The mandi Package

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PLEASE DO NOT DISTRIBUTE THIS VERSION.

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Acknowledgements

To all of the students who have learned LaTeX in my introductory physics courses over the years, I say a heartfelt thank you. You have contributed directly to the state of this software and to its use in introductory physics courses and to innovating how physics is taught.

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1 Introduction

This is the documentation for the mandi,[1] which is designed primarily for students in introductory physics courses. This document serves to document what commands mandi provides and does not necessarily fully demonstrate how students would use them. There is a separate document that serves that purpose.

1.1 Loading the Package

Load mandi as you would any package in your preamble.

```
\usepackage[options]{mandi}
```

\mandiversion

Typesets the current version and build date.

```
The version is \mandiversion\ and is a stable build.
```

The version is v3.0.0i dated 2021-03-18 and is a stable build.

1.2 Package Options

N 2021-01-30 **units**=⟨*type of unit*⟩ (initially unspecified, set to `alternate`)
N 2021-01-30 **preciseconstants**=⟨*boolean*⟩ (initially unspecified, set to `false`)

Now mandi uses a key-value interface for options. The `units` key can be set to `base`, `derived`, or `alternate`. The `preciseconstants` key is always either `true` or `false`.

1.3 The `mandisetup` Command

N 2021-02-17 **\mandisetup**{⟨*options*⟩}

Command to set package options on the fly after loadtime. This can be done in the preamble or inside the `\begin{document}...\end{document}` environment.

```
\mandisetup{units=base}
```

[1] The package name can be pronounced either with two syllables, to rhyme with *candy*, or with three syllables, as *M and I*.

2 Student/Instructor Quick Guide

Use `\vec`→P. 35 to typeset the symbol for a vector. Use `\magnitude`→P. 38 to typeset the symbol for a vector's magnitude. Use `\dirvec`→P. 35 to typeset the symbol for a vector's direction. Use `\changein`→P. 36 to typeset the symbol for the change in a vector or scalar. Use `\zerovec`→P. 35 to typeset the zero vector. Use `\timestento`→P. 39 to typeset scientific notation.

```
\( \vec{p} \) or \( \vec*{p} \) \\
\( \vec{p}_{\symup{final}} \) or \( \vec*{p}_{\symup{final}} \) \\
\( \magnitude{\vec{p}} \) or \( \magnitude*{\vec{p}_{\symup{final}}} \) \\
\( \dirvec{p} \) or \( \dirvec*{p} \) \\
\( \changein \vec{p} \) or \( \changein t \) \\
\( \zerovec \) or \( \zerovec* \) \\
\( 6.02\timestento{-19} \)
```

$\boldsymbol{p}$ or $\vec{p}$
$\boldsymbol{p}_{\mathrm{final}}$ or $\vec{p}_{\mathrm{final}}$
$\|\boldsymbol{p}\|$ or $\left\|\boldsymbol{p}_{\mathrm{final}}\right\|$
$\widehat{\boldsymbol{p}}$ or $\widehat{p}$
$\Delta\boldsymbol{p}$ or Δt
$\mathbf{0}$ or $\vec{0}$
6.02×10^{-19}

Use a `physical quantity's`→P. 8 name to typeset a magnitude and that quantity's units. If the quantity is a vector, you can add `vector` either to the beginning or the end of the quantity's name. For example, if you want momentum, use `\momentum`→P. 8 and its variants.

```
\( \momentum{7.071} \) \\
\( \vectormomentum{3,-4,5} \) \\
\( \momentumvector{3,-4,5} \)
```

$7.071\,\mathrm{kg}\cdot\mathrm{m}/\mathrm{s}$
$\langle 3,-4,5\rangle\ \mathrm{kg}\cdot\mathrm{m}/\mathrm{s}$
$\langle 3,-4,5\rangle\ \mathrm{kg}\cdot\mathrm{m}/\mathrm{s}$

