath{\frac{1}{4\pi\epsilon_0}}}
[\perfarad]
[\newton\per\coulomb\squared]
```

Using this command causes several things to happen.

- A command \textbf{newname} is created and contains the constant and units typeset according to the options given when \textbf{mandi} was loaded.
- A command \textbf{newnamemathsymbol} is created that expresses **only** the constant's mathematical symbol.
- A command \textbf{newnamevalue} is created that expresses **only** the constant's numerical value.
- A command \textbf{newnamebaseunit} is created that expresses the constant and its units in *baseunits* form.
- A command \textbf{newnamedrvunit} is created that expresses the constant and its units in *drvunits* 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 `\newnameonlydrvunit` is created that expresses **only** the constant's units in *drvunits* form.
- A command `\newnameonlytradunit` is created that expresses **only** the constant's units in *tradunits* form.

None of these commands takes any arguments.

5.8.2 Predefined Physical Constants

`\oofpez`

Coulomb constant.

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

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

`\oofpezcs`

Alternate form of Coulomb constant.

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

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

`\vacuumpermittivity`

Vacuum permittivity.

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

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

`\mzofp`

Biot-Savart constant.

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

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

`\vacuumpermeability`

Vacuum permeability.

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

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

\boltzmann

Boltzmann constant.

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

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

\boltzmanninev

Alternate form of Boltzmann constant.

```
\(\boltzmanninevmathsymbol \approx \boltzmanninev\)
```

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

\stefan

Stefan-Boltzmann constant.

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

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

\planck

Planck constant.

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

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

\planckinev

Alternate form of Planck constant.

```
\(\planckmathsymbol \approx \planckinev\)
```

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

\planckbar

Reduced Planck constant (Dirac constant).

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

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

\planckbarinev

Alternate form of reduced Planck constant (Dirac constant).

`\(\(\mathrm{planckbar}\mathsf{symbol} \approx \mathrm{planckbarinev}\)`

$$\hbar \approx 6.5821 \times 10^{-34} \text{ eV} \cdot \text{s}$$

\planckc

Planck constant times light speed.

`\(\(\mathrm{planckcm}\mathsf{symbol} \approx \mathrm{planckc}\)`

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

\planckcinev

Alternate form of Planck constant times light speed.

`\(\(\mathrm{planckcinev}\mathsf{symbol} \approx \mathrm{planckcinev}\)`

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

\rydberg

Rydberg constant.

`\(\(\mathrm{rydberg}\mathsf{symbol} \approx \mathrm{rydberg}\)`

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

\bohrradius

Bohr radius.

`\(\(\mathrm{bohrradius}\mathsf{symbol} \approx \mathrm{bohrradius}\)`

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

\finestructure

Fine structure constant.

`\(\(\mathrm{finestructure}\mathsf{symbol} \approx \zeta\mathrm{finestructure}\)`

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

\avogadro

Avogadro constant.

`\(\(\mathrm{avogadrom}\mathsf{symbol} \approx \mathrm{avogadro}\)`

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

\universalgrav

Universal gravitational constant.

$$\backslash(\backslash universalgravmathsymbol \approx \backslash universalgrav\backslash)$$

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

\surfacegravfield

Earth's surface gravitational field strength.

$$\backslash(\backslash surfacegravfieldmathsymbol \approx \backslash surfacegravfield\backslash)$$

$$g \approx 9.80 \text{ m/s}^2$$

\clight

Magnitude of light's velocity (photon constant).

$$\backslash(\backslash clightmathsymbol \approx \backslash clight\backslash)$$

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

\clightinfeet

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

$$\backslash(\backslash clightinfeetmathsymbol \approx \backslash clightinfeet\backslash)$$

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

\Ratom

Approximate atomic radius.

$$\backslash(\backslash Ratommathsymbol \approx \backslash Ratom\backslash)$$

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

\Mproton

Proton mass.

$$\backslash(\backslash Mprotonmathsymbol \approx \backslash Mproton\backslash)$$

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

\Mneutron

Neutron mass.

$\backslash(\backslash M_{neutron} \mathbf{symbol} \backslash approx \backslash M_{neutron})$

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

\Mhydrogen

Hydrogen atom mass.

$\backslash(\backslash M_{hydrogen} \mathbf{symbol} \backslash approx \backslash M_{hydrogen})$

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

\Melectron

Electron mass.

$\backslash(\backslash M_{electron} \mathbf{symbol} \backslash approx \backslash M_{electron})$

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

\echarge

Elementary charge quantum.

$\backslash(\backslash echarge \mathbf{symbol} \backslash approx \backslash echarge)$

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

\Qelectron

Electron charge.

$\backslash(\backslash Q_{electron} \mathbf{symbol} \backslash approx \backslash Q_{electron})$

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

\qelectron

Alias for \Qelectron.

\Qproton

Proton charge.

$\backslash(\backslash Q_{proton} \mathbf{symbol} \backslash approx \backslash Q_{proton})$

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

\qproton

Alias for \Qproton.

\MEarth

Earth's mass.

$\backslash(\backslash\text{MEarthmathsymbol}\ \backslash\approx\ \backslash\text{MEarth}\backslash)$

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

\MMoon

Moon's mass.

$\backslash(\backslash\text{MMoonmathsymbol}\ \backslash\approx\ \backslash\text{MMoon}\backslash)$

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

\MSun

Sun's mass.

$\backslash(\backslash\text{MSunmathsymbol}\ \backslash\approx\ \backslash\text{MSun}\backslash)$

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

\REarth

Earth's radius.

$\backslash(\backslash\text{REarthmathsymbol}\ \backslash\approx\ \backslash\text{REarth}\backslash)$

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

\RMoon

Moon's radius.

$\backslash(\backslash\text{RMoonmathsymbol}\ \backslash\approx\ \backslash\text{RMoon}\backslash)$

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

\RSun

Sun's radius.

$\backslash(\backslash\text{RSunmathsymbol}\ \backslash\approx\ \backslash\text{RSun}\backslash)$

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

\ESdist

Earth-Sun distance.

`\(\(\text{\ESdistmathsymbol} \approx \text{\SEdist}\)\)`

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

\SEdist

Alias for `\ESdist`.

\EMdist

Earth-Moon distance.

`\(\(\text{\EMdistmathsymbol} \approx \text{\EMdist}\)\)`

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

\MEdist

Alias for `\EMdist`.

5.9 Astronomical Constants and Quantities

\LSun

Sun's luminosity.

`\(\(\text{\LSunmathsymbol} \approx \text{\LSun}\)\)`

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

\TSun

Sun's effective temperature.

`\(\(\text{\TSunmathsymbol} \approx \text{\TSun}\)\)`

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

\MagSun

Sun's absolute magnitude.

`\(\(\text{\MagSunmathsymbol} \approx \text{\MagSun}\)\)`

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

\magSun

Sun's apparent magnitude.

`\(\(\text{\magSunmathsymbol} \approx \text{\magSun}\)\)`

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

\Lstar[*<object>*]

Symbol for stellar luminosity.

```
\Lstar \Lstar[Sirius]
```

$$L_{\star} L_{\text{Sirius}}$$

\Lsolar

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

```
\Lsolar
```

$$L_{\odot}$$

\Tstar[*<object>*]

Symbol for stellar temperature.

```
\Tstar \Tstar[Sirius]
```

$$T_{\star} T_{\text{Sirius}}$$

\Tsolar

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

```
\Tsolar
```

$$T_{\odot}$$

\Rstar[*<object>*]

Symbol for stellar radius.

```
\Rstar \Rstar[Sirius]
```

$$R_{\star} R_{\text{Sirius}}$$

\Rsolar

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

```
\Rsolar
```

$$R_{\odot}$$

\Mstar[*<object>*]

Symbol for stellar mass.

```
\Mstar \Mstar[Sirius]
```

$$M_{\star} M_{\text{Sirius}}$$

\Msolar

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

```
\Msolar
```

$$M_{\odot}$$

\Fstar[*<object>*]

Symbol for stellar flux.

```
\Fstar \Fstar[Sirius]
```

$$F_{\star} F_{\text{Sirius}}$$

\Fsolar

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

```
\Fsolar
```

$$F_{\odot}$$

\fstar

Alias for `\Fstar`.

\fsolar

Alias for `\fsolar`.

\Magstar[*<object>*]

Symbol for stellar absolute magnitude.

```
\Magstar \Magstar[Sirius]
```

$$M_{\star} M_{\text{Sirius}}$$

\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 \magstar[Sirius]
```

$$m_{\star} m_{\text{Sirius}}$$

\magsolar

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

```
\magsolar
```

$$m_{\odot}$$

\Dstar[\langle object \rangle]

Symbol for stellar distance.

```
\Dstar \Dstar[Sirius]
```

$$D_{\star} D_{\text{Sirius}}$$

\Dsolar

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

```
\Dsolar
```

$$D_{\odot}$$

\dstar

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

\dsolar

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

5.10 Frequently Used Fractions

\onehalf

Small fractions with numerator 1 and denominators up to 10.

```
\(\onehalf \cdots \onetenth\)
```

$$\frac{1}{2} \dots \frac{1}{10}$$

\twooneths

Small fractions with numerator 2 and denominators up to 10.

```
\(\twooneths \cdots \twotenths\)
```

$$\frac{2}{1} \dots \frac{2}{10}$$

\threeoneths

Small fractions with numerator 3 and denominators up to 10.

```
\(\threeoneths \cdots \threetenths\)
```

$$\frac{3}{1} \dots \frac{3}{10}$$

\fouroneths{\(magnitude\)}

Small fractions with numerator 4 and denominators up to 10.

```
\(\fouroneths \cdots \fourtenths\)
```

$$\frac{4}{1} \dots \frac{4}{10}$$

5.11 Calculus

\dx{\(variable\)}

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

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

$$dy$$

\evalfromto{\(antiderivative\)}{\(lower\)}{\(upper\)}

Properly typesets the evaluation of definite integrals.

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

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

\evalat{\(expression\)}{\(evaluationpoint\)}

Properly typesets quantities evaluated at a particular point or value.

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

$$\left. \frac{dx}{dt} \right|_{t=1}$$

\evaluatedat{\(evaluationpoint\)}

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

```
\(\ \mbox{LMST}\) evaluated at {\longitude{0}} \)
```

LMST
|
 $_{0^\circ}$

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

Typesets indefinite and definite integrals.

```
\[ \int y^2 dy \]
\[ \int_0^3 y^2 dy \]
```

$$\int_{y=0}^{y=3} y^2 dy$$

\Integral [*lower*] [*upper*] {*integrand*} {*var*}

Typesets indefinite and definite integrals.

```
\[ \int y^2 dy \]
\[ \int_0^3 y^2 dy \]
```

$$\int_{y=0}^{y=3} y^2 dy$$

\opensurfintegral {*surfacename*} {*vectorname*}

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

```
\[ \int_S \vec{E} \bullet \hat{n} dA \]
```

$$\int_S \vec{E} \bullet \hat{n} dA$$

\opensurfIntegral {*surfacename*} {*vectorname*}

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

```
\[ \int_S \vec{E} \bullet \hat{n} dA \]
```

$$\int_S \vec{E} \bullet \hat{n} dA$$

\closedsurfintegral{*surfacename*}{{*vectorname*}}

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

```
\[ \closedsurfintegral{S}{E} \]
```

$$\oint_S \vec{E} \bullet \hat{n} dA$$

\closedsurfIntegral{*surfacename*}{{*vectorname*}}

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

```
\[ \closedsurfIntegral{S}{E} \]
```

$$\oint_S \vec{E} \bullet \hat{n} dA$$

\openlineintegral{*pathname*}{{*vectorname*}}

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

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

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

\openlineIntegral{*pathname*}{{*vectorname*}}

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

```
\[ \openlineIntegral{C}{E} \]
```

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

\closedlineintegral{*pathname*}{{*vectorname*}}

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

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

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

\closedlineIntegral{*pathname*}{{*vectorname*}}

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

```
\[ \closedlineIntegral{C}{E} ]
```

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

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

\dbydt [*operand*] (operator)

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

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

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

\ddbydt [*operand*] (operator)

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

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

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

\pbypt [*operand*] (operator)

First partial time derivative operator.

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

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

\ppbypt [*operand*] (operator)

Second partial time derivative operator.

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

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

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

Generic first derivative operator. Use \DbyD to get Δ instead of d.

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

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

\ddbyd{*dependentvariable*} {*indvar*}

Generic second derivative operator. Use \DDbyD to get Δ instead of d.

<code>\(\ddbyd{f}{y}\)</code>	$\frac{d^2 f}{dy^2}$
-------------------------------	----------------------

\pbyp{*dependentvariable*} {*indvar*}

Generic first partial derivative operator.

<code>\(\pbyp{f}{y}\)</code>	$\frac{\partial f}{\partial y}$
------------------------------	---------------------------------

\ppbyp{*dependentvariable*} {*indvar*}

Generic second partial derivative operator.

<code>\(\ppbyp{f}{y}\)</code>	$\frac{\partial^2 f}{\partial y^2}$
-------------------------------	-------------------------------------

\gradient

Gradient operator.

<code>\gradient</code>	∇
------------------------	----------

\divergence

Divergent operator.

<code>\divergence</code>	$\nabla \bullet$
--------------------------	------------------

\curl

Curl operator.

<code>\curl</code>	$\nabla \times$
--------------------	-----------------

\laplacian

Laplacian operator.

\laplacian

$$\nabla^2$$

\dalembertian

D'Alembertian operator.

\dalembertian

$$\square$$

\seriesofx

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

\seriesofx

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

\seriesexpx

Series expansion of e^x .

\seriesexpx

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

\seriesssinx

Series expansion of $\sin x$.

\seriesssinx

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

\seriescosx

Series expansion of $\cos x$.

\seriescosx

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

\seriesstanx

Series expansion of $\tan x$.

```
\seriesstanx
```

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

\seriesatox

Series expansion of a^x .

```
\seriesatox
```

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

\serieslnoneplusx

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

```
\serieslnoneplusx
```

$$\ln(1 \pm x) \approx \pm x - \frac{x^2}{2} \pm \frac{x^3}{3} - \frac{x^4}{4} \pm \dots$$

\binomialseries

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

```
\binomialseries
```

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

\diracdelta{<arg>}

Dirac delta function.

```
\diracdelta{x}
```

$$\delta(x)$$

5.12 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 L^AT_EX.

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

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

\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}
```

$B\vec{B}$

\newpi

Bob Palais' symbol for 2π .

```
\newpi
```

π

\scripty{*kernel*}

Command to get fonts in Griffith's electrodynamics textbook.

```
\scripty{r}
```

\mathbb{z}

`\flux[\langle label\rangle]`

Symbol for flux of a vector field.

<code>\flux \flux[E]</code>	$\Phi \Phi_E$
-----------------------------	---------------

`\abs{\langle arg\rangle}`

Absolute value function.

<code>\abs{-4}</code>	$ -4 $
-----------------------	--------

`\magof{\langle arg\rangle}`

Magnitude of a quantity (lets you selectively use double bars without setting the **doubleabsbars** option).

<code>\magof{\vect{E}}</code>	$\ \vec{E}\ $
-------------------------------	---------------

`\dimsof{\langle arg\rangle}`

Notation for showing the dimensions of a quantity.

<code>\(\dimsof{\vect{v}} = L \cdot T^{-1} \)</code>	$[\vec{v}] = L \cdot T^{-1}$
-------------------------------------------------------	------------------------------

`\unitsof{\langle arg\rangle}`

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.

<code>\unitsof{\vect{v}} = \velocityonlytradunit</code>	$[\vec{v}]_u = \text{m/s}$
---------------------------------------------------------	----------------------------

`\quant{\langle arg\rangle}`

Surrounds the argument with variable sized parentheses. Use `\bquant` to get square brackets.

<code>\quant{\oofpez}</code>	$(8.9876 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)$
------------------------------	--------------------------------------------------------------

`\Changein{\langle arg\rangle}`

Notation for *the change in a quantity*.

```
\Changeinf{\vect{E}}
```

$$\Delta \vec{E}$$

\scin{*mantissa*}{{*exponent*}}[*unit*]

Command for scientific notation with an optional unit.

```
\scin[2.99]{8}[\velocityonlytradunit]
```

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

\ee{*mantissa*}{{*exponent*}}

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

```
\ee[2.99]{8}
```

$$2.99\text{e}8$$

\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}
```

$$\begin{aligned} &23^\circ 34' 10.27'' \\ &23^{\text{h}} 34^{\text{m}} 10.27^{\text{s}} \end{aligned}$$

\clockreading{*hrs*}{{*min*}}{{*sec*}}

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

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

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

\latitude{*arg*}

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

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

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

\longitude{*arg*}

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

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

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

\ssup{*kernel*} {*sup*}

Command for typesetting text superscripts.

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

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

\ssub{*kernel*} {*sub*}

Command for typesetting text subscripts.

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

$$N_{\text{AB}}$$

\ssud{*sup*} {*sub*}

Command for typesetting text superscripts and subscripts.

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

$$N_{\text{AB}}^{\text{contact}}$$

\msup{*kernel*} {*sup*}

Command for typesetting mathematical superscripts.

```
\msup{R}{\gamma}
```

$$R^\gamma$$

\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}
```

$$\Gamma_{\alpha\beta}^\gamma$$

\levicivita{*indices*}

Command for Levi-Civita symbol.

```
\levicivita{ijk}
```

$$\varepsilon_{ijk}$$

\kronecker{*indices*}

Command for Kronecker delta symbol.

```
\kronecker{ij}
```

$$\delta_{ij}$$

\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

\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

\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}
```

$$\sqrt[4]{x} \quad x^{\frac{1}{4}}$$

\fifthroot{<arg>}

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

```
\fifthroot{x} \fffifthroot{x}
```

$$\sqrt[5]{x} \quad x^{\frac{1}{5}}$$

\relgamma{<arg>}

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

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

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

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{0.5c}{c}\right)^2}}$$

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

$$\gamma = \left(1 - \frac{(0.5c)^2}{c^2}\right)^{-\frac{1}{2}}$$

\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}
```

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

5.13 Custom Operators

The = operator is frequently misused, and we need other operators for other situations.

\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}
```

added
to
(added)
to

\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
```

defined and associated and adjusted by
earlier with later for
than and every
(defined) and (associated) and (adjusted)
(earlier) and (later) and (every)

\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.

```
\vect{p} \inframe[S] \\ \momentum{\mivector{1,2,3}} \\ \vect{p} \inframe[S'] \\ \momentum{\mivector{\sqrt{14},0,0}}
```

$\vec{p} \xrightarrow{S} \langle 1, 2, 3 \rangle \text{ kg} \cdot \text{m/s}$
 $\vec{p} \xrightarrow{S'} \langle \sqrt{14}, 0, 0 \rangle \text{ kg} \cdot \text{m/s}$

Make the arrow's length fixed.

\associates

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

```
kinetic energy \associates velocity
```

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

\becomes

Command for *becomes* operator.

```
\(\gamma m\)\vect{v} \becomes \(\mathbf{m}\)\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 > \mathfrak{c}_{\text{diff}})
```

$$(\text{flux ratio}) \xrightarrow{\text{taking logarithm}} (\text{mag diff})$$

\lrelatedto{\rightoperation}

Command for right-to-left relationship.

```
(flux ratio) \lrelatedto{exponentiation} (mag > \mathfrak{c}_{\text{diff}})
```

$$(\text{flux ratio}) \xleftarrow[\text{exponentiation}]{\text{taking logarithm}} (\text{mag diff})$$

\brelatedto{\leftoperation}{\rightoperation}

Command for bidirectional relationship.

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

$$(\text{mag diff}) \xleftrightarrow[\text{taking logarithm}]{\text{exponentiation}} (\text{flux ratio})$$

5.14 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
```

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

\energyprinciple

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

```
\energyprinciple
```

$$E_{\text{sys,f}} = E_{\text{sys,i}} + W_{\text{ext}} + Q$$

\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
```

$$\vec{L}_{\text{sys,A,f}} = \vec{L}_{\text{sys,A,i}} + \vec{T}_{\text{net,sys}} \Delta t$$

\gravitationalinteraction

Expression for gravitational interaction.

```
\gravitationalinteraction
```

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

\electricinteraction

Expression for electric interaction.

```
\electricinteraction
```

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

\Efieldofparticle

Expression for a particle's electric field.