Use a `physical constant's`→P. 22 name to typeset its numerical value and units. Append `mathsymbol` to the constant's name to get its mathematical symbol. For example, if you want to typeset the vacuum permittivity, use `\vacuumpermittivity`→P. 28 and its variant.

```
\( \vacuumpermittivitymathsymbol = \vacuumpermittivity \)
```

$\epsilon_{\mathrm{o}} = 9 \times 10^{-12}\,\mathrm{C}^2/\mathrm{N}\cdot\mathrm{m}^2$

Use `\mivector`→P. 36 to typeset symbolic vectors with components. Use the aliases `\direction`→P. 36 or `\unitvector`→P. 36 to typeset a direction or unit vector.

```
\( \mivector{\slot,\slot,\slot} \) or \( \mivector{p_x,p_y,p_z} \) \\
\( \direction{\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}} \) or
\( \unitvector{\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}} \)
```

$\langle \_\_\_, \_\_\_, \_\_\_ \rangle$ or $\left\langle p_x, p_y, p_z \right\rangle$
$\left\langle \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}} \right\rangle$ or $\left\langle \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}}, \frac{1}{\sqrt{3}} \right\rangle$

Use `physicsproblem`→P. 40 and `parts`→P. 40 and `\problempart`→P. 40 to typeset problems. Use `physicssolution`→P. 41 to typeset step-by-step mathematical solutions. Use `glowscriptblock`→P. 29 to typeset `GlowScript` programs. Use `\vpythonfile`→P. 32 to typeset VPython program files.

3 Intelligent Commands for Physical Quantities and Constants

3.1 Physical Quantities

3.1.1 Typesetting Physical Quantities

Typesetting physical quantities and constants using semantically appropriate names, along with the correct SI units, is the core function of mandi. Take momentum as the prototypical physical quantity in an introductory physics course.

N 2021-02-24

\momentum{⟨*magnitude*⟩}
\momentumvector{⟨$c_1, \ldots, c_n$⟩}
\vectormomentum{⟨$c_1, \ldots, c_n$⟩}

Command for momentum and its vector variant. The default units will depend on the options passed to mandi at load time. Alternate units are the default. Other units can be forced as demonstrated. The vector variant can take more than three components. Note the other variants for the quantity's value and units.

```
\momentum{5}                 \\
\momentumvalue{5}            \\
\momentumbaseunits{5}        \\
\momentumderivedunits{5}     \\
\momentumalternateunits{5}   \\
\momentumonlybaseunits       \\
\momentumonlyderivedunits    \\
\momentumonlyalternateunits  \\
\vectormomentum{2,3,4}       \\
\momentumvector{2,3,4}       \\
\momentum{\mivector{2,3,4}}
```

$5\,\mathrm{kg \cdot m\,/\,s}$
5
$5\,\mathrm{m \cdot kg \cdot s^{-1}}$
$5\,\mathrm{N \cdot s}$
$5\,\mathrm{kg \cdot m\,/\,s}$
$\mathrm{m \cdot kg \cdot s^{-1}}$
$\mathrm{N \cdot s}$
$\mathrm{kg \cdot m\,/\,s}$
$\langle 2, 3, 4 \rangle\,\mathrm{kg \cdot m\,/\,s}$
$\langle 2, 3, 4 \rangle\,\mathrm{kg \cdot m\,/\,s}$
$\langle 2, 3, 4 \rangle\,\mathrm{kg \cdot m\,/\,s}$

Commands that include the name of a physical quantity typeset units, so they shouldn't be used for algebraic or symbolic values of components. For example, one shouldn't use `\vectormomentum{mv_x,mv_y,mv_z}` but instead the generic `\mivector{mv_x,mv_y,mv_z}` instead.

3.1.2 Checking Physical Quantities

N 2021-02-16

\checkquantity{⟨*name*⟩}

Command to check and typeset the command, base units, derived units, and alternate units of a defined physical quantity.