```
\Efieldofparticle
```

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

\Bfieldofparticle

Expression for a particle's magnetic field.

`\Bfieldofparticle`

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

`\Esys`

Symbol for system energy.

`\Esys`

$$E_{\text{sys}}$$

`\Us`

Symbol for spring potential energy.

`\Us`

$$U_s$$

`\Ug`

Symbol for gravitational potential energy.

`\Ug`

$$U_g$$

`\Ue`

Symbol for electric potential energy.

`\Ue`

$$U_e$$

`\Ktrans`

Symbol for translational kinetic energy.

`\Ktrans`

$$K_{\text{trans}}$$

`\Krot`

Symbol for rotational kinetic energy.

`\Krot`

$$K_{\text{rot}}$$

\Eparticle

Symbol for particle energy.

\Eparticle

$$E_{\text{particle}}$$

\Einternal

Symbol for internal energy.

\Einternal

$$E_{\text{internal}}$$

\Erest

Symbol for rest energy.

\Erest

$$E_{\text{rest}}$$

\Echem

Symbol for chemical energy.

\Echem

$$E_{\text{chem}}$$

\Etherm

Symbol for thermal energy.

\Etherm

$$E_{\text{therm}}$$

\Evib

Symbol for vibrational energy.

\Evib

$$E_{\text{vib}}$$

\Ephoton

Symbol for photon energy.

`\Ephoton`

$$E_{\text{photon}}$$

`\DUs`

Symbol for change in spring potential energy.

`\DUs`

$$\Delta U_s$$

`\DUs`

Symbol for change in gravitational potential energy.

`\DUs`

$$\Delta U_g$$

`\DUe`

Symbol for change in electric potential energy.

`\DUe`

$$\Delta U_e$$

`\DKtrans`

Symbol for change in translational kinetic energy.

`\DKtrans`

$$\Delta K_{\text{trans}}$$

`\DKrot`

Symbol for change in rotational kinetic energy.

`\DKrot`

$$\Delta K_{\text{rot}}$$

`\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

$$\Delta E_{\text{rest}}$$

\DEchem

Symbol for change in chemical energy.

\DEchem

$$\Delta E_{\text{chem}}$$

\DEtherm

Symbol for change in thermal energy.

\DEtherm

$$\Delta E_{\text{therm}}$$

\DEVib

Symbol for change in vibrational energy.

\DEVib

$$\Delta E_{\text{vib}}$$

\DEphoton

Symbol for change in photon energy.

\DEphoton

$$\Delta E_{\text{photon}}$$

\Usfinal

Expression for final spring potential energy.

\Usfinal

$$\left(\frac{1}{2} k_s s^2 \right)_f$$

\Usinitial

Expression for initial spring potential energy.

\Usinitial

$$\left(\frac{1}{2} k_s s^2 \right)_i$$

\Uefinal

Expression for final electric potential energy.

\Uefinal

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

\Ueinitial

Expression for initial electric potential energy.

\Ueinitial

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

\Ugfinal

Expression for final gravitational potential energy.

\Ugfinal

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

\Uginitial

Expression for initial gravitational potential energy.

\Uginitial

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

\ks

Symbol for spring stiffness.

```
\ks
```

 k_s

\Fnet

Various symbols for net force.

```
\Fnet \Fnettext \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 \Tnettext \Tnetsys \Tsub{ball, bat}
```

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

\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 visual import *
    sphere(center=pos(1,2,3),color=color.green)
    MyArrow=arrow(pos=earth.pos, axis=fscale*Fnet, color=color.green)
    print ("arrow.pos = "), arrow.pos
\end{vpythonblock}
```

```
1  from visual import *
2  sphere(center=pos(1,2,3),color=color.green)
3  MyArrow=arrow(pos=earth.pos, axis=fscale*Fnet, color=color.green)
4  print ("arrow.pos = "), arrow.pos
```

\vpythonfile{filename}

Typesets a file in the current directory containing VPython code.

```
\vpythonfile{vdemo.py}

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

5.15 Boxes and Environments

\emptyanswer[<wdth>][<ght>]

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

```
\emptyanswer[0.75][0.2]
```

```
\begin{activityanswer} [<bgclr>] [<frmclr>] [<txtclr>] [<wdth>] [<ght>]
<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}[\langle bgclr \rangle] [\langle frmclr \rangle] [\langle txtclr \rangle] [\langle wdth \rangle] [\langle hght \rangle]
  \langle environment content \rangle
\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 consectetur. Sed aliquam,
  nunc eget euismod ullamcorper, lectus nunc ullamcorper orci,
  fermentum bibendum enim nibh eget ipsum. Donec porttitor ligula
  eu dolor. Maecenas vitae nulla consequat libero cursus venenatis.
  Nam magna enim, accumsan eu, blandit sed, blandit a, eros.
\end{adjactivityanswer}
```

Lorem ipsum dolor sit amet, 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 consectetur. Sed aliquam, nunc eget euismod ullamcorper, lectus nunc ullamcorper orci, fermentum bibendum enim nibh eget ipsum. Donec porttitor ligula eu dolor. Maecenas vitae nulla consequat libero cursus venenatis. Nam magna enim, accumsan eu, blandit sed, blandit a, eros.

```
\emptybox[\langle txt \rangle] [\langle bgclr \rangle] [\langle frmclr \rangle] [\langle txtclr \rangle] [\langle wdth \rangle] [\langle hght \rangle]
```

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`.

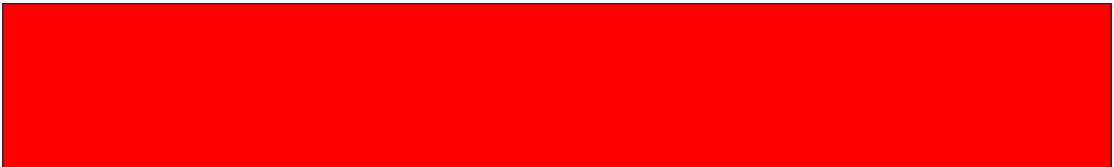
```
\adjanswerbox[Lorem ipsum dolor sit amet, consectetur adipiscing  
elit. Morbi commodo, ipsum sed pharetra gravida, orci magna rhoncus  
neque, id pulvinar odio lorem non turpis. Nullam sit amet enim.]
```

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

\smallanswerbox[*txt*] [*bgclr*]

Answer box with height 0.10 that of current \textheight and width 0.90 that of current \linewidth.

```
\smallanswerbox[] [red]
```



\mediumanswerbox[*txt*] [*bgclr*]

Answer box with height 0.20 that of current \textheight and width 0.90 that of current \linewidth.

```
\mediumanswerbox[] [lightgray]
```



\largeanswerbox[*txt*] [*bgclr*]

Answer box with height 0.25 that of current \textheight and width 0.90 that of current \linewidth (too large to show here).

```
\largeanswerbox[] [lightgray]
```

\largeanswerbox[*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).

```
\largeanswerbox[] [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{minstructornote}  
  <environment content>  
\end{minstructornote}
```

Environment for highlighting notes to instructors.

```
\begin{miinstructornote}
Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
neque dolor, adipiscing sed, consectetur et, lacinia sit amet,
quam. Suspendisse wisi quam, consectetur in, blandit sed,
suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
interdum sapien.
\end{miinstructornote}
```

INSTRUCTOR NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim,
elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed,
consectetur et, lacinia sit amet, quam. Suspendisse wisi quam, consectetur in, blandit
sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam
cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis.
Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

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

Environment for highlighting notes to students.

```
\begin{mistudentnote}
Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam
enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce
neque dolor, adipiscing sed, consectetur et, lacinia sit amet,
quam. Suspendisse wisi quam, consectetur in, blandit sed,
suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
interdum sapien.
\end{mistudentnote}
```

STUDENT NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim,
elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed,
consectetur et, lacinia sit amet, quam. Suspendisse wisi quam, consectetur in, blandit
sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam
cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis.
Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

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

Environment for mathematical derivations based on the `align` environment.

```

\begin{miderivation}
\gamma &= \relgamma{\magvect{v}}
&& \text{given} \\
\msup{\gamma}{2} &= \oomx{\msup{(\frac{\magvect{v}}{c})}{2}}
&& \text{square both sides} \\
\frac{1}{\msup{\gamma}{2}} &= 1 - \msup{(\frac{\magvect{v}}{c})}{2}
&& \text{reciprocal of both sides} \\
\frac{1}{\gamma^2} &= 1 - \frac{|\vec{v}|^2}{c^2}
&& \text{rearrange} \\
\frac{|\vec{v}|^2}{c^2} &= 1 - \frac{1}{\gamma^2}
&& \text{square root of both sides}
\end{miderivation}

```

DERIVATION

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

given

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

square both sides

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

reciprocal of both sides

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

rearrange

$$\frac{|\vec{v}|}{c} = \sqrt{1 - \frac{1}{\gamma^2}}$$

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, consectetur et, lacinia sit amet, quam. Suspendisse wisi quam, consectetur in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.
\end{bwinstructornote}
```

INSTRUCTOR NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim, elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed, consectetur et, lacinia sit amet, quam. Suspendisse wisi quam, consectetur in, blandit sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

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

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, consectetur et, lacinia sit amet,
quam. Suspendisse wisi quam, consectetur in, blandit sed,
suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec,
mollis eu, lectus. Nam cursus. Vivamus iaculis. Aenean risus
purus, pharetra in, blandit quis, gravida a, turpis. Donec nisl.
Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus
interdum sapien.
\end{bwstudentnote}
```

STUDENT NOTE

Nunc auctor bibendum eros. Maecenas porta accumsan mauris. Etiam enim enim,
elementum sed, bibendum quis, rhoncus non, metus. Fusce neque dolor, adipiscing sed,
consectetur et, lacinia sit amet, quam. Suspendisse wisi quam, consectetur in, blandit
sed, suscipit eu, eros. Etiam ligula enim, tempor ut, blandit nec, mollis eu, lectus. Nam
cursus. Vivamus iaculis. Aenean risus purus, pharetra in, blandit quis, gravida a, turpis.
Donec nisl. Aenean eget mi. Fusce mattis est id diam. Phasellus faucibus interdum sapien.

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

Environment for mathematical derivations based on the `align` environment.

```
\begin{bwderivation}
\gamma &= \relgamma{\magvect{v}}
&& \text{given} \\
\msup{\gamma}{2} &= \oomx{\msup{(\frac{\magvect{v}}{c})}{2}}
&& \text{square both sides} \\
\frac{1}{\msup{\gamma}{2}} &= 1 - \msup{(\frac{\magvect{v}}{c})}{2} \\
&& \text{reciprocal of both sides} \\
\frac{1}{\gamma^2} &= 1 - \frac{|\vec{v}|^2}{c^2} \\
&& \text{rearrange} \\
\frac{|\vec{v}|^2}{c^2} &= 1 - \frac{1}{\gamma^2} \\
\frac{|\vec{v}|}{c} &= \sqrt{1 - \frac{1}{\gamma^2}}
&& \text{square root of both sides}
\end{bwderivation}
```

DERIVATION

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

given

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

square both sides

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

reciprocal of both sides

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

rearrange

$$\frac{|\vec{v}|}{c} = \sqrt{1 - \frac{1}{\gamma^2}}$$

square root of both sides

5.16 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}`

$$\frac{1}{m}$$

5.17 Experimental Commands

Commands defined in this section are not guaranteed to work consistently and are included for experimental uses only. They may or may not exist in future releases. Most are an attempt to simplify existing commands for subscripted vectors.

Experimental Syntax	Existing Syntax
<code>\vecto{E}</code>	\vec{E}
<code>\vecto{E}[ball]</code>	\vec{E}_{ball}
<code>\compvecto{E}{y}</code>	E_y
<code>\compvecto{E}{x}[ball]</code>	$E_{x,\text{ball}}$
<code>\scampsvecto{E}</code>	$\langle E_x, E_y, E_z \rangle$
<code>\scampsvecto{E}[ball]</code>	$\langle E_{x,\text{ball}}, E_{y,\text{ball}}, E_{z,\text{ball}} \rangle$
<code>\compposo{y}</code>	y
<code>\compposo{y}[ball]</code>	y_{ball}
<code>\scampsposo</code>	$\langle x, y, z \rangle$
<code>\scampsposo[ball]</code>	$\langle x_{\text{ball}}, y_{\text{ball}}, z_{\text{ball}} \rangle$

6 Source Code

Note the packages that must be present.

```
1 \RequirePackage{amsmath}
2 \RequirePackage{amssymb}
3 \RequirePackage{array}
4 \RequirePackage{bigints}
5 \RequirePackage{cancel}
6 \RequirePackage[dvipsnames]{xcolor}
7 \RequirePackage{environ}
8 \RequirePackage{etoolbox}
9 \RequirePackage{filehook}
10 \RequirePackage{extarrows}
11 \RequirePackage[T1]{fontenc}
12 \RequirePackage{graphicx}
13 \RequirePackage{epstopdf}
14 \RequirePackage{textcomp}
15 \RequirePackage{letltxmacro}
16 \RequirePackage{listings}
17 \RequirePackage[framemethod=TikZ]{mdframed}
18 \RequirePackage{suffix}
19 \RequirePackage{xargs}
20 \RequirePackage{xparse}
21 \RequirePackage{xspace}
22 \RequirePackage{ifthen}
23 \RequirePackage{calligra}
24 \DeclareMathAlphabet{\mathcalligra}{T1}{calligra}{m}{n}
25 \DeclareFontShape{T1}{calligra}{m}{n}{<->s*[2.2] callig15}{}
26 \DeclareGraphicsRule{.tif}{png}{.png}{`convert #1 `basename #1 .tif`.png}
27 \DeclareMathAlphabet{\mathpzc}{OT1}{pzc}{m}{it}
28 \usetikzlibrary{shadows}
29 \definecolor{vpythoncolor}{rgb}{0.95,0.95,0.95}
30 \newcommand{\lstvpython}{\lstset{language=Python,numbers=left,numberstyle=\tiny,
31   backgroundcolor=\color{vpythoncolor},upquote=true,breaklines}}
32 \newcolumntype{C}[1]{>{\centering}m{#1}}
33 \newboolean{@optitalicvectors}
34 \newboolean{@optdoubleabsbars}
35 \newboolean{@optbaseunits}
36 \newboolean{@optdrvunits}
37 \setboolean{@optitalicvectors}{false}
38 \setboolean{@optdoubleabsbars}{false}
39 \setboolean{@optbaseunits}{false}
40 \setboolean{@optdrvunits}{false}
41 \DeclareOption{italicvectors}{\setboolean{@optitalicvectors}{true}}
42 \DeclareOption{doubleabsbars}{\setboolean{@optdoubleabsbars}{true}}
43 \DeclareOption{baseunits}{\setboolean{@optbaseunits}{true}}
44 \DeclareOption{drvunits}{\setboolean{@optdrvunits}{true}}
45 \ProcessOptions\relax
```

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

```
46 \@ifpackageloaded{amssymb}{%
47   \csundef{square}
48   \typeout{mandi: Package amssymb detected. Its \protect\square\space has been redefined.}
49 }{%
50   \typeout{mandi: Package amssymb not detected.}
51 }%
```

This block of code defines unit names and symbols.

```
52 \newcommand{\per}{\ensuremath{/}}
53 \newcommand{\usk}{\ensuremath{\cdot}}
54 \newcommand{\unit}[2]{\ensuremath{\#1\,\#2}}
55 \newcommand{\ampere}{\ensuremath{\mathrm{A}}}
56 \newcommand{\arcminute}{\ensuremath{'}}
57 \newcommand{\arcsecond}{\ensuremath{''}}
58 \newcommand{\atomicmassunit}{\ensuremath{\mathrm{u}}}
59 \newcommand{\candela}{\ensuremath{\mathrm{cd}}}
60 \newcommand{\coulomb}{\ensuremath{\mathrm{C}}}
61 \newcommand{\degree}{\ensuremath{^\circ}}
62 \newcommand{\electronvolt}{\ensuremath{\mathrm{eV}}}
63 \newcommand{\eV}{\text{eV}}
64 \newcommand{\farad}{\ensuremath{\mathrm{F}}}
65 \newcommand{\henry}{\ensuremath{\mathrm{H}}}
66 \newcommand{\hertz}{\ensuremath{\mathrm{Hz}}}
67 \newcommand{\hour}{\ensuremath{\mathrm{h}}}
68 \newcommand{\joule}{\ensuremath{\mathrm{J}}}
69 \newcommand{\kelvin}{\ensuremath{\mathrm{K}}}
70 \newcommand{\kilogram}{\ensuremath{\mathrm{kg}}}
71 \newcommand{\metre}{\ensuremath{\mathrm{m}}}
72 \newcommand{\minute}{\ensuremath{\mathrm{min}}}
73 \newcommand{\mole}{\ensuremath{\mathrm{mol}}}
74 \newcommand{\newton}{\ensuremath{\mathrm{N}}}
75 \newcommand{\ohm}{\ensuremath{\Omega}}
76 \newcommand{\pascal}{\ensuremath{\mathrm{Pa}}}
77 \newcommand{\radian}{\ensuremath{\mathrm{rad}}}
78 \newcommand{\second}{\ensuremath{\mathrm{s}}}
79 \newcommand{\siemens}{\ensuremath{\mathrm{S}}}
80 \newcommand{\steradian}{\ensuremath{\mathrm{sr}}}
81 \newcommand{\tesla}{\ensuremath{\mathrm{T}}}
82 \newcommand{\volt}{\ensuremath{\mathrm{V}}}
83 \newcommand{\watt}{\ensuremath{\mathrm{W}}}
84 \newcommand{\weber}{\ensuremath{\mathrm{Wb}}}
85 \newcommand{\C}{\text{Coulomb}}
86 \newcommand{\F}{\text{farad}}
87 %\H is already defined as a LaTeX accent
88 \newcommand{\J}{\text{joule}}
89 \newcommand{\N}{\text{newton}}
90 \newcommand{\Pa}{\text{pascal}}
91 \newcommand{\rad}{\text{radian}}
92 \newcommand{\sr}{\text{steradian}}
93 %\S is already defined as a LaTeX symbol
```

```

94 \newcommand{\T}{\tesla}
95 \newcommand{\V}{\volt}
96 \newcommand{\W}{\watt}
97 \newcommand{\Wb}{\weber}
98 \newcommand{\square}[1]{\ensuremath{\mathrm{#1}^2}} % prefix 2
99 \newcommand*{\cubic}[1]{\ensuremath{\mathrm{#1}^3}} % prefix 3
100 \newcommand*{\quartic}[1]{\ensuremath{\mathrm{#1}^4}} % prefix 4
101 \newcommand*{\reciprocal}[1]{\ensuremath{\mathrm{#1}^{-1}}} % prefix -1
102 \newcommand*{\reciprocalsquare}[1]{\ensuremath{\mathrm{#1}^{-2}}} % prefix -2
103 \newcommand*{\reciprocalcubic}[1]{\ensuremath{\mathrm{#1}^{-3}}} % prefix -3
104 \newcommand*{\reciprocalquartic}[1]{\ensuremath{\mathrm{#1}^{-4}}} % prefix -4
105 \newcommand*{\squared}{\ensuremath{\mathrm{^2}}} % postfix 2
106 \newcommand*{\cubed}{\ensuremath{\mathrm{^3}}} % postfix 3
107 \newcommand*{\quartered}{\ensuremath{\mathrm{^4}}} % postfix 4
108 \newcommand*{\reciprocated}{\ensuremath{\mathrm{^{-1}}}} % postfix -1
109 \newcommand*{\reciprocalsquared}{\ensuremath{\mathrm{^{-2}}}} % postfix -2
110 \newcommand*{\reciprocalcubed}{\ensuremath{\mathrm{^{-3}}}} % postfix -3
111 \newcommand*{\reciprocalquartered}{\ensuremath{\mathrm{^{-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.

```

112 \newcommand\mi@exchangeargs[2]{#2#1}%
113 \newcommand\mi@name{}%
114 \long\def\mi@name#1{\romannumeral0\mi@innername{#1}}%
115 \newcommand\mi@innername[2]{%
116   \expandafter\mi@exchangeargs\expandafter{\csname#2\endcsname}{#1}}%
117 \begingroup
118 @firstofone{%
119   \endgroup
120   \newcommand\mi@forkifnull[3]{%
121     \romannumeral\iffalse{\fi\expandafter\@secondoftwo\expandafter
122     {\expandafter{\string#1}\expandafter\@secondoftwo\string}%
123     \expandafter\@firstoftwo\expandafter{\iffalse}\fi0 #3}{0 #2}}%
124 \newcommand\selectbaseunit[3]{#1}
125 \newcommand\selectdrvunit[3]{#2}
126 \newcommand\selecttradunit[3]{#3}
127 \newcommand\selectunit{}%
128 \newcommand\perpusebaseunit{\let\selectunit=\selectbaseunit}
129 \newcommand\perpusedrvunit{\let\selectunit=\selectdrvunit}
130 \newcommand\perpusetradunit{\let\selectunit=\selecttradunit}
131 \newcommand\hereusebaseunit[1]{%
132   \begingroup\perpusebaseunit#1\endgroup}%
133 \newcommand\hereusedrvunit[1]{%
134   \begingroup\perpusedrvunit#1\endgroup}%
135 \newcommand\hereusetradunit[1]{%
136   \begingroup\perpusetradunit#1\endgroup}%
137 \newenvironment{usebaseunit}{\perpusebaseunit}{}%
138 \newenvironment{usedrvunit}{\perpusedrvunit}{}%
139 \newenvironment{usetradunit}{\perpusetradunit}{}%
140 \newcommand*\newphysicsquantity{\definephysicsquantity{\newcommand}}
141 \newcommand*\redefinephysicsquantity{\definephysicsquantity{\renewcommand}}

```

```

142 \newcommandx\definephysicsquantity[5][4=,5=]{%
143   \innerdefinewhatsoeverquantityfork{#3}{#4}{#5}{#1}{#2}{[]}{[1]}{##1}}%
144 \newcommand*\newphysicsconstant{\definephysicsconstant{\newcommand}}
145 \newcommand*\redefinephysicsconstant{\definephysicsconstant{\renewcommand}}
146 \newcommandx\definephysicsconstant[7][6=,7=]{%
147   \innerdefinewhatsoeverquantityfork{#5}{#6}{#7}{#1}{#2}{#3}{#4}}%
148 \newcommand\innerdefinewhatsoeverquantityfork[3]{%
149   \expandafter\innerdefinewhatsoeverquantity\romannumeral0%
150   \mi@forkifnull{#3}{\mi@forkifnull{#2}{#1}{#2}{#1}}{%
151     \mi@forkifnull{#2}{#1}{#2}{#3}{#1}}{%
152 \newcommand\innerdefinewhatsoeverquantity[8]{%
153   \mi@name#4{#5}#7{\ensuremath{\unit{#8}{\selectunit{#3}{#1}{#2}}}}{%
154   \mi@name#4{#5baseunit}#7{\ensuremath{\unit{#8}{#3}}}}{%
155   \mi@name#4{#5drvunit}#7{\ensuremath{\unit{#8}{#1}}}}{%
156   \mi@name#4{#5tradunit}#7{\ensuremath{\unit{#8}{#2}}}}{%
157   \mi@name#4{#5onlyunit}{\ensuremath{\selectunit{#3}{#1}{#2}}}}{%
158   \mi@name#4{#5onlybaseunit}{\ensuremath{\unit{#3}}}}{%
159   \mi@name#4{#5onlydrvunit}{\ensuremath{\unit{#1}}}}{%
160   \mi@name#4{#5onlytradunit}{\ensuremath{\unit{#2}}}}{%
161   \mi@name#4{#5value}#7{\ensuremath{\unit{#8}}}}{%
162   \mi@forkifnull{#7}}{%
163   \ifx#4\renewcommand\mi@name\let{#5mathsymbol}=\relax\fi
164   \mi@name\newcommand{#5mathsymbol}{\ensuremath{\unit{#6}}}}{%

```

This block of code processes the options.

```

165 \ifthenelse{\boolean{@optitalicvectors}}
166   {\typeout{mandi: You'll get italic vector kernels.}}
167   {\typeout{mandi: You'll get Roman vector kernels.}}
168 \ifthenelse{\boolean{@optdoubleabsbars}}
169   {\typeout{mandi: You'll get double absolute value bars.}}
170   {\typeout{mandi: You'll get single absolute value bars.}}
171 \ifthenelse{\boolean{@optbaseunits}}
172   {\perpusebaseunit %
173    \typeout{mandi: You'll get base units.}}
174   {\ifthenelse{\boolean{@optdrvunits}}
175    {\perpusedrvunit %
176     \typeout{mandi: You'll get derived units.}}
177    {\perpusetradunit %
178     \typeout{mandi: You'll get traditional units.}}}

```

This block of code makes parentheses adjustable.

```

179 \def\resetMathstrut@{%
180   \setbox\z@\hbox{%
181     \mathchardef\@tempa\mathcode`[\relax
182     \def\@tempb##1##2##3{\the\textfont##3\char"}%
183     \expandafter\@tempb\meaning\@tempa \relax}%
184   \ht\Mathstrutbox@\ht\z@ \dp\Mathstrutbox@\dp\z@}
185 \begingroup
186   \catcode`(\active \xdef{(\left\string{}%
187   \catcode`)\active \xdef){(\right\string{})}
188 \endgroup

```

```

189 \mathcode`("=8000 \mathcode`)=8000
190 \typeout{mandi: parentheses made adjustable in math mode.}

This block of code fixes square root symbol.

191 \let\oldr@@t\r@@t
192 \def\r@@t#1#2{%
193 \setbox0=\hbox{\(\oldr@@t#1{#2},\)}\dimen0=\ht0
194 \advance\dimen0-0.2\ht0
195 \setbox2=\hbox{\vrule height\ht0 depth -\dimen0}%
196 {\box0\lower0.4pt\box2}}
197 \LetLtxMacro{\oldsqrt}{\sqrt}
198 \renewcommand*{\sqrt}[2][\relax]{\oldsqrt[#1]{#2}}
199 \typeout{mandi: square root symbol fixed.}

SI base unit of length or spatial displacement
200 \newcommand{\m}{\metre}

SI base unit of mass
201 \newcommand{\kg}{\kilogram}

SI base unit of time or temporal displacement
202 \newcommand{\s}{\second}

SI base unit of electric current
203 \newcommand{\A}{\ampere}

SI base unit of thermodynamic temperature
204 \newcommand{\K}{\kelvin}

SI base unit of amount
205 \newcommand{\mol}{\mole}

SI base unit of luminous intensity
206 \newcommand{\cd}{\candela}

207 \newphysicsquantity{displacement}{\m}{\m}
208 \newphysicsquantity{mass}{\kg}{\kg}{\kg}
209 \newphysicsquantity{duration}{\s}{\s}{\s}
210 \newphysicsquantity{current}{\A}{\A}{\A}
211 \newphysicsquantity{temperature}{\K}{\K}{\K}
212 \newphysicsquantity{amount}{\mol}{\mol}{\mol}
213 \newphysicsquantity{luminous}{\cd}{\cd}{\cd}
214 \newphysicsquantity{planeangle}{\m\us{k}\reciprocal\m}{\rad}{\rad}
215 \newphysicsquantity{solidangle}{\m\squared\us{k}\reciprocal\m}{\sr}{\sr}
216 \newcommand{\indegrees}[1]{\ensuremath{\unit{#1}{\degree}}}
217 \newcommand{\inFarenheit}[1]{\ensuremath{\unit{#1}{\degree\mathbf{F}}}}
218 \newcommand{\inCelsius}[1]{\ensuremath{\unit{#1}{\degree\mathbf{C}}}}
219 \newcommand{\inarcminutes}[1]{\ensuremath{\unit{#1}{\arcminute}}}
220 \newcommand{\inarcseconds}[1]{\ensuremath{\unit{#1}{\arcsecond}}}
221 \newcommand{\ineV}[1]{\ensuremath{\unit{#1}{\electronvolt}}}
222 \newcommand{\inMeVcs}[1]{\ensuremath{\unit{#1}{\mathbf{MeV}}\per\mathbf{msup{c}{2}}}}
223 \newcommand{\inMeVoc}[1]{\ensuremath{\unit{#1}{\mathbf{MeV}}\per c}}
224 \newcommand{\inAU}[1]{\ensuremath{\unit{#1}{\mathbf{AU}}}}
225 \newcommand{\inly}[1]{\ensuremath{\unit{#1}{\mathbf{ly}}}}

```

```

226 \newcommand{\incyr}[1]{\ensuremath{\unit{#1}{c\mathbf{usk}\mathrm{year}}}}
227 \newcommand{\inpc}[1]{\ensuremath{\unit{#1}{\mathrm{pc}}}}
228 \newcommand{\insolarL}[1]{\ensuremath{\unit{#1}{\mathrm{L}_{\mathrm{solar}}}}}
229 \newcommand{\insolarT}[1]{\ensuremath{\unit{#1}{\mathrm{T}_{\mathrm{solar}}}}}
230 \newcommand{\insolarR}[1]{\ensuremath{\unit{#1}{\mathrm{R}_{\mathrm{solar}}}}}
231 \newcommand{\insolarM}[1]{\ensuremath{\unit{#1}{\mathrm{M}_{\mathrm{solar}}}}}
232 \newcommand{\insolarF}[1]{\ensuremath{\unit{#1}{\mathrm{F}_{\mathrm{solar}}}}}
233 \newcommand{\insolarf}[1]{\ensuremath{\unit{#1}{\mathrm{f}_{\mathrm{solar}}}}}
234 \newcommand{\insolarMag}[1]{\ensuremath{\unit{#1}{\mathrm{M}_{\mathrm{agsolar}}}}}
235 \newcommand{\insolarmag}[1]{\ensuremath{\unit{#1}{\mathrm{m}_{\mathrm{agsolar}}}}}
236 \newcommand{\insolarD}[1]{\ensuremath{\unit{#1}{\mathrm{D}_{\mathrm{solar}}}}}
237 \newcommand{\insolard}[1]{\ensuremath{\unit{#1}{\mathrm{d}_{\mathrm{solar}}}}}
238 \newcommand{\velocityc}[1]{\ensuremath{\unit{#1}{\mathrm{c}}}}
239 \newphysicsquantity{velocity}{\mathbf{m}\mathbf{usk}\mathbf{reciprocal}\mathbf{s}}[\mathbf{m}\mathbf{usk}\mathbf{reciprocal}\mathbf{s}][\mathbf{m}\mathbf{per}\mathbf{s}]
240 \newphysicsquantity{acceleration}{\mathbf{m}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{N}\mathbf{per}\mathbf{kg}][\mathbf{m}\mathbf{per}\mathbf{s}\mathbf{squared}]
241 \newcommand{\lorentz}[1]{\ensuremath{\unit{#1}{\mathrm{c}}}}
242 \newphysicsquantity{momentum}{\mathbf{m}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{reciprocal}\mathbf{s}}[\mathbf{N}\mathbf{usk}\mathbf{s}][\mathbf{kg}\mathbf{usk}\mathbf{m}\mathbf{per}\mathbf{s}]
243 \newphysicsquantity{impulse}{\mathbf{m}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{N}\mathbf{usk}\mathbf{s}][\mathbf{kg}\mathbf{usk}\mathbf{m}\mathbf{per}\mathbf{s}]
244 \newphysicsquantity{force}{\mathbf{m}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{N}][\mathbf{N}]
245 \newphysicsquantity{springstiffness}{\mathbf{kg}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{N}\mathbf{per}\mathbf{m}][\mathbf{N}\mathbf{per}\mathbf{m}]
246 \newphysicsquantity{springstretch}{\mathbf{m}}
247 \newphysicsquantity{area}{\mathbf{m}\mathbf{squared}}
248 \newphysicsquantity{volume}{\mathbf{cubic}\mathbf{m}}
249 \newphysicsquantity{linemassdensity}{\mathbf{reciprocal}\mathbf{m}\mathbf{usk}\mathbf{kg}}[\mathbf{kg}\mathbf{per}\mathbf{m}][\mathbf{kg}\mathbf{per}\mathbf{m}]
250 \newphysicsquantity{areamassdensity}{\mathbf{m}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{kg}\mathbf{per}\mathbf{m}\mathbf{squared}]
251 [\mathbf{kg}\mathbf{per}\mathbf{m}\mathbf{squared}]
252 \newphysicsquantity{volumemassdensity}{\mathbf{m}\mathbf{reciprocal}\mathbf{cubed}\mathbf{usk}\mathbf{kg}}[\mathbf{kg}\mathbf{per}\mathbf{m}\mathbf{cubed}]
253 [\mathbf{kg}\mathbf{per}\mathbf{m}\mathbf{cubed}]
254 \newphysicsquantity{youngsmodulus}{\mathbf{reciprocal}\mathbf{m}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{N}\mathbf{per}\mathbf{m}\mathbf{squared}]
255 [\mathbf{Pa}]
256 \newphysicsquantity{work}{\mathbf{m}\mathbf{squared}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{J}][\mathbf{N}\mathbf{usk}\mathbf{m}]
257 \newphysicsquantity{energy}{\mathbf{m}\mathbf{squared}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{J}][\mathbf{N}\mathbf{usk}\mathbf{m}]
258 \newphysicsquantity{power}{\mathbf{m}\mathbf{squared}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{cubed}}[\mathbf{W}][\mathbf{J}\mathbf{per}\mathbf{s}]
259 \newphysicsquantity{angularvelocity}{\mathbf{rad}\mathbf{usk}\mathbf{reciprocal}\mathbf{s}}[\mathbf{rad}\mathbf{per}\mathbf{s}][\mathbf{rad}\mathbf{per}\mathbf{s}]
260 \newphysicsquantity{angularacceleration}{\mathbf{rad}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{rad}\mathbf{per}\mathbf{s}\mathbf{squared}]
261 [\mathbf{rad}\mathbf{per}\mathbf{s}\mathbf{squared}]
262 \newphysicsquantity{angularmomentum}{\mathbf{m}\mathbf{squared}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{reciprocal}\mathbf{s}}[\mathbf{J}\mathbf{usk}\mathbf{s}]
263 [\mathbf{kg}\mathbf{usk}\mathbf{m}\mathbf{squared}\mathbf{per}\mathbf{s}]
264 \newphysicsquantity{momentofinertia}{\mathbf{m}\mathbf{squared}\mathbf{usk}\mathbf{kg}}[\mathbf{J}\mathbf{usk}\mathbf{s}\mathbf{squared}][\mathbf{kg}\mathbf{usk}\mathbf{m}\mathbf{squared}]
265 \newphysicsquantity{torque}{\mathbf{m}\mathbf{squared}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{J}\mathbf{per}\mathbf{rad}][\mathbf{N}\mathbf{usk}\mathbf{m}]
266 \newphysicsquantity{entropy}{\mathbf{m}\mathbf{squared}\mathbf{usk}\mathbf{kg}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}\mathbf{reciprocal}\mathbf{s}}[\mathbf{J}\mathbf{per}\mathbf{K}][\mathbf{J}\mathbf{per}\mathbf{K}]
267 [\mathbf{J}\mathbf{per}\mathbf{K}][\mathbf{J}\mathbf{per}\mathbf{K}]
268 \newphysicsquantity{wavelength}{\mathbf{m}}[\mathbf{m}][\mathbf{m}]
269 \newphysicsquantity{wavenumber}{\mathbf{reciprocal}\mathbf{m}}[\mathbf{per}\mathbf{m}][\mathbf{per}\mathbf{m}]
270 \newphysicsquantity{frequency}{\mathbf{reciprocal}\mathbf{s}}[\mathbf{hertz}][\mathbf{hertz}]
271 \newphysicsquantity{angularfrequency}{\mathbf{rad}\mathbf{usk}\mathbf{reciprocal}\mathbf{s}}[\mathbf{rad}\mathbf{per}\mathbf{s}][\mathbf{rad}\mathbf{per}\mathbf{s}]
272 \newphysicsquantity{charge}{\mathbf{A}\mathbf{usk}\mathbf{s}}[\mathbf{C}][\mathbf{C}]
273 \newphysicsquantity{permittivity}{\mathbf{reciprocal}\mathbf{cubed}\mathbf{usk}\mathbf{reciprocal}\mathbf{kg}\mathbf{usk}\mathbf{s}\mathbf{reciprocal}\mathbf{quarted}\mathbf{usk}\mathbf{A}\mathbf{squared}}
274 [\mathbf{F}\mathbf{per}\mathbf{m}][\mathbf{C}\mathbf{squared}\mathbf{per}\mathbf{N}\mathbf{usk}\mathbf{m}\mathbf{squared}]

```

```

276 \newphysicsquantity{permeability}
277 {\m\usk\kg\usk\s\reciprocalssquared\usk\A\reciprocalssquared}[\henry\per\m] [\T\usk\m\per\A]
278 \newphysicsquantity{electricfield}{\m\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}
279 [\V\per\m] [\N\per\C]
280 \newphysicsquantity{electricdipolemoment}{\m\usk\s\usk\A}[\C\usk\m] [\C\usk\m]
281 \newphysicsquantity{electricflux}{\m\cubed\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}
282 [\V\usk\m] [\N\usk\m\squared\per\C]
283 \newphysicsquantity{magneticfield}{\kg\usk\s\reciprocalssquared\usk\reciprocal\A}[\T]
284 [\N\per\C\usk(\m\per\s)] % also \Wb\per\m\squared
285 \newphysicsquantity{magneticflux}
286 {\m\squared\usk\kg\usk\s\reciprocalssquared\usk\reciprocal\A}[\volt\usk\s]
287 [\T\usk\m\squared] % also \Wb and \J\per\A
288 \newphysicsquantity{cmagneticfield}{\m\usk\kg\usk\s\reciprocalcubed\usk\reciprocal\A}
289 [\V\per\m] [\N\per\C]
290 \newphysicsquantity{linearchargedensity}{\reciprocal\m\usk\s\usk\A}[\C\per\m] [\C\per\m]
291 \newphysicsquantity{areachargedensity}{\reciprocal\m\usk\s\usk\A}
292 [\C\per\m\square] [\C\per\square\m]
293 \newphysicsquantity{volumechargedensity}{\reciprocal\m\usk\s\usk\A}
294 [\C\per\cubic\m] [\C\per\cubic\m]
295 \newphysicsquantity{mobility}
296 {\m\squared\usk\kg\usk\s\reciprocalquarted\usk\reciprocal\A}[\m\squared\per\volt\usk\s]
297 [(\m\per\s)\per(\N\per\C)]
298 \newphysicsquantity{numberdensity}{\reciprocal\m\per\cubic\m} [\per\cubic\m] [\per\cubic\m]
299 \newphysicsquantity{polarizability}{\reciprocal\kg\usk\s\quarted\usk\m\square\A}
300 [\C\usk\m\per\V] [\C\usk\m\per(\N\per\C)]
301 \newphysicsquantity{electricpotential}
302 {\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocal\A}[\J\per\C] [\V]
303 \newphysicsquantity{emf}{\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocal\A}
304 [\J\per\C] [\V]
305 \newphysicsquantity{dielectricconstant}{}[] []
306 \newphysicsquantity{indexofrefraction}{}[] []
307 \newphysicsquantity{relativepermittivity}{}[] []
308 \newphysicsquantity{relativepermeability}{}[] []
309 \newphysicsquantity{energydensity}{\m\reciprocal\m\usk\kg\usk\reciprocal\m\s}
310 [\J\per\cubic\m] [\J\per\cubic\m]
311 \newphysicsquantity{energyflux}{\kg\usk\s\reciprocalcubed}
312 [\W\per\m\squared] [\W\per\m\squared]
313 \newphysicsquantity{electroncurrent}{\reciprocal\s}
314 [\ensuremath{\mathbf{e}}\per\s] [\ensuremath{\mathbf{e}}\per\s]
315 \newphysicsquantity{conventionalcurrent}{\A}[\C\per\s] [\A]
316 \newphysicsquantity{magneticdipolemoment}{\square\m\usk\A}[\J\per\T] [\A\usk\square\m]
317 \newphysicsquantity{currentdensity}{\reciprocal\m\usk\A}[\C\usk\s\per\square\m]
318 [\A\per\square\m]
319 \newphysicsquantity{capacitance}
320 {\reciprocal\m\usk\reciprocal\kg\usk\quartic\s\usk\square\A}[\F] [\C\per\V]
321 % also \C\squared\per\N\usk\m, \s\per\ohm
322 \newphysicsquantity{inductance}
323 {\square\m\usk\kg\usk\reciprocal\s\usk\reciprocal\A}[\henry]
324 [\volt\usk\s\per\A] % also \square\m\usk\kg\per\C\squared, \Wb\per\A
325 \newphysicsquantity{conductivity}

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326 {\reciprocalcubic\m\usk\reciprocal\kg\usk\cubic\s\usk\square\A}[\siemens\per\m]
327 [(\A\per\square\m)\per(\V\per\m)]
328 \newphysicsquantity{resistivity}
329 {\cubic\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocalsquare\A}[\ohm\usk\m]
330 [(\V\per\m)\per(\A\per\square\m)]
331 \newphysicsquantity{resistance}
332 {\square\m\usk\kg\usk\reciprocalcubic\s\usk\reciprocalsquare\A}[\V\per\A] [\ohm]
333 \newphysicsquantity{conductance}
334 {\reciprocalsquare\m\usk\reciprocal\kg\usk\cubic\s\usk\square\A}[\A\per\V] [\siemens]
335 \newphysicsquantity{magneticcharge}{\m\usk\A}[\m\usk\A] [\m\usk\A]
336 \newcommand{\lv}{\ensuremath{\left\langle}}
337 \newcommand{\rv}{\ensuremath{\right\rangle}}
338 \newcommand{\symvect}{\mivector}
339 \newcommand{\ncompsvect}{\mivector}
340 \ExplSyntaxOn % Written in LaTeX3
341 \NewDocumentCommand{\magvectncomps}{ m O{} }
342 {%
343     \sum_of_squares:nn { #1 }{ #2 }
344 }%
345 \cs_new:Npn \sum_of_squares:nn #1 #2
346 {%
347     \tl_if_empty:nTF { #2 }
348     {%
349         \clist_set:Nn \l_tmpa_clist { #1 }
350         \ensuremath{%
351             \sqrt{(\clist_use:Nnnn \l_tmpa_clist { })^2+( } { })^2+( } { })^2+( } )^2 }
352     }%
353 }%
354 {%
355     \clist_set:Nn \l_tmpa_clist { #1 }
356     \ensuremath{%
357         \sqrt{(\clist_use:Nnnn \l_tmpa_clist { };{ #2 })^2+({ };{ #2 })^2+({ }
358             { #2 })^2+({ };{ #2 })^2 } }
359     }%
360 }%
361 }%
362 \ExplSyntaxOff
363 %
364 \newcommand{\zerovect}{\vect{0}}
365 \newcommand{\ncompszerovect}{\mivector{0,0,0}}
366 \ifthenelse{\boolean{@optitalicvectors}}
367   {\newcommand{\vect}[1]{\ensuremath{\vec{#1}}}}
368   {\newcommand{\vect}[1]{\ensuremath{\vec{\mathrm{#1}}}}}
369 \ifthenelse{\boolean{@optdoubleabsbars}}
370   {\newcommand{\magvect}[1]{\ensuremath{\mathrm{magof}\{\vect{#1}\}}}}
371   {\newcommand{\magvect}[1]{\ensuremath{\mathrm{abs}\{\vect{#1}\}}}}
372 \newcommand{\dmagvect}[1]{\ensuremath{\mathrm{dx}\{\magvect{#1}\}}}
373 \newcommand{\Dmagvect}[1]{\ensuremath{\mathrm{Delta}\!\!\!/\!\!\!\mathrm{magvect}\{#1\}}}
374 \ifthenelse{\boolean{@optitalicvectors}}
375   {\newcommand{\dirvect}[1]{\ensuremath{\widehat{\#1}}}}

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376  {\newcommand{\dirvect}[1]{\ensuremath{\widehat{\mathbf{#1}}}}}
377 \ifthenelse{\boolean{@optitalicvectors}}
378  {\newcommand{\compvect}[2]{\ensuremath{\mathbf{s}_{\mathbf{#1}\mathbf{#2}}}}}
379  {\newcommand{\compvect}[2]{\ensuremath{\mathbf{s}_{\mathbf{#1}\mathbf{#2}}}}}
380 \newcommand{\scmpsvect}[1]{\ensuremath{\mathbf{l}_{\mathbf{v}}}
381  \mathbf{c}_{\mathbf{#1}\mathbf{x}},}
382  \mathbf{c}_{\mathbf{#1}\mathbf{y}},}
383  \mathbf{c}_{\mathbf{#1}\mathbf{z}\mathbf{r}_{\mathbf{v}}}}
384 \newcommand{\magvectscomps}[1]{\ensuremath{\sqrt{
385  \mathbf{m}^2_{\mathbf{c}_{\mathbf{#1}\mathbf{x}}}\mathbf{+}
386  \mathbf{m}^2_{\mathbf{c}_{\mathbf{#1}\mathbf{y}}}\mathbf{+}
387  \mathbf{m}^2_{\mathbf{c}_{\mathbf{#1}\mathbf{z}}}}}}
388 \newcommand{\dvect}[1]{\ensuremath{\mathbf{d}_{\mathbf{v}_{\mathbf{#1}}}}}
389 \newcommand{\Dvect}[1]{\ensuremath{\Delta_{\mathbf{v}_{\mathbf{#1}}}}}
390 \newcommand{\dirdvect}[1]{\ensuremath{\widehat{\mathbf{d}_{\mathbf{v}_{\mathbf{#1}}}}}}
391 \newcommand{\dirDvect}[1]{\ensuremath{\widehat{\mathbf{\Delta}_{\mathbf{v}_{\mathbf{#1}}}}}}
392 \newcommand{\ddirvect}[1]{\ensuremath{\mathbf{d}_{\mathbf{d}_{\mathbf{v}_{\mathbf{#1}}}}}}
393 \newcommand{\DDirvect}[1]{\ensuremath{\Delta_{\mathbf{d}_{\mathbf{v}_{\mathbf{#1}}}}}}
394 \ifthenelse{\boolean{@optdoubleabsbars}}
395  {\newcommand{\magdvect}[1]{\ensuremath{\mathbf{m}_{\mathbf{d}_{\mathbf{v}_{\mathbf{#1}}}}}}}
396  {\newcommand{\magDvect}[1]{\ensuremath{\mathbf{m}_{\mathbf{\Delta}_{\mathbf{v}_{\mathbf{#1}}}}}}}
397  {\newcommand{\magdvect}[1]{\ensuremath{\mathbf{a}_{\mathbf{d}_{\mathbf{v}_{\mathbf{#1}}}}}}}
398  {\newcommand{\magDvect}[1]{\ensuremath{\mathbf{a}_{\mathbf{\Delta}_{\mathbf{v}_{\mathbf{#1}}}}}}}
399 \newcommand{\compdvect}[2]{\ensuremath{\mathbf{d}_{\mathbf{c}_{\mathbf{#1}\mathbf{#2}}}}}
400 \newcommand{\compDvect}[2]{\ensuremath{\Delta_{\mathbf{c}_{\mathbf{#1}\mathbf{#2}}}}}
401 \newcommand{\scmpsdvect}[1]{\ensuremath{\mathbf{l}_{\mathbf{v}}}
402  \mathbf{c}_{\mathbf{#1}\mathbf{x}},}
403  \mathbf{c}_{\mathbf{#1}\mathbf{y}},}
404  \mathbf{c}_{\mathbf{#1}\mathbf{z}\mathbf{r}_{\mathbf{v}}}}
405 \newcommand{\scmpsDvect}[1]{\ensuremath{\mathbf{l}_{\mathbf{v}}}
406  \mathbf{c}_{\mathbf{#1}\mathbf{x}},}
407  \mathbf{c}_{\mathbf{#1}\mathbf{y}},}
408  \mathbf{c}_{\mathbf{#1}\mathbf{z}\mathbf{r}_{\mathbf{v}}}}
409 \newcommand{\dervect}[2]{\frac{\mathbf{d}_{\mathbf{v}_{\mathbf{#1}}}}{\mathbf{d}_{\mathbf{v}_{\mathbf{#2}}}}}
410 \newcommand{\Dervect}[2]{\frac{\mathbf{\Delta}_{\mathbf{v}_{\mathbf{#1}}}}{\mathbf{\Delta}_{\mathbf{v}_{\mathbf{#2}}}}}
411 \newcommand{\compdervect}[3]{\frac{\mathbf{d}_{\mathbf{b}_{\mathbf{y}_{\mathbf{#1}}\mathbf{#2}}}}{\mathbf{d}_{\mathbf{b}_{\mathbf{y}_{\mathbf{#3}}}}}}
412 \newcommand{\compDervect}[3]{\frac{\mathbf{\Delta}_{\mathbf{b}_{\mathbf{y}_{\mathbf{#1}}\mathbf{#2}}}}{\mathbf{\Delta}_{\mathbf{b}_{\mathbf{y}_{\mathbf{#3}}}}}}
413 \newcommand{\scmpsdervect}[2]{\ensuremath{\mathbf{l}_{\mathbf{v}}}
414  \mathbf{c}_{\mathbf{#1}\mathbf{x}\mathbf{#2}},}
415  \mathbf{c}_{\mathbf{#1}\mathbf{y}\mathbf{#2}},}
416  \mathbf{c}_{\mathbf{#1}\mathbf{z}\mathbf{#2}\mathbf{r}_{\mathbf{v}}}}
417 \newcommand{\scmpsDervect}[2]{\ensuremath{\mathbf{l}_{\mathbf{v}}}
418  \mathbf{c}_{\mathbf{#1}\mathbf{x}\mathbf{#2}},}
419  \mathbf{c}_{\mathbf{#1}\mathbf{y}\mathbf{#2}},}
420  \mathbf{c}_{\mathbf{#1}\mathbf{z}\mathbf{#2}\mathbf{r}_{\mathbf{v}}}}
421 \ifthenelse{\boolean{@optdoubleabsbars}}
422  {\newcommand{\magdervect}[2]{\ensuremath{\mathbf{m}_{\mathbf{d}_{\mathbf{v}_{\mathbf{#1}\mathbf{#2}}}}}}}
423  {\newcommand{\magDervect}[2]{\ensuremath{\mathbf{m}_{\mathbf{\Delta}_{\mathbf{v}_{\mathbf{#1}\mathbf{#2}}}}}}}
424  {\newcommand{\magdervect}[2]{\ensuremath{\mathbf{a}_{\mathbf{d}_{\mathbf{v}_{\mathbf{#1}\mathbf{#2}}}}}}}
425  {\newcommand{\magDervect}[2]{\ensuremath{\mathbf{a}_{\mathbf{\Delta}_{\mathbf{v}_{\mathbf{#1}\mathbf{#2}}}}}}}

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426 \newcommand{\dermagvect}[2]{\ensuremath{\mathrm{dbyd}\{\mathrm{magvect}\{#1\}\{#2\}\}}}
427 \newcommand{\Dermagvect}[2]{\ensuremath{\mathrm{DbyD}\{\mathrm{magvect}\{#1\}\{#2\}\}}}
428 \newcommand{\scompspos}{\mivector{x,y,z}}
429 \newcommand{\comppos}[1]{\ensuremath{\{#1\}}}
430 \newcommand{\scompsdpos}{\mivector{\mathrm{d}x,\mathrm{d}y,\mathrm{d}z}}
431 \newcommand{\scompsDpos}{\mivector{\Delta x,\Delta y,\Delta z}}
432 \newcommand{\compdpos}[1]{\ensuremath{\mathrm{mathrm}\{d\}\{#1\}}}
433 \newcommand{\compDpos}[1]{\ensuremath{\mathrm{Delta}\{#1\}}}
434 \newcommand{\scompsderpos}[1]{\ensuremath{\mathrm{ensuremath}\{\mathrm{lv}}}
435   \frac{\mathrm{mathrm}\{d\}x}{\mathrm{mathrm}\{d\}y},\frac{\mathrm{mathrm}\{d\}y}{\mathrm{mathrm}\{d\}z},\frac{\mathrm{mathrm}\{d\}z}{\mathrm{mathrm}\{d\}x}\mathrm{rv}\}}
436 \newcommand{\scompsDerpos}[1]{\ensuremath{\mathrm{ensuremath}\{\mathrm{lv}}}
437 \frac{\Delta x}{\Delta y},\frac{\Delta y}{\Delta z},\frac{\Delta z}{\Delta x}\mathrm{rv}\}}
438 \newcommand{\compperpos}[2]{\frac{\mathrm{frac}\{\mathrm{mathrm}\{d\}x\}\{\mathrm{mathrm}\{d\}y\}}{\mathrm{frac}\{\mathrm{mathrm}\{d\}y\}\{\mathrm{mathrm}\{d\}z\}}}
439 \frac{\mathrm{frac}\{\mathrm{mathrm}\{d\}z\}\{\mathrm{mathrm}\{d\}x\}}{\mathrm{frac}\{\mathrm{mathrm}\{d\}x\}\{\mathrm{mathrm}\{d\}y\}}\mathrm{rv}\}}
440 \newcommand{\compDerpos}[2]{\frac{\mathrm{frac}\{\mathrm{mathrm}\{d\}x\}\{\mathrm{mathrm}\{d\}y\}}{\mathrm{frac}\{\mathrm{mathrm}\{d\}y\}\{\mathrm{mathrm}\{d\}z\}}}
441 \newcommand{\compDerpos}[2]{\frac{\mathrm{frac}\{\mathrm{mathrm}\{d\}x\}\{\mathrm{mathrm}\{d\}y\}}{\mathrm{frac}\{\mathrm{mathrm}\{d\}y\}\{\mathrm{mathrm}\{d\}z\}}}
442 \newcommand{\vectsub}[2]{\ssub{\mathrm{vect}\{#1\}}{\mathrm{#2}}}
443 \ifthenelse{\boolean{@optitalicvectors}}
444 {\newcommand{\compvectsub}[3]{\ssub{\mathrm{#1}}{\mathrm{(#2\),#3}}}}
445 {\newcommand{\compvectsub}[3]{\ssub{\mathrm{#1}}{\mathrm{(#2\),#3}}}}
446 \newcommand{\scompsvectsub}[2]{\mathrm{lv}}
447 \compvectsub{\mathrm{#1}}{\mathrm{x}}{\mathrm{#2}},\\
448 \compvectsub{\mathrm{#1}}{\mathrm{y}}{\mathrm{#2}},\\
449 \compvectsub{\mathrm{#1}}{\mathrm{z}}{\mathrm{#2}}\mathrm{rv}\}}
450 \ifthenelse{\boolean{@optdoubleabsbars}}
451 {\newcommand{\magvectsub}[2]{\mathrm{magof}\{\mathrm{vectsub}\{#1\}\{#2\}\}}}
452 {\newcommand{\magvectsub}[2]{\mathrm{abs}\{\mathrm{vectsub}\{#1\}\{#2\}\}}}
453 \newcommand{\magvectsubscoms}[2]{\mathrm{sqrt}\{
454   \mathrm{msup}\{\mathrm{compvectsub}\{#1\}\mathrm{x}\}\{#2\}\}\{2\}+\\
455   \mathrm{msup}\{\mathrm{compvectsub}\{#1\}\mathrm{y}\}\{#2\}\}\{2\}+\\
456   \mathrm{msup}\{\mathrm{compvectsub}\{#1\}\mathrm{z}\}\{#2\}\}\{2\}\}}
457 \ifthenelse{\boolean{@optitalicvectors}}
458 {\newcommand{\dirvectsub}[2]{\ssub{\widehat{\mathrm{#1}}}{\mathrm{#2}}}}
459 {\newcommand{\dirvectsub}[2]{\ssub{\widehat{\mathrm{mathrm}\{#1\}}}{\mathrm{#2}}}}
460 \newcommand{\dvectsub}[2]{\mathrm{mathrm}\{d\}\mathrm{vectsub}\{#1\}\{#2\}}}
461 \newcommand{\Dvectsub}[2]{\mathrm{Delta}\mathrm{vectsub}\{#1\}\{#2\}}}
462 \newcommand{\compdvectsub}[3]{\mathrm{mathrm}\{d\}\mathrm{compvectsub}\{#1\}\{#2\}\{#3\}}}
463 \newcommand{\compDvectsub}[3]{\mathrm{Delta}\mathrm{compvectsub}\{#1\}\{#2\}\{#3\}}}
464 \newcommand{\scompsdvectsub}[2]{\mathrm{lv}}
465 \compdvectsub{\mathrm{#1}}{\mathrm{x}}{\mathrm{#2}},\\
466 \compdvectsub{\mathrm{#1}}{\mathrm{y}}{\mathrm{#2}},\\
467 \compdvectsub{\mathrm{#1}}{\mathrm{z}}{\mathrm{#2}}\mathrm{rv}\}}
468 \newcommand{\scompsDvectsub}[2]{\mathrm{lv}}
469 \compDvectsub{\mathrm{#1}}{\mathrm{x}}{\mathrm{#2}},\\
470 \compDvectsub{\mathrm{#1}}{\mathrm{y}}{\mathrm{#2}},\\
471 \compDvectsub{\mathrm{#1}}{\mathrm{z}}{\mathrm{#2}}\mathrm{rv}\}}
472 \newcommand{\dermagvectsub}[3]{\mathrm{dbyd}\{\mathrm{magvectsub}\{#1\}\{#2\}\}\{#3\}}}
473 \newcommand{\Dermagvectsub}[3]{\mathrm{DbyD}\{\mathrm{magvectsub}\{#1\}\{#2\}\}\{#3\}}}
474 \newcommand{\dervectsub}[3]{\mathrm{dbyd}\{\mathrm{vectsub}\{#1\}\{#2\}\}\{#3\}}}
475 \newcommand{\Dervectsub}[3]{\mathrm{DbyD}\{\mathrm{vectsub}\{#1\}\{#2\}\}\{#3\}}}

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476 \ifthenelse{\boolean{@optdoubleabsbars}}
477   {\newcommand{\magdervectsub}[3]{\ensuremath{\text{magof}\{\text{dervectsub}\{#1\}\{#2\}\{#3\}}}}
478   \newcommand{\magDervectsub}[3]{\ensuremath{\text{magof}\{\text{Dervectsub}\{#1\}\{#2\}\{#3\}}}}
479   {\newcommand{\magdervectsub}[3]{\ensuremath{\text{abs}\{\text{dervectsub}\{#1\}\{#2\}\{#3\}}}}
480   \newcommand{\magDervectsub}[3]{\ensuremath{\text{abs}\{\text{Dervectsub}\{#1\}\{#2\}\{#3\}}}}
481 \newcommand{\compdervectsub}[4]{\ensuremath{\text{dbyd}\{\text{compvectsub}\{#1\}\{#2\}\{#3\}\{#4\}}}}
482 \newcommand{\compDervectsub}[4]{\ensuremath{\text{DbyD}\{\text{compvectsub}\{#1\}\{#2\}\{#3\}\{#4\}}}}
483 \newcommand{\scmpsdervectsub}[3]{\ensuremath{\text{lv}}
484   \text{compdervectsub}\{#1\}\{x\}\{#2\}\{#3\},
485   \text{compdervectsub}\{#1\}\{y\}\{#2\}\{#3\},
486   \text{compdervectsub}\{#1\}\{z\}\{#2\}\{#3\}\text{rv}}
487 \newcommand{\scmpsDervectsub}[3]{\ensuremath{\text{lv}}
488   \text{compDervectsub}\{#1\}\{x\}\{#2\}\{#3\},
489   \text{compDervectsub}\{#1\}\{y\}\{#2\}\{#3\},
490   \text{compDervectsub}\{#1\}\{z\}\{#2\}\{#3\}\text{rv}}
491 \newcommand{\comppossub}[2]{\ensuremath{\text{ssub}\{#1\}\{#2\}}}
492 \newcommand{\scmpspossub}[1]{\ensuremath{\text{lv}}
493   \text{comppossub}\{x\}\{#1\},
494   \text{comppossub}\{y\}\{#1\},
495   \text{comppossub}\{z\}\{#1\}\text{rv}}
496 \newcommand{\compdpossub}[2]{\ensuremath{\text{d}\text{comppossub}\{#1\}\{#2\}}}
497 \newcommand{\compDpossub}[2]{\ensuremath{\Delta\text{comppossub}\{#1\}\{#2\}}}
498 \newcommand{\scmpsdpossub}[1]{\ensuremath{\text{lv}}
499   \text{compdpossub}\{x\}\{#1\},
500   \text{compdpossub}\{y\}\{#1\},
501   \text{compdpossub}\{z\}\{#1\}\text{rv}}
502 \newcommand{\scmpsDpossub}[1]{\ensuremath{\text{lv}}
503   \text{compDpossub}\{x\}\{#1\},
504   \text{compDpossub}\{y\}\{#1\},
505   \text{compDpossub}\{z\}\{#1\}\text{rv}}
506 \newcommand{\compderpossub}[3]{\ensuremath{\text{dbyd}\{\text{comppossub}\{#1\}\{#2\}\{#3\}}}}
507 \newcommand{\compDerpossub}[3]{\ensuremath{\text{DbyD}\{\text{comppossub}\{#1\}\{#2\}\{#3\}}}}
508 \newcommand{\scmpsdDerpossub}[2]{\ensuremath{\text{lv}}
509   \text{compderpossub}\{x\}\{#1\}\{#2\},
510   \text{compderpossub}\{y\}\{#1\}\{#2\},
511   \text{compderpossub}\{z\}\{#1\}\{#2\}\text{rv}}
512 \newcommand{\scmpsDerpossub}[2]{\ensuremath{\text{lv}}
513   \text{compDerpossub}\{x\}\{#1\}\{#2\},
514   \text{compDerpossub}\{y\}\{#1\}\{#2\},
515   \text{compDerpossub}\{z\}\{#1\}\{#2\}\text{rv}}
516 \newcommand{\relpos}[1]{\ensuremath{\text{vectsub}\{r\}\{#1\}}}
517 \newcommand{\relvel}[1]{\ensuremath{\text{vectsub}\{v\}\{#1\}}}
518 \newcommand{\relmom}[1]{\ensuremath{\text{vectsub}\{p\}\{#1\}}}
519 \newcommand{\relfor}[1]{\ensuremath{\text{vectsub}\{F\}\{#1\}}}
520 \newcommand{\vectdotvect}[2]{\ensuremath{\{\text{#1}\}\text{bullet}\{\text{#2}\}}}
521 \newcommand{\vectdotsvect}[2]{\ensuremath{\text{scmpsvect}\{#1\}\text{bullet}\text{scmpsvect}\{#2\}}}
522 \newcommand{\vectdotevect}[2]{\ensuremath{\text{scmpsvect}\{#1\}\text{bullet}\text{scmpsvect}\{#2\}}}
523   \text{compvect}\{#1\}\{x\}\text{compvect}\{#2\}\{x\}+
524   \text{compvect}\{#1\}\{y\}\text{compvect}\{#2\}\{y\}+
525   \text{compvect}\{#1\}\{z\}\text{compvect}\{#2\}\{z\}}

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526 \newcommand{\vectdotpos}[1]{\ensuremath{\scompsvect{#1}\bullet\scompspos}}
527 \newcommand{\vectdotepon}[1]{\ensuremath{\scompsvect{#1}\bullet\scompspos}}
528   \compvect{#1}{x}\comppos{x}+
529   \compvect{#1}{y}\comppos{y}+
530   \compvect{#1}{z}\comppos{z}}}
531 \newcommand{\vectdotsdvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsdvect{#2}}}
532 \newcommand{\vectdotsDvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsDvect{#2}}}
533 \newcommand{\vectdoteddvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsdvect{#2}}}
534   \compvect{#1}{x}\compdvect{#2}{x}+
535   \compvect{#1}{y}\compdvect{#2}{y}+
536   \compvect{#1}{z}\compdvect{#2}{z}}}
537 \newcommand{\vectdoteDvect}[2]{\ensuremath{\scompsvect{#1}\bullet\scompsdvect{#2}}}
538   \compvect{#1}{x}\compDvect{#2}{x}+
539   \compvect{#1}{y}\compDvect{#2}{y}+
540   \compvect{#1}{z}\compDvect{#2}{z}}}
541 \newcommand{\vectdotsdpos}[1]{\ensuremath{\scompsvect{#1}\bullet\scompsdpos}}
542 \newcommand{\vectdotsDpos}[1]{\ensuremath{\scompsvect{#1}\bullet\scompsDpos}}
543 \newcommand{\vectdoteddpos}[1]{\ensuremath{\scompsvect{#1}\bullet\scompsdpos}}
544   \compvect{#1}{x}\compdpos{x}+
545   \compvect{#1}{y}\compdpos{y}+
546   \compvect{#1}{z}\compdpos{z}}}
547 \newcommand{\vectdoteDpos}[1]{\ensuremath{\scompsvect{#1}\bullet\scompsDpos}}
548   \compvect{#1}{x}\compDpos{x}+
549   \compvect{#1}{y}\compDpos{y}+
550   \compvect{#1}{z}\compDpos{z}}}
551 \newcommand{\vectsubdotsvectsub}[4]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsvectsub{#3}{#4}}}
552 \newcommand{\vectsubdotevectsub}[4]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsvectsub{#3}{#4}}}
553   \compvectsub{#1}{x}{#2}\compvectsub{#3}{x}{#4}+
554   \compvectsub{#1}{y}{#2}\compvectsub{#3}{y}{#4}+
555   \compvectsub{#1}{z}{#2}\compvectsub{#3}{z}{#4}}}
556 \newcommand{\vectsubdotsdvectsub}[4]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsdvectsub{#3}{#4}}}
557 \newcommand{\vectsubdotsDvectsub}[4]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsDvectsub{#3}{#4}}}
558 \newcommand{\vectsubdotteddvectsub}[4]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsDvectsub{#3}{#4}}}
559 \newcommand{\vectsubdoteDvectsub}[4]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsDvectsub{#3}{#4}}}
560   \scompsvectsub{#1}{#2}\bullet\scompsDvectsub{#3}{#4}}}
561 \newcommand{\vectsubdotteddvectsub}[4]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsdvectsub{#3}{#4}}}
562   \compvectsub{#1}{x}{#2}\compdvectsub{#3}{x}{#4}+
563   \compvectsub{#1}{y}{#2}\compdvectsub{#3}{y}{#4}+
564   \compvectsub{#1}{z}{#2}\compdvectsub{#3}{z}{#4}}}
565 \newcommand{\vectsubdoteDvectsub}[4]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsDvectsub{#3}{#4}}}
566   \compvectsub{#1}{x}{#2}\compDvectsub{#3}{x}{#4}+
567   \compvectsub{#1}{y}{#2}\compDvectsub{#3}{y}{#4}+
568   \compvectsub{#1}{z}{#2}\compDvectsub{#3}{z}{#4}}}
569 \newcommand{\vectsubdotsdvect}[3]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsdvect{#3}}}
570   \scompsvectsub{#1}{#2}\bullet\scompsdvect{#3}}}
571 \newcommand{\vectsubdotsDvect}[3]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsDvect{#3}}}
572   \scompsvectsub{#1}{#2}\bullet\scompsDvect{#3}}}
573 \newcommand{\vectsubdotteddvect}[3]{\ensuremath{\scompsvectsub{#1}{#2}\bullet\scompsDvect{#3}}}
574   \compvectsub{#1}{x}{#2}\compdvect{x}{#3}+
575   \compvectsub{#1}{y}{#2}\compdvect{y}{#3}+}
```

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576 \compvectsub{\#1}{z}{\#2}\compdvect{z}{\#3}}}
577 \newcommand{\vectsubdoteDvect}[3]{\ensuremath{
578 \compvectsub{\#1}{x}{\#2}\compDvect{x}{\#3}+
579 \compvectsub{\#1}{y}{\#2}\compDvect{y}{\#3}+
580 \compvectsub{\#1}{z}{\#2}\compDvect{z}{\#3}}}
581 \newcommand{\vectsubdotspos}[2]{\ensuremath{
582 \scompsvectsub{\#1}{\#2}\bullet\scompsdpos}}
583 \newcommand{\vectsubdotsDpos}[2]{\ensuremath{
584 \scompsvectsub{\#1}{\#2}\bullet\scompsDpos}}
585 \newcommand{\vectsubdotedpos}[2]{\ensuremath{
586 \compvectsub{\#1}{x}{\#2}\compdpos{x}+
587 \compvectsub{\#1}{y}{\#2}\compdpos{y}+
588 \compvectsub{\#1}{z}{\#2}\compdpos{z}}}
589 \newcommand{\vectsubdoteDpos}[2]{\ensuremath{
590 \compvectsub{\#1}{x}{\#2}\compDpos{x}+
591 \compvectsub{\#1}{y}{\#2}\compDpos{y}+
592 \compvectsub{\#1}{z}{\#2}\compDpos{z}}}
593 \newcommand{\dervectdotsvect}[3]{\ensuremath{
594 \scompsdervect{\#1}{\#2}\bullet\scompsvect{\#3}}}
595 \newcommand{\Dervectdotsvect}[3]{\ensuremath{
596 \scompsDervect{\#1}{\#2}\bullet\scompsvect{\#3}}}
597 \newcommand{\dervectdotevect}[3]{\ensuremath{
598 \compdervect{\#1}{x}{\#2}\compvect{x}{\#3}+
599 \compdervect{\#1}{y}{\#2}\compvect{y}{\#3}+
600 \compdervect{\#1}{z}{\#2}\compvect{z}{\#3}}}
601 \newcommand{\Dervectdotevect}[3]{\ensuremath{
602 \compDervect{\#1}{x}{\#2}\compvect{x}{\#3}+
603 \compDervect{\#1}{y}{\#2}\compvect{y}{\#3}+
604 \compDervect{\#1}{z}{\#2}\compvect{z}{\#3}}}
605 \newcommand{\vectdotsdervect}[3]{\ensuremath{
606 \scompsvect{\#1}\bullet\scompsdervect{\#2}{\#3}}}
607 \newcommand{\vectdotsDervect}[3]{\ensuremath{
608 \scompsvect{\#1}\bullet\scompsDervect{\#2}{\#3}}}
609 \newcommand{\vectdotedervect}[3]{\ensuremath{
610 \compvect{\#1}{x}\compdervect{\#2}{x}{\#3}+
611 \compvect{\#1}{y}\compdervect{\#2}{y}{\#3}+
612 \compvect{\#1}{z}\compdervect{\#2}{z}{\#3}}}
613 \newcommand{\vectdoteDervect}[3]{\ensuremath{
614 \compvect{\#1}{x}\compDervect{\#2}{x}{\#3}+
615 \compvect{\#1}{y}\compDervect{\#2}{y}{\#3}+
616 \compvect{\#1}{z}\compDervect{\#2}{z}{\#3}}}
617 \newcommand{\dervectdotpos}[2]{\ensuremath{
618 \scompsdervect{\#1}{\#2}\bullet\scompspos}}
619 \newcommand{\Dervectdotpos}[2]{\ensuremath{
620 \scompsDervect{\#1}{\#2}\bullet\scompspos}}
621 \newcommand{\dervectdotePos}[2]{\ensuremath{
622 \compdervect{\#1}{x}{\#2}\comppos{x}+
623 \compdervect{\#1}{y}{\#2}\comppos{y}+
624 \compdervect{\#1}{z}{\#2}\comppos{z}}}
625 \newcommand{\DervectdotePos}[2]{\ensuremath{

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626 \compDervect{\#1}{x}{\#2}\comppos{x}+
627 \compDervect{\#1}{y}{\#2}\comppos{y}+
628 \compDervect{\#1}{z}{\#2}\comppos{z}}}
629 \newcommand{\dervectdotsdvect}[3]{\ensuremath{
630 \scompsdervect{\#1}{\#2}\bullet\scompsdvect{\#3}}}
631 \newcommand{\DervectdotsDvect}[3]{\ensuremath{
632 \scompsDervect{\#1}{\#2}\bullet\scompsDvect{\#3}}}
633 \newcommand{\dervectdottedvect}[3]{\ensuremath{
634 \compdervect{\#1}{x}{\#2}\compdvect{\#3}{x}+
635 \compdervect{\#1}{y}{\#2}\compdvect{\#3}{y}+
636 \compdervect{\#1}{z}{\#2}\compdvect{\#3}{z}}}
637 \newcommand{\DervectdotDvect}[3]{\ensuremath{
638 \compDervect{\#1}{x}{\#2}\compDvect{\#3}{x}+
639 \compDervect{\#1}{y}{\#2}\compDvect{\#3}{y}+
640 \compDervect{\#1}{z}{\#2}\compDvect{\#3}{z}}}
641 \newcommand{\dervectdotsdpos}[2]{\ensuremath{
642 \scompsdervect{\#1}{\#2}\bullet\scompsdpos}}
643 \newcommand{\DervectdotsDpos}[2]{\ensuremath{
644 \scompsDervect{\#1}{\#2}\bullet\scompsDpos}}
645 \newcommand{\dervectdottedpos}[2]{\ensuremath{
646 \compdervect{\#1}{x}{\#2}\compdpos{x}+
647 \compdervect{\#1}{y}{\#2}\compdpos{y}+
648 \compdervect{\#1}{z}{\#2}\compdpos{z}}}
649 \newcommand{\DervectdotDpos}[2]{\ensuremath{
650 \compDervect{\#1}{x}{\#2}\compDpos{x}+
651 \compDervect{\#1}{y}{\#2}\compDpos{y}+
652 \compDervect{\#1}{z}{\#2}\compDpos{z}}}
653 \newcommand{\vectcrossvect}[2]{\ensuremath{\#1\times\#2}}
654 \newcommand{\ltriplecross}[3]{\ensuremath{(\#1\times\#2)\times\#3}}
655 \newcommand{\rtriplecross}[3]{\ensuremath{\#1\times(\#2\times\#3)}}
656 \newcommand{\ltriplescalar}[3]{\ensuremath{\#1\times\#2}\bullet\#3}}
657 \newcommand{\rtriplescalar}[3]{\ensuremath{\#1\bullet\#2\times\#3}}
658 \newcommand{\ezero}{\ensuremath{\msub{\mathbf{e}}{0}}}
659 \newcommand{\eone}{\ensuremath{\msub{\mathbf{e}}{1}}}
660 \newcommand{\etwo}{\ensuremath{\msub{\mathbf{e}}{2}}}
661 \newcommand{\ethree}{\ensuremath{\msub{\mathbf{e}}{3}}}
662 \newcommand{\efour}{\ensuremath{\msub{\mathbf{e}}{4}}}
663 \newcommand{\ek[1]}{\ensuremath{\msub{\mathbf{e}}{1}}}
664 \newcommand{\e}{\ek}
665 \newcommand{\uezero}{\ensuremath{\msub{\widehat{\mathbf{e}}}{0}}}
666 \newcommand{\ueone}{\ensuremath{\msub{\widehat{\mathbf{e}}}{1}}}
667 \newcommand{\uetwo}{\ensuremath{\msub{\widehat{\mathbf{e}}}{2}}}
668 \newcommand{\uethree}{\ensuremath{\msub{\widehat{\mathbf{e}}}{3}}}
669 \newcommand{\uefour}{\ensuremath{\msub{\widehat{\mathbf{e}}}{4}}}
670 \newcommand{\uek[1]}{\ensuremath{\msub{\widehat{\mathbf{e}}}{1}}}
671 \newcommand{\ue}{\uek}
672 \newcommand{\ezerozero}{\ek{00}}
673 \newcommand{\ezeroone}{\ek{01}}
674 \newcommand{\ezerotwo}{\ek{02}}
675 \newcommand{\ezerothree}{\ek{03}}

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676 \newcommand{\ezerofour}{\ek{04}}
677 \newcommand{\eoneone}{\ek{11}}
678 \newcommand{\eonetwo}{\ek{12}}
679 \newcommand{\eonethree}{\ek{13}}
680 \newcommand{\eonefour}{\ek{14}}
681 \newcommand{\etwoone}{\ek{21}}
682 \newcommand{\etwotwo}{\ek{22}}
683 \newcommand{\etwothree}{\ek{23}}
684 \newcommand{\etwofour}{\ek{24}}
685 \newcommand{\ethreeone}{\ek{31}}
686 \newcommand{\ethreetwo}{\ek{32}}
687 \newcommand{\ethreethree}{\ek{33}}
688 \newcommand{\ethreefour}{\ek{34}}
689 \newcommand{\efourone}{\ek{41}}
690 \newcommand{\efourtwo}{\ek{42}}
691 \newcommand{\efourthree}{\ek{43}}
692 \newcommand{\efourfour}{\ek{44}}
693 \newcommand{\euzero}{\ensuremath{\msup{\mathbf{e}}{0}}}
694 \newcommand{\euone}{\ensuremath{\msup{\mathbf{e}}{1}}}
695 \newcommand{\eutwo}{\ensuremath{\msup{\mathbf{e}}{2}}}
696 \newcommand{\euthree}{\ensuremath{\msup{\mathbf{e}}{3}}}
697 \newcommand{\eufour}{\ensuremath{\msup{\mathbf{e}}{4}}}
698 \newcommand{\euk}[1]{\ensuremath{\msup{\mathbf{e}}{#1}}}
699 \newcommand{\eu}{\euk}
700 \newcommand{\ezerozero}{\euk{00}}
701 \newcommand{\ezeroone}{\euk{01}}
702 \newcommand{\ezerotwo}{\euk{02}}
703 \newcommand{\ezerothree}{\euk{03}}
704 \newcommand{\ezerofour}{\euk{04}}
705 \newcommand{\eoneone}{\euk{11}}
706 \newcommand{\eonetwo}{\euk{12}}
707 \newcommand{\eonethree}{\euk{13}}
708 \newcommand{\eonefour}{\euk{14}}
709 \newcommand{\etwoone}{\euk{21}}
710 \newcommand{\etwotwo}{\euk{22}}
711 \newcommand{\etwothree}{\euk{23}}
712 \newcommand{\etwofour}{\euk{24}}
713 \newcommand{\ethreeone}{\euk{31}}
714 \newcommand{\ethreetwo}{\euk{32}}
715 \newcommand{\ethreethree}{\euk{33}}
716 \newcommand{\ethreefour}{\euk{34}}
717 \newcommand{\efourone}{\euk{41}}
718 \newcommand{\efourtwo}{\euk{42}}
719 \newcommand{\efourthree}{\euk{43}}
720 \newcommand{\efourfour}{\euk{44}}
721 \newcommand{\gzero}{\ensuremath{\msub{\mathbf{\gamma}}{0}}}
722 \newcommand{\gone}{\ensuremath{\msub{\mathbf{\gamma}}{1}}}
723 \newcommand{\gtwo}{\ensuremath{\msub{\mathbf{\gamma}}{2}}}
724 \newcommand{\gthree}{\ensuremath{\msub{\mathbf{\gamma}}{3}}}
725 \newcommand{\gfour}{\ensuremath{\msub{\mathbf{\gamma}}{4}}}

```

```

726 \newcommand{\gk}[1]{\ensuremath{\msub{\mathbf{\gamma}}{#1}}}
727 \newcommand{\g}{\gk}
728 \newcommand{\gzerozero}{\gk{00}}
729 \newcommand{\gzeroone}{\gk{01}}
730 \newcommand{\gzerotwo}{\gk{02}}
731 \newcommand{\gzerothree}{\gk{03}}
732 \newcommand{\gzerofour}{\gk{04}}
733 \newcommand{\goneone}{\gk{11}}
734 \newcommand{\gonetwo}{\gk{12}}
735 \newcommand{\gonethree}{\gk{13}}
736 \newcommand{\gonefour}{\gk{14}}
737 \newcommand{\gtwoone}{\gk{21}}
738 \newcommand{\gtwotwo}{\gk{22}}
739 \newcommand{\gtwothree}{\gk{23}}
740 \newcommand{\gtwofour}{\gk{24}}
741 \newcommand{\gthreeone}{\gk{31}}
742 \newcommand{\gthreetwo}{\gk{32}}
743 \newcommand{\gthreethree}{\gk{33}}
744 \newcommand{\gthreefour}{\gk{34}}
745 \newcommand{\gfourone}{\gk{41}}
746 \newcommand{\gfourtwo}{\gk{42}}
747 \newcommand{\gfourthree}{\gk{43}}
748 \newcommand{\gfourfour}{\gk{44}}
749 \newcommand{\guzero}{\ensuremath{\msup{\mathbf{\gamma}}{0}}}
750 \newcommand{\guone}{\ensuremath{\msup{\mathbf{\gamma}}{1}}}
751 \newcommand{\gutwo}{\ensuremath{\msup{\mathbf{\gamma}}{2}}}
752 \newcommand{\guthree}{\ensuremath{\msup{\mathbf{\gamma}}{3}}}
753 \newcommand{\gufour}{\ensuremath{\msup{\mathbf{\gamma}}{4}}}
754 \newcommand{\guk}[1]{\ensuremath{\msup{\mathbf{\gamma}}{#1}}}
755 \newcommand{\gu}{\guk}
756 \newcommand{\guzerozero}{\guk{00}}
757 \newcommand{\guzeroone}{\guk{01}}
758 \newcommand{\guzerotwo}{\guk{02}}
759 \newcommand{\guzerothree}{\guk{03}}
760 \newcommand{\guzerofour}{\guk{04}}
761 \newcommand{\guoneone}{\guk{11}}
762 \newcommand{\guonetwo}{\guk{12}}
763 \newcommand{\guonethree}{\guk{13}}
764 \newcommand{\guonefour}{\guk{14}}
765 \newcommand{\gutwoone}{\guk{21}}
766 \newcommand{\gutwotwo}{\guk{22}}
767 \newcommand{\gutwothree}{\guk{23}}
768 \newcommand{\gutwofour}{\guk{24}}
769 \newcommand{\guthreeone}{\guk{31}}
770 \newcommand{\guthreetwo}{\guk{32}}
771 \newcommand{\guthreethree}{\guk{33}}
772 \newcommand{\guthreefour}{\guk{34}}
773 \newcommand{\gfourone}{\guk{41}}
774 \newcommand{\gfourtwo}{\guk{42}}
775 \newcommand{\gfourthree}{\guk{43}}

```

```

776 \newcommand{\gufourfour}{\guk{44}}
777 \ExplSyntaxOn % Vectors formated as in M\&I, written in LaTeX3
778 \NewDocumentCommand{\mivector}{ O{,} m o }%
779 {%
780   \mi_vector:nn { #1 } { #2 }
781   \IfValueT{#3}{\;{#3}}
782 }%
783 \seq_new:N \l__mi_list_seq
784 \cs_new_protected:Npn \mi_vector:nn #1 #2
785 {%
786   \ensuremath{%
787     \seq_set_split:Nnn \l__mi_list_seq { , } { #2 }
788     \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \left\langle }
789     \seq_use:Nnnn \l__mi_list_seq { #1 } { #1 } { #1 }
790     \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \right\rangle }
791   }%
792 }%
793 \ExplSyntaxOff
794 \ExplSyntaxOn % Column and row vectors, written in LaTeX3
795 \seq_new:N \l__vector_arg_seq
796 \cs_new_protected:Npn \vector_main:nnnn #1 #2 #3 #4
797 {%
798   \seq_set_split:Nnn \l__vector_arg_seq { #3 } { #4 }
799   \begin{#1matrix}
800     \seq_use:Nnnn \l__vector_arg_seq { #2 } { #2 } { #2 }
801   \end{#1matrix}
802 }%
803 \NewDocumentCommand{\rowvector}{ O{,} m }
804 {%
805   \ensuremath{%
806     \vector_main:nnnn { p } { \cdot, } { #1 } { #2 }
807   }%
808 }%
809 \NewDocumentCommand{\colvector}{ O{,} m }
810 {%
811   \ensuremath{%
812     \vector_main:nnnn { p } { \cdot } { #1 } { #2 }
813   }%
814 }%
815 \ExplSyntaxOff
816 \newcommandx{\scompscvect}[2][1,usedefault]{%
817   \ifthenelse{\equal{#1}{}}{%
818   {%
819     \colvector{\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
820   }%
821   {%
822     \colvector{\msub{#2}{0},\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
823   }%
824 }%
825 \newcommandx{\scompsrvect}[2][1,usedefault]{%

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```

826 \ifthenelse{\equal{#1}{}}%
827 {%
828   \rowvector[,]{\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
829 }%
830 {%
831   \rowvector[,]{\msub{#2}{0},\msub{#2}{1},\msub{#2}{2},\msub{#2}{3}}%
832 }%
833 }%
834 \newphysicsconstant{oofpez}{\ensuremath{\frac{1}{4\pi\epsilon_0}}}
835 {\scin[8.9876]{9}}{\m\cubed\usk\kg\usk\reciprocalquartic\s\usk\A\reciprocalssquared}
836 [\m\per\farad][\newton\usk\m\squared\per\coulomb\squared]
837 \newcommand{\coulombconstant}{\oofpez}
838 \newphysicsconstant{oofpezcs}{\ensuremath{\frac{1}{4\pi\epsilon_0}}}
839 {\scin[-7]}{\m\usk\kg\usk\s\reciprocalssquared\usk\A\reciprocalssquared}
840 [\T\usk\m\squared][\N\usk\s\squared\per\c\squared]
841 \newcommand{\altcoulombconstant}{\oofpezcs}
842 \newphysicsconstant{vacuumpermittivity}{\ssub{\epsilon_0}}{\scin[8.8542]{-12}}
843 {\m\reciprocalcubed\usk\reciprocal\kg\usk\s\quartered\usk\A\squared}[\F\per\m]
844 [\c\squared\per\N\usk\m\squared]
845 \newphysicsconstant{mzofp}{\ensuremath{\frac{\mu_0}{4\pi}}}
846 {\scin[-7]}{\m\usk\kg\usk\s\reciprocalssquared\usk\A\reciprocalssquared}
847 [\henry\per\m][\tesla\usk\m\per\A]
848 \newcommand{\biotsavartconstant}{\mzofp}
849 \newphysicsconstant{vacuumpermeability}{\ssub{\mu_0}}{\scin[4\pi]{-7}}
850 {\m\usk\kg\usk\s\reciprocalssquared\usk\A\reciprocalssquared}[\henry\per\m]
851 [\T\usk\m\per\A]
852 \newphysicsconstant{boltzmann}{\ssub{k}{B}}{\scin[1.3806]{-23}}
853 {\m\squared\usk\kg\usk\reciprocalsquare\s\usk\reciprocal\K}[\joule\per\K][\J\per\K]
854 \newcommand{\boltzmannconstant}{\boltzmann}
855 \newphysicsconstant{boltzmanninev}{\ssub{k}{B}}{\scin[8.6173]{-5}}
856 {\eV\usk\reciprocal\K}[\eV\per\K][\eV\per\K]
857 \newphysicsconstant{stefanboltzmann}{\sigma}{\scin[5.6704]{-8}}
858 {\kg\usk\s\reciprocalcubed\usk\K\reciprocalquarted}[\W\per\m\squared\usk\K^4]
859 [\W\per\m\squared\usk\K\quartered]
860 \newcommand{\stefanboltzmannconstant}{\stefanboltzmann}
861 \newphysicsconstant{planck}{\h}{\scin[6.6261]{-34}}
862 {\m\squared\usk\kg\usk\reciprocal\s}[\J\usk\s][\J\usk\s]
863 \newcommand{\planckconstant}{\planck}
864 \newphysicsconstant{planckinev}{\h}{\scin[4.1357]{-15}}
865 {\eV\usk\s}[\eV\usk\s][\eV\usk\s]
866 \newphysicsconstant{planckbar}{\hbar}{\scin[1.0546]{-34}}
867 {\m\squared\usk\kg\usk\reciprocal\s}[\J\usk\s][\J\usk\s]
868 \newcommand{\reducedplanckconstant}{\planckbar}
869 \newphysicsconstant{planckbarinev}{\hbar}{\scin[6.5821]{-16}}
870 {\eV\usk\s}[\eV\usk\s][\eV\usk\s]
871 \newphysicsconstant{planckc}{\hc}{\scin[1.9864]{-25}}
872 {\m\cubed\usk\kg\usk\reciprocalsquare\s}[\J\usk\m][\J\usk\m]
873 \newcommand{\planckconstanttimesc}{\planckc}
874 \newphysicsconstant{planckcinev}{\hc}{\scin[1.9864]{-25}}
875 {\eV\usk\ensuremath{\mathrm{n}}\m}[\eV\usk\ensuremath{\mathrm{n}}\m]

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876 [ $\text{eV}$ ] $\text{\uskip}\text{\ensuremath{\mathit{n}}}$  $\text{\uskip}\text{\m}$ ]
877 \newphysicsconstant{rydberg}{\ensuremath{\text{\msub{R}{\infty}}}}{\text{\scin[1.0974]{7}}}
878 {\reciprocal{\m}}[\reciprocal{\m}][\reciprocal{\m}]
879 \newcommand{\rydbergconstant}{\rydberg}
880 \newphysicsconstant{bohradius}{\ensuremath{\text{\msub{a}{0}}}}{\text{\scin[5.2918]{-11}}}{\m}{\m}
881 \newphysicsconstant{finestructure}{\ensuremath{\text{\alpha}}}{\text{\scin[7.2974]{-3}}}{\relax}
882 \newcommand{\finestructureconstant}{\finestructure}
883 \newphysicsconstant{avogadro}{\ensuremath{\text{\ssub{N}{A}}}}{\text{\scin[6.0221]{23}}}
884 {\reciprocal{\mol}}[\reciprocal{\mol}][\reciprocal{\mol}]
885 \newcommand{\avogadroconstant}{\avogadro}
886 \newphysicsconstant{universalgrav}{\ensuremath{\text{G}}}{\text{\scin[6.6738]{-11}}}
887 {\m}{\cubed}\text{\uskip}\text{\reciprocal{\kg}}\text{\uskip}\text{\s}\text{\reciprocal{\s}}{\text{\J}}\text{\uskip}\text{\m}\text{\per}\text{\kg}{\text{\squared}}
888 [\N\text{\uskip}\text{\m}{\text{\squared}}\text{\per}\text{\kg}{\text{\squared}}]
889 \newcommand{\universalgravitationalconstant}{\universalgrav}
890 \newphysicsconstant{surfacegravfield}{\ensuremath{\text{g}}}{\text{\scin[9.80]{\m\per\s\reciprocal{\s}}}}
891 [\N\text{\per}\text{\kg}]{\m\per\s}{\text{\squared}}
892 \newcommand{\earthssurfacegravitationalfield}{\surfacegravfield}
893 \newphysicsconstant{clight}{\ensuremath{\text{c}}}{\text{\scin[2.9979]{8}}}{\m\text{\uskip}\text{\reciprocal{\s}}}
894 [\m\per\s]{\m\per\s}
895 \newcommand{\photonconstant}{\clight}
896 \newphysicsconstant{clightinfeet}{\ensuremath{\text{c}}}{\text{\scin[0.9836]}}
897 {\text{\ensuremath{\mathit{ft}}}}\text{\uskip}\text{\reciprocal{\mathit{n}}}{\text{\s}}
898 [\text{\ensuremath{\mathit{ft}}}\text{\per}\text{\mathit{n}}]{\text{\s}}[\text{\ensuremath{\mathit{ft}}}\text{\per}\text{\mathit{n}}]{\text{\s}}
899 \newphysicsconstant{Ratom}{\ensuremath{\text{\ssub{r}{atom}}}}{\text{\scin[-10]}{\m}{\m}}
900 \newcommand{\radiusofatom}{\Ratom}
901 \newphysicsconstant{Mproton}{\ensuremath{\text{\ssub{m}{proton}}}}{\text{\scin[1.6726]{-27}}}
902 {\kg}{\kg}
903 \newcommand{\massofproton}{\Mproton}
904 \newphysicsconstant{Mneutron}{\ensuremath{\text{\ssub{m}{neutron}}}}{\text{\scin[1.6749]{-27}}}
905 {\kg}{\kg}{\kg}
906 \newcommand{\massofneutron}{\Mneutron}
907 \newphysicsconstant{Mhydrogen}{\ensuremath{\text{\ssub{m}{hydrogen}}}}{\text{\scin[1.6737]{-27}}}
908 {\kg}{\kg}{\kg}
909 \newcommand{\massofhydrogen}{\Mhydrogen}
910 \newphysicsconstant{Melectron}{\ensuremath{\text{\ssub{m}{electron}}}}{\text{\scin[9.1094]{-31}}}
911 {\kg}{\kg}{\kg}
912 \newcommand{\massofelectron}{\Melectron}
913 \newphysicsconstant{echarge}{\ensuremath{\text{e}}}{\text{\scin[1.6022]{-19}}}{\text{\A}\text{\uskip}\text{\s}}[\text{\C}][\text{\C}]
914 \newcommand{\elementarycharge}{\echarge}
915 \newphysicsconstant{Qelectron}{\ensuremath{\text{\ssub{Q}{electron}}}}{-\echargevalue}
916 {\text{\A}\text{\uskip}\text{\s}}[\text{\C}][\text{\C}]
917 \newphysicsconstant{qelectron}{\ensuremath{\text{\ssub{q}{electron}}}}{-\echargevalue}
918 {\text{\A}\text{\uskip}\text{\s}}[\text{\C}][\text{\C}]
919 \newcommand{\chargeofelectron}{\Qelectron}
920 \newphysicsconstant{Qproton}{\ensuremath{\text{\ssub{Q}{proton}}}}{+\echargevalue}
921 {\text{\A}\text{\uskip}\text{\s}}[\text{\C}][\text{\C}]
922 \newphysicsconstant{qproton}{\ensuremath{\text{\ssub{q}{proton}}}}{+\echargevalue}
923 {\text{\A}\text{\uskip}\text{\s}}[\text{\C}][\text{\C}]
924 \newcommand{\chargeofproton}{\Qproton}
925 \newphysicsconstant{MEarth}{\ensuremath{\text{\ssub{M}{Earth}}}}{\text{\scin[5.9736]{24}}}{\kg}{\kg}{\kg}

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926 \newcommand{\massofEarth}{\MEarth}
927 \newphysicsconstant{MMoon}{\ensuremath{\ssub{M}{Moon}}}{\scin[7.3459]{22}}{\kg}{\kg}{\kg}
928 \newcommand{\massofMoon}{\MMoon}
929 \newphysicsconstant{MSun}{\ensuremath{\ssub{M}{Sun}}}{\scin[1.9891]{30}}{\kg}{\kg}{\kg}
930 \newcommand{\massofSun}{\MSun}
931 \newphysicsconstant{REarth}{\ensuremath{\ssub{R}{Earth}}}{\scin[6.3675]{6}}{\m}{\m}{\m}
932 \newcommand{\radiusofEarth}{\REarth}
933 \newphysicsconstant{RMoon}{\ensuremath{\ssub{R}{Moon}}}{\scin[1.7375]{6}}{\m}{\m}{\m}
934 \newcommand{\radiusofMoon}{\RMoon}
935 \newphysicsconstant{RSun}{\ensuremath{\ssub{R}{Sun}}}{\scin[6.9634]{8}}{\m}{\m}{\m}
936 \newcommand{\radiusofSun}{\RSun}
937 \newphysicsconstant{ESdist}{\magvectsub{r}{ES}}{\scin[1.4960]{11}}{\m}{\m}{\m}
938 \newphysicsconstant{SEdist}{\magvectsub{r}{SE}}{\scin[1.4960]{11}}{\m}{\m}{\m}
939 \newcommand{\EarthSundistance}{\ESdist}
940 \newcommand{\SunEarthdistance}{\SEdist}
941 \newphysicsconstant{EMdist}{\magvectsub{r}{EM}}{\scin[3.8440]{8}}{\m}{\m}{\m}
942 \newphysicsconstant{MEDist}{\magvectsub{r}{ME}}{\scin[3.8440]{8}}{\m}{\m}{\m}
943 \newcommand{\EarthMoondistance}{\ESdist}
944 \newcommand{\MoonEarthdistance}{\SEdist}
945 \newphysicsconstant{LSun}{\ensuremath{\ssub{L}{Sun}}}{\scin[3.8460]{26}}
946 {\m\squared\usk\kg\usk\s\reciprocalcubed}{\W}{\J\per\s}
947 \newphysicsconstant{TSun}{\ensuremath{\ssub{T}{Sun}}}{5778}{\K}{\K}{\K}
948 \newphysicsconstant{MagSun}{\ensuremath{\ssub{M}{Sun}}}{+4.83}{.}{.}{.}
949 \newphysicsconstant{magSun}{\ensuremath{\ssub{m}{Sun}}}{-26.74}{.}{.}{.}
950 \newcommand{\Lstar}[1][\(\star)]{\ensuremath{\ssub{L}{#1}}}
951 \newcommand{\Lsolar}{\Lstar}
952 \newcommand{\Tstar}[1][\(\star)]{\ensuremath{\ssub{T}{#1}}}
953 \newcommand{\Tsolar}{\Tstar}
954 \newcommand{\Rstar}[1][\(\star)]{\ensuremath{\ssub{R}{#1}}}
955 \newcommand{\Rsolar}{\Rstar}
956 \newcommand{\Mstar}[1][\(\star)]{\ensuremath{\ssub{M}{#1}}}
957 \newcommand{\Msolar}{\Mstar}
958 \newcommand{\Fstar}[1][\(\star)]{\ensuremath{\ssub{F}{#1}}}
959 \newcommand{\fstar}[1][\(\star)]{\ensuremath{\ssub{f}{#1}}}
960 \newcommand{\Fsolar}{\Fstar}
961 \newcommand{\fsolar}{\fstar}
962 \newcommand{\Magstar}[1][\(\star)]{\ensuremath{\ssub{M}{#1}}}
963 \newcommand{\magstar}{\Magstar}
964 \newcommand{\Magsolar}{\Magstar}
965 \newcommand{\magsolar}{\magstar}
966 \newcommand{\Dstar}[1][\(\star)]{\ensuremath{\ssub{D}{#1}}}
967 \newcommand{\dstar}{\Dstar}
968 \newcommand{\Dsolar}{\Dstar}
969 \newcommand{\dsolar}{\dstar}
970 \newcommand{\onehalf}{\frac{1}{2}\xspace}
971 \newcommand{\onethird}{\frac{1}{3}\xspace}
972 \newcommand{\onefourth}{\frac{1}{4}\xspace}
973 \newcommand{\onefifth}{\frac{1}{5}\xspace}
974 \newcommand{\onesixth}{\frac{1}{6}\xspace}
975 \newcommand{\oneseventh}{\frac{1}{7}\xspace}

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976 \newcommand{\oneeighth}{\ensuremath{\frac{1}{8}}\xspace}
977 \newcommand{\oneninth}{\ensuremath{\frac{1}{9}}\xspace}
978 \newcommand{\onetenth}{\ensuremath{\frac{1}{10}}\xspace}
979 \newcommand{\twooneths}{\ensuremath{\frac{2}{1}}\xspace}
980 \newcommand{\twohalves}{\ensuremath{\frac{2}{2}}\xspace}
981 \newcommand{\twothirds}{\ensuremath{\frac{2}{3}}\xspace}
982 \newcommand{\twofourths}{\ensuremath{\frac{2}{4}}\xspace}
983 \newcommand{\twofifths}{\ensuremath{\frac{2}{5}}\xspace}
984 \newcommand{\twosixths}{\ensuremath{\frac{2}{6}}\xspace}
985 \newcommand{\twosevenths}{\ensuremath{\frac{2}{7}}\xspace}
986 \newcommand{\twoeighths}{\ensuremath{\frac{2}{8}}\xspace}
987 \newcommand{\twoninths}{\ensuremath{\frac{2}{9}}\xspace}
988 \newcommand{\twotenths}{\ensuremath{\frac{2}{10}}\xspace}
989 \newcommand{\threeoneths}{\ensuremath{\frac{3}{1}}\xspace}
990 \newcommand{\threehalves}{\ensuremath{\frac{3}{2}}\xspace}
991 \newcommand{\threethirds}{\ensuremath{\frac{3}{3}}\xspace}
992 \newcommand{\threefourths}{\ensuremath{\frac{3}{4}}\xspace}
993 \newcommand{\threefifths}{\ensuremath{\frac{3}{5}}\xspace}
994 \newcommand{\threesixths}{\ensuremath{\frac{3}{6}}\xspace}
995 \newcommand{\threesevenths}{\ensuremath{\frac{3}{7}}\xspace}
996 \newcommand{\threeneighths}{\ensuremath{\frac{3}{8}}\xspace}
997 \newcommand{\threeninths}{\ensuremath{\frac{3}{9}}\xspace}
998 \newcommand{\threetenths}{\ensuremath{\frac{3}{10}}\xspace}
999 \newcommand{\fouroneths}{\ensuremath{\frac{4}{1}}\xspace}
1000 \newcommand{\fourhalves}{\ensuremath{\frac{4}{2}}\xspace}
1001 \newcommand{\fourthirds}{\ensuremath{\frac{4}{3}}\xspace}
1002 \newcommand{\fourfourths}{\ensuremath{\frac{4}{4}}\xspace}
1003 \newcommand{\fourfifths}{\ensuremath{\frac{4}{5}}\xspace}
1004 \newcommand{\foursixths}{\ensuremath{\frac{4}{6}}\xspace}
1005 \newcommand{\foursevenths}{\ensuremath{\frac{4}{7}}\xspace}
1006 \newcommand{\fourneighths}{\ensuremath{\frac{4}{8}}\xspace}
1007 \newcommand{\fourninths}{\ensuremath{\frac{4}{9}}\xspace}
1008 \newcommand{\fourtenths}{\ensuremath{\frac{4}{10}}\xspace}
1009 \newcommand{\dx}[1]{\ensuremath{\mathrm{d}}\{#1\}}
1010 \newcommand{\evalfromto}[3]{\ensuremath{\Bigg.\{#1\}\Bigg|_{#2}^{#3}}}
1011 @ifpackageloaded{physymb}{%
1012   \typeout{mandi: Package physymb detected. Its commands will be used.}
1013 }%
1014 \newcommand{\evalat}[2]{\ensuremath{\Bigg.\{#1\}\Bigg|_{#2}}}
1015 }%
1016 \newcommand{\evaluatedat}[1]{\ensuremath{\Bigg.\{#1\}\Bigg|_{#1}}}
1017 \newcommandx{\integral}[4][1,2]{\usedefault}{\ensuremath{%
1018   \int_{#1}^{#2} \ifthenelse{\equal{#1}{}}{}{#4=#1}^{\ifthenelse{\equal{#2}{}}{}{#4=#2}} \\
1019   {#3}\mathrm{d}#4}}
1020 \newcommandx{\Integral}[4][1,2]{\usedefault}{\ensuremath{%
1021   \bigint_{#1}^{#2} \ifthenelse{\equal{#1}{}}{}{#4=#1}^{\ifthenelse{\equal{#2}{}}{}{#4=#2}} \\
1022   {#3}\mathrm{d}#4}}
1023 \newcommand{\opensurfintegral}[2]{\ensuremath{%
1024   \int\nolimits_{#1}^{#2} \mathrm{vect}\{#2\} \cdot \mathrm{dirvect}\{#1\} \mathrm{d}#2}}
1025 \newcommand{\opensurfIntegral}[2]{\ensuremath{%

```

```

1026 \bigint\nolimits_{\mskip -25.00mu\displaystyle\mathbf{#1}}
1027 \vectdotvect{\vect{#2}}{\dirvect{n}}
1028 \dx{A}}}
1029 \newcommand{\closedsurfintegral}[2]{\ensuremath{
1030 \oint\nolimits_{\#1}\vectdotvect{\vect{#2}}{\dirvect{n}}\dx{A}}}
1031 \newcommand{\closedsurfIntegral}[2]{\ensuremath{
1032 \bigoint\nolimits_{\mskip -25.00mu\displaystyle\mathbf{#1}}\; ;\;
1033 \vectdotvect{\vect{#2}}{\dirvect{n}}\dx{A}}}
1034 \newcommand{\openlineintegral}[2]{\ensuremath{
1035 \int\nolimits_{\#1}\vectdotvect{\vect{#2}}{\dirvect{t}}
1036 \dx{\ell}}}
1037 \newcommand{\openlineIntegral}[2]{\ensuremath{
1038 \bigint\nolimits_{\mskip -25.00mu\displaystyle\mathbf{#1}}
1039 \vectdotvect{\vect{#2}}{\dirvect{t}}\dx{\ell}}}
1040 \newcommand{\closedlineintegral}[2]{\ensuremath{
1041 \oint\nolimits_{\#1}\vectdotvect{\vect{#2}}{\dirvect{t}}\dx{\ell}}}
1042 \newcommand{\closedlineIntegral}[2]{\ensuremath{
1043 \bigoint\nolimits_{\mskip -25.00mu\displaystyle\mathbf{#1}}\; ;\;
1044 \vectdotvect{\vect{#2}}{\dirvect{t}}\dx{\ell}}}
1045 \newcommandx{\dbydt}[1][1]{\ensuremath{\frac{\mathsf{d}\{#1\}}{\mathsf{d} t}}}
1046 \newcommandx{\DbyDt}[1][1]{\ensuremath{\frac{\Delta\{#1\}}{\Delta t}}}
1047 \newcommandx{\ddbydt}[1][1]{\ensuremath{\frac{\mathsf{d}^2\{#1\}}{\mathsf{d} t^2}}}
1048 \newcommandx{\DDbyDt}[1][1]{\ensuremath{\frac{\Delta^2\{#1\}}{\Delta t^2}}}
1049 \newcommandx{\pbyp}{[1][1]{\frac{\partial\{#1\}}{\partial t}}}
1050 \newcommandx{\ppbyp}{[1][1]{\frac{\partial^2\{#1\}}{\partial t^2}}}
1051 \newcommand{\dbyd}[2]{\ensuremath{\frac{\mathsf{d}\{#1\}}{\mathsf{d} \{#2\}}}}
1052 \newcommand{\DbyD}[2]{\ensuremath{\frac{\Delta\{#1\}}{\Delta \{#2\}}}}
1053 \newcommand{\ddbyd}[2]{\ensuremath{\frac{\mathsf{d}^2\{#1\}}{\mathsf{d} \{#2\}^2}}}
1054 \newcommand{\DDbyD}[2]{\ensuremath{\frac{\Delta^2\{#1\}}{\Delta \{#2\}^2}}}
1055 \newcommand{\pbyp}{[2]{\frac{\partial\{#1\}}{\partial \{#2\}}}}
1056 \newcommand{\ppbyp}{[2]{\frac{\partial^2\{#1\}}{\partial \{#2\}^2}}}
1057 \newcommand{\seriesfofx}{\ensuremath{%
1058 f(x) \approx f(a) + \frac{f'(\mathbf{a})\{1!\}(x-a)}{1!} + \frac{f''(\mathbf{a})\{2!\}(x-a)^2}{2!} + \dots \xspace}
1059 + \frac{f'''(\mathbf{a})\{3!\}(x-a)^3}{3!} + \dots \xspace}
1060 \newcommand{\seriesexpx}{\ensuremath{%
1061 e^x \approx 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots \xspace}}
1062 \newcommand{\seriesinx}{\ensuremath{%
1063 \sin x \approx x - \frac{x^3}{3!} + \frac{x^5}{5!} - \dots \xspace}}
1064 \newcommand{\seriescosx}{\ensuremath{%
1065 \cos x \approx 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \dots \xspace}}
1066 \newcommand{\seriesstanx}{\ensuremath{%
1067 \tan x \approx x + \frac{x^3}{3} + \frac{2x^5}{15} + \dots \xspace}}
1068 \newcommand{\seriesatox}{\ensuremath{%
1069 a^x \approx 1 + x \ln a + \frac{(x \ln a)^2}{2!} + \frac{(x \ln a)^3}{3!} + \dots \xspace}}
1070 \xspace}
1071 \newcommand{\serieslnoneplusx}{\ensuremath{%
1072 \ln(1 \pm x) \approx \pm x - \frac{x^2}{2} \pm \frac{x^3}{3} - \frac{x^4}{4} \pm \dots \xspace}}
1073 \xspace}
1074 \newcommand{\binomialseries}{\ensuremath{%
1075 (1 + x)^n \approx 1 + nx + \frac{n(n-1)}{2!}x^2 + \dots \xspace}}

```

```

1076 \@ifpackageloaded{physymb}{%
1077   \typeout{mandi: Package physymb detected. Its commands will be used.}
1078 }{%
1079   \newcommand{\gradient}{\ensuremath{\nabla}}
1080   \newcommand{\divergence}{\ensuremath{\nabla \cdot \bullet}}
1081   \newcommand{\curl}{\ensuremath{\nabla \times \bullet}}
1082   \newcommand{\laplacian}{\ensuremath{\nabla^2}}
1083   \newcommand{\dalembertian}{\ensuremath{\Box}}
1084 }{%
1085 \newcommand{\diracdelta}[1]{\boldsymbol{\delta}^{(1)}_{#1}}
1086 \@ifpackageloaded{physymb}{%
1087   \typeout{mandi: Package physymb detected. Its commands will be used.}
1088 }{%
1089 \DeclareMathOperator{\asin}{\sin^{-1}}
1090 \DeclareMathOperator{\acos}{\cos^{-1}}
1091 \DeclareMathOperator{\atan}{\tan^{-1}}
1092 \DeclareMathOperator{\asec}{\sec^{-1}}
1093 \DeclareMathOperator{\acsc}{\csc^{-1}}
1094 \DeclareMathOperator{\acot}{\cot^{-1}}
1095 \DeclareMathOperator{\sech}{\operatorname{sech}}
1096 \DeclareMathOperator{\csch}{\operatorname{csch}}
1097 \DeclareMathOperator{\asinh}{\sinh^{-1}}
1098 \DeclareMathOperator{\acosh}{\cosh^{-1}}
1099 \DeclareMathOperator{\atanh}{\tanh^{-1}}
1100 \DeclareMathOperator{\asech}{\operatorname{sech^{-1}}}
1101 \DeclareMathOperator{\acsch}{\operatorname{csch^{-1}}}
1102 \DeclareMathOperator{\acoth}{\coth^{-1}}
1103 \DeclareMathOperator{\sgn}{\operatorname{sgn}}
1104 }{%
1105 \DeclareMathOperator{\dex}{\operatorname{dex}}
1106 \newcommand{\logb}[1][\relax]{\ensuremath{\log_{-#1}}}
1107 \ifthenelse{\boolean{@optitalicvectors}}{%
1108   \newcommand{\cB}{\mskip -5.00mu B}
1109   \newcommand{\cB}{\textsf{c}\mskip -3.00mu\mathit{B}}
1110 \newcommand{\newpi}{\mskip -7.8mu\pi}
1111 \newcommand{\scripty}[1]{\mathcal{#1}}
1112 \newcommandx{\flux}[1][1]{\mskip -3.00mu\Phi{#1}}
1113 \@ifpackageloaded{physymb}{%
1114   \typeout{mandi: Package physymb detected. Its commands will be used.}
1115 }{%
1116   \newcommand{\abs}[1]{\left| #1 \right|}
1117 }{%
1118 \newcommand{\magof}[1]{\left| #1 \right|}%
1119 \newcommand{\dimsof}[1]{\left[ #1 \right]{}}
1120 \newcommand{\unitsof}[1]{\left[ #1 \right]_u{}}
1121 \newcommand{\quant}[1]{\left( #1 \right)}%
1122 \newcommand{\bquant}[1]{\left[ #1 \right]}%
1123 \newcommand{\changein}[1]{\delta{#1}}%
1124 \newcommand{\Changein}[1]{\Delta{#1}}%
1125 \newcommandx{\scin}[3][1,3=\!\!,usedefault]{\left[ #1, #2 = #3 \right]}{%

```

```

1126 \ifthenelse{\equal{#1}{}}%
1127   {\unit{\msup{10}{#2}}{#3}}%
1128   {\unit{\msup{{#1}\times 10}{#2}}{#3}}}}%
1129 \newcommand{\ee}[2]{\texttt{{#1}e{#2}}}%
1130 \newcommand{\EE}[2]{\texttt{{#1}E{#2}}}%
1131 \newcommand{\dms}[3]{\ensuremath{\indegrees{#1}\inarcminutes{#2}\inarcseconds{#3}}}%
1132 \newcommand{\hms}[3]{\ensuremath{{#1}^{\mathrm{h}}{#2}^{\mathrm{m}}{#3}^{\mathrm{s}}}}}}%
1133 \newcommand{\clockreading}{\hms}%
1134 \newcommand{\latitude}[1]{\ensuremath{\unit{#1}{\degree}}}%
1135 \newcommand{\latitudeN}[1]{\ensuremath{\unit{#1}{\degree};\mathit{N}}}}}%
1136 \newcommand{\latitudeS}[1]{\ensuremath{\unit{#1}{\degree};\mathit{S}}}}}%
1137 \newcommand{\longitude}[1]{\ensuremath{\unit{#1}{\degree}}}%
1138 \newcommand{\longitudeE}[1]{\ensuremath{\unit{#1}{\degree};\mathit{E}}}}}%
1139 \newcommand{\longitudeW}[1]{\ensuremath{\unit{#1}{\degree};\mathit{W}}}}}%
1140 % I have never liked \LaTeX's default subscript positioning, so I have this
1141 % command instead. There may be a better way of doing this.
1142 \newcommand{\ssub}[2]{\ensuremath{{{}_{\tiny{#1}}}{\scriptstyle{_{\tiny{#2}}}}}}}}%
1143 % I have never liked \LaTeX's default superscript positioning, so I have this
1144 % command instead. There may be a better way of doing this.
1145 \newcommand{\ssup}[2]{\ensuremath{{{}^{\tiny{#1}}}{\scriptstyle{^{\tiny{#2}}}}}}}}%
1146 \newcommand{\ssud}[3]{\ensuremath{{{}^{\tiny{#1}}}{\scriptstyle{^{\tiny{#2}}}}}{\scriptstyle{_{\tiny{#3}}}}}}}}%
1147 % I have never liked \LaTeX's default subscript positioning, so I have this
1148 % command instead. There may be a better way of doing this.
1149 \newcommand{\msub}[2]{\ensuremath{{{}_{\scriptstyle{#1}}}{\scriptstyle{^{#2}}}}}}%
1150 % I have never liked \LaTeX's default superscript positioning, so I have this
1151 % command instead. There may be a better way of doing this.
1152 \newcommand{\msup}[2]{\ensuremath{{{}^{\scriptstyle{#1}}}{\scriptstyle{_{#2}}}}}}%
1153 \newcommand{\msud}[3]{\ensuremath{{{}^{\scriptstyle{#1}}}{\scriptstyle{_{#2}}}{\scriptstyle{^{#3}}}}}}%
1154 \newcommand{\levicivita}[1]{\ensuremath{\msub{\varepsilon}{#1}}}}%
1155 \newcommand{\kronecker}[1]{\ensuremath{\msub{\delta}{#1}}}}%
1156 \newcommand{\xaxis}{\ensuremath{x\mbox{-axis }}}}}%
1157 \newcommand{\yaxis}{\ensuremath{y\mbox{-axis }}}}}%
1158 \newcommand{\zaxis}{\ensuremath{z\mbox{-axis }}}}}%
1159 \newcommand{\naxis}[1]{\ensuremath{{{}_{\scriptstyle{#1}}}\mbox{-axis}}}}%
1160 \newcommand{\xyplane}{\ensuremath{xy\mbox{-plane }}}}}%
1161 \newcommand{\yzplane}{\ensuremath{yz\mbox{-plane }}}}}%
1162 \newcommand{\zxplane}{\ensuremath{zx\mbox{-plane }}}}}%
1163 \newcommand{\yxplane}{\ensuremath{yx\mbox{-plane }}}}}%
1164 \newcommand{\zyplane}{\ensuremath{zy\mbox{-plane }}}}}%
1165 \newcommand{\xzplane}{\ensuremath{xz\mbox{-plane }}}}}%
1166 % Frequently used roots. Prepend |f| for fractional exponents.
1167 \newcommand{\cuberoot}[1]{\ensuremath{\sqrt[3]{#1}}}}%
1168 \newcommand{\fourthroot}[1]{\ensuremath{\sqrt[4]{#1}}}}%
1169 \newcommand{\fifthroot}[1]{\ensuremath{\sqrt[5]{#1}}}}%
1170 \newcommand{\fsqrt}[1]{\ensuremath{\msup{#1}{\frac{1}{2}}}}}}%
1171 \newcommand{\fcuberoot}[1]{\ensuremath{\msup{#1}{\frac{1}{3}}}}}}%
1172 \newcommand{\ffourthroot}[1]{\ensuremath{\msup{#1}{\frac{1}{4}}}}}}%
1173 \newcommand{\ffifthroot}[1]{\ensuremath{\msup{#1}{\frac{1}{5}}}}}}%
1174 \newcommand{\relgamma}[1]{\ensuremath{\frac{1}{\sqrt{1-\msup{\quant{\frac{#1}{c}}}{2}}}}}}%
1175 \frac{1}{\sqrt{1-\msup{\quant{\frac{#1}{c}}}{2}}}}}}%

```

```

1176 \newcommand{\frelgamma}[1]{\ensuremath{%
1177   \msup{\quant{1-\frac{\msup{\{#1\}}{2}}{\msup{c}{2}}}}{-\onehalf}}}
1178 \newcommand{\oosqrtomx}[1]{\ensuremath{\frac{1}{\sqrt{1-\msup{\{#1\}}{2}}}}}
1179 \newcommand{\oosqrtoomx}[1]{\ensuremath{\frac{1}{\sqrt{1-\{#1\}}}}}
1180 \newcommand{\oomx}[1]{\ensuremath{\frac{1}{\{#1\}}}}
1181 \newcommand{\oopx}[1]{\ensuremath{\frac{1}{1+\{#1\}}}}
1182 \newcommand{\isequals}{\wordoperator{?}{=}\xspace}
1183 \newcommand{\wordoperator}[2]{\ensuremath{%
1184   \mathrel{\vcenter{\offinterlineskip
1185     \halign{\hfil\tiny\upshape#\hfil\cr\noalign{\vskip-.5ex}
1186     {#1}\cr\noalign{\vskip.5ex}{#2}\cr}}}}}
1187 \newcommand{\definedas}{\wordoperator{defined}{as}\xspace}
1188 \newcommand{\associated}{\wordoperator{associated}{with}\xspace}
1189 \newcommand{\adjustedby}{\wordoperator{adjusted}{by}\xspace}
1190 \newcommand{\earlierthan}{\wordoperator{earlier}{than}\xspace}
1191 \newcommand{\laterthan}{\wordoperator{later}{than}\xspace}
1192 \newcommand{\forevery}{\wordoperator{for}{every}\xspace}
1193 \newcommand{\pwordoperator}[2]{\ensuremath{%
1194   \left(\mathrel{\vcenter{\offinterlineskip
1195     \halign{\hfil\tiny\upshape#\hfil\cr\noalign{\vskip-.5ex}
1196     {#1}\cr\noalign{\vskip.5ex}{#2}\cr}}\right)}}
1197 \newcommand{\pdefinedas}{\pwordoperator{defined}{as}\xspace}
1198 \newcommand{\passociated}{\pwordoperator{associated}{with}\xspace}
1199 \newcommand{\padjustedby}{\pwordoperator{adjusted}{by}\xspace}
1200 \newcommand{\pearlierthan}{\pwordoperator{earlier}{than}\xspace}
1201 \newcommand{\platerthan}{\pwordoperator{later}{than}\xspace}
1202 \newcommand{\pforevery}{\pwordoperator{for}{every}\xspace}
1203 \newcommand{\defines}{\ensuremath{\stackrel{=}{\text{\tiny def}}}\xspace}
1204 \newcommand{\inframe}[1]{\relax{\ensuremath{\rightarrow[\text{\tiny \mathcal{#1}}]}}\xspace}
1205 \newcommand{\associates}{\ensuremath{\rightarrow[\text{\tiny assoc}]}}\xspace}
1206 \newcommand{\becomes}{\ensuremath{\rightarrow[\text{\tiny becomes}]}}\xspace}
1207 \newcommand{\rrelatedto}[1]{\ensuremath{\rightarrow[\text{\tiny #1}]}}\xspace}
1208 \newcommand{\lrelatedto}[1]{\ensuremath{\leftarrow[\text{\tiny #1}]}}\xspace}
1209 \newcommand{\brelatedto}[2]{\ensuremath{%
1210   \rightarrow[\text{\tiny #1}]\leftarrow[\text{\tiny #2}]}}
1211 \newcommand{\momentumprinciple}{\ensuremath{%
1212   \text{vectsub}\{p\}\{sys,f\}=\text{vectsub}\{p\}\{sys,i\}+\text{Fnetsys}\Delta t}}
1213 \newcommand{\LHSmomentumprinciple}{\ensuremath{%
1214   \text{vectsub}\{p\}\{sys,f\}}}
1215 \newcommand{\RHSmomentumprinciple}{\ensuremath{%
1216   \text{vectsub}\{p\}\{sys,i\}+\text{Fnetsys}\Delta t}}
1217 \newcommand{\energyprinciple}{\ensuremath{%
1218   \text{ssub}\{E\}\{sys,f\}=\text{ssub}\{E\}\{sys,i\}+
1219   \text{ssub}\{W\}\{ext\}+Q}}
1220 \newcommand{\LHSenergyprinciple}{\ensuremath{%
1221   \text{ssub}\{E\}\{sys,f\}}}
1222 \newcommand{\RHSenergyprinciple}{\ensuremath{%
1223   \text{ssub}\{E\}\{sys,i\}+\text{ssub}\{W\}\{ext\}+Q}}
1224 \newcommand{\angularmomentumprinciple}{\ensuremath{%
1225   \text{vectsub}\{L\}\{sys,A,f\}=\text{vectsub}\{L\}\{sys,A,i\}+
   \text{Fnetsys}\Delta t}}

```

```

1226 \newcommand{\gravitationalinteraction}{\ensuremath{%
1227   \universalgravmathsymbol\frac{\msub{M}{1}\msub{M}{2}}{\msup{\magvectsub{r}{12}}{2}}%
1228   \quant{-\dirvectsub{r}{12}}}}
1229 \newcommand{\electricinteraction}{\ensuremath{%
1230   \oofpezmathsymbol\frac{\msub{Q}{1}\msub{Q}{2}}{\msup{\magvectsub{r}{12}}{2}}%
1231   \dirvectsub{r}{12}}}
1232 \newcommand{\Bfieldofparticle}{\ensuremath{%
1233   \mzofpmathsymbol\frac{Q\magvect{v}}{\msup{\magvect{r}}{2}}\dirvect{v}\times\dirvect{r}}}
1234 \newcommand{\Efieldofparticle}{\ensuremath{%
1235   \oofpezmathsymbol\frac{Q\msup{\magvect{r}}{2}}{\dirvect{r}}}}
1236 \newcommand{\Esys}{\ssub{E}{sys}}
1237 \newcommandx{\Us}[1][1]{\ssub{\ssub{U}{s}}{#1}}
1238 \newcommandx{\Ug}[1][1]{\ssub{\ssub{U}{g}}{#1}}
1239 \newcommandx{\Ue}[1][1]{\ssub{\ssub{U}{e}}{#1}}
1240 \newcommandx{\Ktrans}[1][1]{\ssub{\ssub{K}{trans}}{#1}}
1241 \newcommandx{\Krot}[1][1]{\ssub{\ssub{K}{rot}}{#1}}
1242 \newcommandx{\Eparticle}[1][1]{\ssub{\ssub{E}{particle}}{#1}}
1243 \newcommandx{\Einternal}[1][1]{\ssub{\ssub{E}{internal}}{#1}}
1244 \newcommandx{\Erest}[1][1]{\ssub{\ssub{E}{rest}}{#1}}
1245 \newcommandx{\Echem}[1][1]{\ssub{\ssub{E}{chem}}{#1}}
1246 \newcommandx{\Etherm}[1][1]{\ssub{\ssub{E}{therm}}{#1}}
1247 \newcommandx{\Evib}[1][1]{\ssub{\ssub{E}{vib}}{#1}}
1248 \newcommandx{\Ephoton}[1][1]{\ssub{\ssub{E}{photon}}{#1}}
1249 \newcommand{\DEsys}{\Changein{\Esys}}
1250 \newcommand{\DUus}{\Changein{\Us}}
1251 \newcommand{\DUG}{\Changein{\Ug}}
1252 \newcommand{\DUe}{\Changein{\Ue}}
1253 \newcommand{\DKtrans}{\Changein{\Ktrans}}
1254 \newcommand{\DKrot}{\Changein{\Krot}}
1255 \newcommand{\DEparticle}{\Changein{\Eparticle}}
1256 \newcommand{\DEinternal}{\Changein{\Einternal}}
1257 \newcommand{\DErest}{\Changein{\Erest}}
1258 \newcommand{\DEchem}{\Changein{\Echem}}
1259 \newcommand{\DEtherm}{\Changein{\Etherm}}
1260 \newcommand{\DEVib}{\Changein{\Evib}}
1261 \newcommand{\DEphoton}{\Changein{\Ephoton}}
1262 \newcommand{\Usfinal}{\ssub{\left(\onehalf\ks\msup{s}{2}\right)}{f}}
1263 \newcommand{\Usinitial}{\ssub{\left(\onehalf\ks\msup{s}{2}\right)}{i}}
1264 \newcommand{\Ugfinal}{\ssub{\left(-G\frac{\msub{M}{1}\msub{M}{2}}{\magvectsub{r}{12}}\right)}{f}}
1265 \newcommand{\Uginital}{\ssub{\left(-G\frac{\msub{M}{1}\msub{M}{2}}{\magvectsub{r}{12}}\right)}{i}}
1266 \newcommand{\Uefinal}{\ssub{\left(\oofpezmathsymbol\frac{\ssub{Q}{1}\ssub{Q}{2}}{\magvectsub{r}{12}}\right)}{f}}
1267 \newcommand{\Ueinitial}{\ssub{\left(\oofpezmathsymbol\frac{\ssub{Q}{1}\ssub{Q}{2}}{\magvectsub{r}{12}}\right)}{i}}
1268 \newcommand{\ks}{\ssub{k}{s}}
1269 \newcommand{\Fnet}{\ensuremath{\vectsub{F}{net}}}
1270 \newcommand{\Fnetext}{\ensuremath{\vectsub{F}{net,ext}}}
1271 \newcommand{\Fnetsys}{\ensuremath{\vectsub{F}{net,sys}}}

```

```

1276 \newcommand{\Fsub}[1]{\ensuremath{\text{vectsub}\{F\}\{#1\}}}
1277 \newcommand{\Tnet}{\ensuremath{\text{vectsub}\{T\}\{net\}}}
1278 \newcommand{\Tnetext}{\ensuremath{\text{vectsub}\{T\}\{net,ext\}}}
1279 \newcommand{\Tnetsys}{\ensuremath{\text{vectsub}\{T\}\{net,sys\}}}
1280 \newcommand{\Tsub}[1]{\ensuremath{\text{vectsub}\{T\}\{#1\}}}
1281 \newcommand{\vpythononline}{\lstinline[language=Python,numbers=left,numberstyle=\tiny,%
1282 upquote=true,breaklines]}
1283 \lstnewenvironment{vpythonblock}{\lstvpython}{}
1284 \newcommand{\vpythonfile}{\lstinputlisting[language=Python,numbers=left,%
1285 numberstyle=\tiny,upquote=true,breaklines]}
1286 \newcommandx{\emptyanswer}[2][1=0.80,2=0.1,usedefault]
1287 {\begin{minipage}{#1\textwidth}\hfill\vspace{#2\textheight}\end{minipage}}
1288 \newenvironmentx{activityanswer}[5][1=white,2=black,3=black,4=0.90,5=0.10,usedefault]{%
1289 \def\skipper{\#5}%
1290 \def\response@fbox{\fcolorbox{#2}{#1}}%
1291 \begin{center}%
1292 \begin{lrbox}{\@tempboxa}%
1293 \begin{minipage}[c]{#5\textheight}[c]{#4\textwidth}\color{#3}%
1294 \vspace{#5\textheight}%
1295 \vspace{\skipper\textheight}%
1296 \end{minipage}%
1297 \end{lrbox}%
1298 \response@fbox{\usebox{\@tempboxa}}%
1299 \end{center}%
1300 }%
1301 \newenvironmentx{adjactivityanswer}[5][1=white,2=black,3=black,4=0.90,5=0.00,%
1302 usedefault]{%
1303 \def\skipper{\#5}%
1304 \def\response@fbox{\fcolorbox{#2}{#1}}%
1305 \begin{center}%
1306 \begin{lrbox}{\@tempboxa}%
1307 \begin{minipage}[c]{#4\textwidth}\color{#3}%
1308 \vspace{#5\textheight}%
1309 \vspace{\skipper\textheight}%
1310 \end{minipage}%
1311 \end{lrbox}%
1312 \response@fbox{\usebox{\@tempboxa}}%
1313 \end{center}%
1314 }%
1315 \newcommandx{\emptybox}[6][1=\hfill,2=white,3=black,4=black,5=0.90,6=0.10,usedefault]
1316 {\begin{center}%
1317 \fcolorbox{#3}{#2}{%
1318 \begin{minipage}[c]{#6\textheight}[c]{#5\textwidth}\color{#4}%
1319 {\#1}%
1320 \end{minipage}}%
1321 \vspace{\baselineskip}%
1322 \end{center}%
1323 }%
1324 \newcommandx{\adjemptybox}[7][1=\hfill,2=white,3=black,4=black,5=0.90,6=,7=0.0,usedefault]
1325 {\begin{center}%

```

```

1326 \fcolorbox{#3}{#2}{%
1327   \begin{minipage}[c]{\textwidth}\color{#4}%
1328     \vspace{#7\textheight}%
1329     {#1}%
1330     \vspace{#7\textheight}%
1331   \end{minipage}}%
1332 \vspace{\baselineskip}%
1333 \end{center}%
1334 }%
1335 \newcommandx{\answerbox}[6] [1=\hfill,2=white,3=black,4=black,5=0.90,6=0.1,usedefault]
1336 {\ifthenelse{\equal{#1}{}}{%
1337   \begin{center}%
1338     \fcolorbox{#3}{#2}{%
1339       \emptyanswer[#5][#6]}%
1340     \vspace{\baselineskip}%
1341   \end{center}}{%
1342   \emptybox[#1][#2][#3][#4][#5][#6]}%
1343 }%
1344 \newcommandx{\adjanswerbox}[7] [1=\hfill,2=white,3=black,4=black,5=0.90,6=0.1,7=0.0,%
1345 usedefault]%
1346 {\ifthenelse{\equal{#1}{}}{%
1347   \begin{center}%
1348     \fcolorbox{#3}{#2}{%
1349       \emptyanswer[#5][#6]}%
1350     \vspace{\baselineskip}%
1351   \end{center}}{%
1352   \adjemptybox[#1][#2][#3][#4][#5][#6][#7]}%
1353 }%
1354 \newcommandx{\smallanswerbox}[6] [1=\hfill,2=white,3=black,4=black,5=0.90,6=0.10,%
1355 usedefault]%
1356 {\ifthenelse{\equal{#1}{}}{%
1357   \begin{center}%
1358     \fcolorbox{#3}{#2}{%
1359       \emptyanswer[#5][#6]}%
1360     \vspace{\baselineskip}%
1361   \end{center}}{%
1362   \emptybox[#1][#2][#3][#4][#5][#6]}%
1363 }%
1364 \newcommandx{\mediumanswerbox}[6] [1=\hfill,2=white,3=black,4=black,5=0.90,6=0.20,%
1365 usedefault]%
1366 {\ifthenelse{\equal{#1}{}}{%
1367   \begin{center}%
1368     \fcolorbox{#3}{#2}{%
1369       \emptyanswer[#5][#6]}%
1370   }%
1371   \vspace{\baselineskip}%
1372   \end{center}}{%
1373   }%
1374   \emptybox[#1][#2][#3][#4][#5][#6]%
1375 }%

```

```

1376 }%
1377 \newcommandx{\largeanswerbox}[6]{1=\hfill,2=white,3=black,4=black,5=0.90,6=0.25,%
1378   usedefault}{%
1379   \ifthenelse{\equal{#1}{}}{%
1380     {\begin{center}}{%
1381       \fcolorbox{#3}{#2}{%
1382         \emptyanswer[#5][#6]}%
1383     }%
1384     \vspace{\baselineskip}%
1385     \end{center}}{%
1386   }%
1387   {\emptybox[#1][#2][#3][#4][#5][#6]}%
1388 }%
1389 }%
1390 \newcommandx{\largeranswerbox}[6]{1=\hfill,2=white,3=black,4=black,5=0.90,6=0.33,%
1391   usedefault}{%
1392   \ifthenelse{\equal{#1}{}}{%
1393     {\begin{center}}{%
1394       \fcolorbox{#3}{#2}{%
1395         \emptyanswer[#5][#6]}%
1396     }%
1397     \vspace{\baselineskip}%
1398     \end{center}}{%
1399   }%
1400   {\emptybox[#1][#2][#3][#4][#5][#6]}%
1401 }%
1402 }%
1403 \newcommandx{\hugeanswerbox}[6]{1=\hfill,2=white,3=black,4=black,5=0.90,6=0.50,%
1404   usedefault}{%
1405   \ifthenelse{\equal{#1}{}}{%
1406     {\begin{center}}{%
1407       \fcolorbox{#3}{#2}{%
1408         \emptyanswer[#5][#6]}%
1409     }%
1410     \vspace{\baselineskip}%
1411     \end{center}}{%
1412   }%
1413   {\emptybox[#1][#2][#3][#4][#5][#6]}%
1414 }%
1415 }%
1416 \newcommandx{\hugeranswerbox}[6]{1=\hfill,2=white,3=black,4=black,5=0.90,6=0.75,%
1417   usedefault}{%
1418   \ifthenelse{\equal{#1}{}}{%
1419     {\begin{center}}{%
1420       \fcolorbox{#3}{#2}{%
1421         \emptyanswer[#5][#6]}%
1422     }%
1423     \vspace{\baselineskip}%
1424     \end{center}}{%
1425   }%

```

```

1426     {\emptybox[#1][#2][#3][#4][#5][#6]%
1427   }%
1428 }%
1429 \newcommandx{\fullpageanswerbox}[6]{1=\hfill,2=white,3=black,4=black,5=0.90,6=1.00,%
1430   usedefault}{%
1431   \ifthenelse{\equal{#1}{}}{%
1432     \begin{center}%
1433       \fcolorbox{#3}{#2}{%
1434         \emptyanswer[#5][#6]}%
1435       \vspace{\baselineskip}%
1436     \end{center}}{%
1437     \emptybox[#1][#2][#3][#4][#5][#6]}%
1438 }%
1439 \mdfdefinestyle{miinstructornotestyle}{%
1440   hidealllines=false, skipbelow=\baselineskip, skipabove=\baselineskip,
1441   leftmargin=40pt, rightmargin=40pt, linewidth=1, roundcorner=10,
1442   frametitle={INSTRUCTOR NOTE},
1443   frametitlebackgroundcolor=cyan!60, frametitlerule=true, frametitlerulewidth=1,
1444   backgroundcolor=cyan!25,
1445   linecolor=black, fontcolor=black, shadow=true}
1446 \NewEnviron{miinstructornote}{%
1447   \begin{mdframed}[style=miinstructornotestyle]
1448     \begin{adjactivityanswer}[cyan!25][cyan!25][black]
1449       \BODY
1450     \end{adjactivityanswer}
1451   \end{mdframed}
1452 }%
1453 \mdfdefinestyle{mistudentnotestyle}{%
1454   hidealllines=false, skipbelow=\baselineskip, skipabove=\baselineskip,
1455   leftmargin=40pt, rightmargin=40pt, linewidth=1, roundcorner=10,
1456   frametitle={STUDENT NOTE},
1457   frametitlebackgroundcolor=cyan!60, frametitlerule=true, frametitlerulewidth=1,
1458   backgroundcolor=cyan!25,
1459   linecolor=black, fontcolor=black, shadow=true}
1460 \NewEnviron{mistudentnote}{%
1461   \begin{mdframed}[style=mistudentnotestyle]
1462     \begin{adjactivityanswer}[cyan!25][cyan!25][black]
1463       \BODY
1464     \end{adjactivityanswer}
1465   \end{mdframed}
1466 }%
1467 \mdfdefinestyle{miderivationstyle}{%
1468   hidealllines=false, skipbelow=\baselineskip, skipabove=\baselineskip,
1469   leftmargin=0pt, rightmargin=0pt, linewidth=1, roundcorner=10,
1470   frametitle={DERIVATION},
1471   frametitlebackgroundcolor=orange!60, frametitlerule=true, frametitlerulewidth=1,
1472   backgroundcolor=orange!25,
1473   linecolor=black, fontcolor=black, shadow=true}
1474 \NewEnviron{miderivation}{%
1475   \begin{mdframed}[style=miderivationstyle]

```

```

1476 \setcounter{equation}{0}
1477 \begin{align*}
1478   \BODY
1479 \end{align*}
1480 \end{mdframed}
1481 }%
1482 \mdfdefinestyle{bwinstructornotestyle}{%
1483   hidealllines=false, skipbelow=\baselineskip, skipabove=\baselineskip,
1484   leftmargin=40pt, rightmargin=40pt, linewidth=1, roundcorner=10,
1485   frametitle={INSTRUCTOR NOTE},
1486   frametitlebackgroundcolor=gray!50, frametitlerule=true, frametitlerulewidth=1,
1487   backgroundcolor=gray!20,
1488   linecolor=black, fontcolor=black, shadow=true}
1489 \NewEnviron{bwinstructornote}{%
1490   \begin{mdframed}[style=bwinstructornotestyle]
1491     \begin{adjactivityanswer}[gray!20][gray!20][black]
1492       \BODY
1493     \end{adjactivityanswer}
1494   \end{mdframed}
1495 }%
1496 \mdfdefinestyle{bwstudentnotestyle}{%
1497   hidealllines=false, skipbelow=\baselineskip, skipabove=\baselineskip,
1498   leftmargin=40pt, rightmargin=40pt, linewidth=1, roundcorner=10,
1499   frametitle={STUDENT NOTE},
1500   frametitlebackgroundcolor=gray!50, frametitlerule=true, frametitlerulewidth=1,
1501   backgroundcolor=gray!20,
1502   linecolor=black, fontcolor=black, shadow=true}
1503 \NewEnviron{bwstudentnote}{%
1504   \begin{mdframed}[style=bwstudentnotestyle]
1505     \begin{adjactivityanswer}[gray!20][gray!20][black]
1506       \BODY
1507     \end{adjactivityanswer}
1508   \end{mdframed}
1509 }%
1510 \mdfdefinestyle{bwderivationstyle}{%
1511   hidealllines=false, skipbelow=\baselineskip, skipabove=\baselineskip,
1512   leftmargin=0pt, rightmargin=0pt, linewidth=1, roundcorner=10,
1513   frametitle={DERIVATION},
1514   frametitlebackgroundcolor=gray!50, frametitlerule=true, frametitlerulewidth=1,
1515   backgroundcolor=gray!20,
1516   linecolor=black, fontcolor=black, shadow=true}
1517 \NewEnviron{bwderivation}{%
1518   \begin{mdframed}[style=bwderivationstyle]
1519     \setcounter{equation}{0}
1520     \begin{align*}
1521       \BODY
1522     \end{align*}
1523   \end{mdframed}
1524 }%
1525 \newcommand{\checkpoint}{%

```

```

1526  \vspace{1cm}\begin{center}|----- CHECKPOINT -----|\end{center}}%
1527 \newcommand{\image}[2]{%
1528   \begin{figure}[h!]
1529     \begin{center}%
1530       \includegraphics[scale=1]{#1}%
1531       \caption{#2}%
1532       \label{#1}%
1533     \end{center}%
1534   \end{figure}}
1535 \newcommand{\sneakyone}[1]{\ensuremath{\cancelto{1}{\frac{#1}{#1}}}}
1536 % undocumented diagnostic command
1537 \newcommand{\chkquantity}[1]{%
1538   \begin{center}
1539     \begin{tabular}{C{3cm} C{3cm} C{3cm} C{3cm}}
1540       name & baseunit & drvdunit & tradunit \tabularnewline
1541       \csname #1onlybaseunit\endcsname & \csname #1onlydrvdunit\endcsname &
1542         \csname #1onlytradunit\endcsname
1543     \end{tabular}
1544   \end{center}
1545 }%
1546 % undocumented diagnostic command
1547 \newcommand{\chkconstant}[1]{%
1548   \begin{center}
1549     \begin{tabular}{C{3cm} C{1cm} C{2cm} C{3cm} C{3cm} C{3cm}}
1550       name & symbol & value & baseunit & drvdunit & tradunit \tabularnewline
1551       \csname #1mathsymbol\endcsname & \csname #1value\endcsname &
1552         \csname #1onlybaseunit\endcsname & \csname #1onlydrvdunit\endcsname &
1553           \csname #1onlytradunit\endcsname
1554     \end{tabular}
1555   \end{center}
1556 }%
1557 % new |\vect| that allows for subscripts
1558 % #1 = kernel #2 = subscript
1559 \newcommandx{\vecto}[2][2,usedefault]{\ensuremath{%
1560   \ifthenelse{\equal{#2}{}}{%
1561     \vec{#1}}{%
1562       \sub{\vec{#1}}{#2}}}}%
1563 % new |\compvect| that allows for subscripts
1564 % #1 = kernel #2 = component #3 = subscript
1565 \newcommandx{\compvecto}[3][3,usedefault]{\ensuremath{%
1566   \ifthenelse{\equal{#3}{}}{%
1567     \sub{\sub{#1}{(\#2)}}{#3}}{%
1568       \sub{\sub{#1}{(\#2)},#3}}}}%
1569 % new |\scmpsvect| that allows for subscripts
1570 % #1 = kernel #2 = subscript
1571 \newcommandx{\scmpsvecto}[2][2,usedefault]{\ensuremath{%
1572   \ifthenelse{\equal{#2}{}}{%
1573     \lvert \compvecto{#1}{x},\compvecto{#1}{y},\compvecto{#1}{z} \rvert}%
1574     \lvert \compvecto{#1}{x}[#2],\compvecto{#1}{y}[#2],\compvecto{#1}{z}[#2] \rvert}}%
1575 % new |\compos| that allows for subscripts

```

```
1576 \newcommandx{\compposo}[2][2,usedefault]{\ensuremath{%
1577 % #1 = component #2 = subscript
1578 \ifthenelse{\equal{#1}{}}{%
1579   {#1}%
1580   {\substack{#1 \\ #2}}}%
1581 % new |\scompspos| that allows for subscripts
1582 % #1 = subscript
1583 \newcommandx{\scompsposo}[1][1,usedefault]{\ensuremath{%
1584 \ifthenelse{\equal{#1}{}}{%
1585   {\substack{\vphantom{#1}\compposo{x} \\ \compposo{y} \\ \compposo{z}\rv}}%
1586   {\substack{\vphantom{#1}\compposo{x}[#1] \\ \compposo{y}[#1] \\ \compposo{z}[#1]\rv}}}}%
```

7 Acknowledgements

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