3.1.3 Commands For Predefined Physical Quantities

Every other defined physical quantity can be treated similarly. Just replace `momentum` with the quantity's name. Obviously, the variants that begin with `\vector` will not be defined for scalar quantities. Here are all the physical quantities, with all their units, defined in mandi. Rememeber that units are not present with symbolic (algebraic) quantities, so do not use the `\vector` variants of these commands for symbolic components. Use `\mivector`→ P. 36 instead.

N 2021-02-24

`\acceleration{⟨magnitude⟩}`
`\accelerationvector{⟨c_1, ..., c_n⟩}`
`\vectoracceleration{⟨c_1, ..., c_n⟩}`

name	base	derived	alternate
`\acceleration`	$\mathrm{m \cdot s^{-2}}$	$\mathrm{N\,/\,kg}$	$\mathrm{m\,/\,s^{2}}$

`\amount{⟨magnitude⟩}`

name	base	derived	alternate
`\amount`	mol	mol	mol

N 2021-02-24

`\angularacceleration{⟨magnitude⟩}`
`\angularaccelerationvector{⟨c_1, ..., c_n⟩}`
`\vectorangularacceleration{⟨c_1, ..., c_n⟩}`

name	base	derived	alternate
`\angularacceleration`	$\mathrm{rad \cdot s^{-2}}$	$\mathrm{rad\,/\,s^{2}}$	$\mathrm{rad\,/\,s^{2}}$

`\angularfrequency{⟨magnitude⟩}`

name	base	derived	alternate
`\angularfrequency`	$\mathrm{rad \cdot s^{-1}}$	rad / s	rad / s

N 2021-02-24

`\angularimpulse{⟨magnitude⟩}`
`\angularimpulsevector{⟨c_1, ..., c_n⟩}`
`\vectorangularimpulse{⟨c_1, ..., c_n⟩}`

name	base	derived	alternate
`\angularimpulse`	$\mathrm{m^{2} \cdot kg \cdot s^{-1}}$	$\mathrm{kg \cdot m^{2}\,/\,s}$	$\mathrm{kg \cdot m^{2}\,/\,s}$

N 2021-02-24

`\angularmomentum{⟨magnitude⟩}`
`\angularmomentumvector{⟨c_1, ..., c_n⟩}`
`\vectorangularmomentum{⟨c_1, ..., c_n⟩}`

name	base	derived	alternate
`\angularmomentum`	$\mathrm{m^{2} \cdot kg \cdot s^{-1}}$	$\mathrm{kg \cdot m^{2}\,/\,s}$	$\mathrm{kg \cdot m^{2}\,/\,s}$

N 2021-02-24

`\angularvelocity{⟨magnitude⟩}`
`\angularvelocityvector{⟨c_1, ..., c_n⟩}`
`\vectorangularvelocity{⟨c_1, ..., c_n⟩}`

name	base	derived	alternate
`\angularvelocity`	$\mathrm{rad \cdot s^{-1}}$	rad / s	rad / s

`\area{⟨magnitude⟩}`

name	base	derived	alternate
`\area`	m^2	m^2	m^2

`\areachargedensity`{⟨*magnitude*⟩}

name	base	derived	alternate
`\areachargedensity`	$m^{-2} \cdot s \cdot A$	C / m^2	C / m^2

`\areamassdensity`{⟨*magnitude*⟩}

name	base	derived	alternate
`\areamassdensity`	$m^{-2} \cdot kg$	kg / m^2	kg / m^2

`\capacitance`{⟨*magnitude*⟩}

name	base	derived	alternate
`\capacitance`	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$	F	C / V

`\charge`{⟨*magnitude*⟩}

name	base	derived	alternate
`\charge`	$A \cdot s$	C	C

N 2021-02-24

`\cmagneticfield`{⟨*magnitude*⟩}
`\cmagneticfieldvector`{⟨$c_1, \ldots, c_n$⟩}
`\vectorcmagneticfield`{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\cmagneticfield`	$m \cdot kg \cdot s^{-3} \cdot A^{-1}$	V / m	N / C

`\conductance`{⟨*magnitude*⟩}

name	base	derived	alternate
`\conductance`	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$	S	A / V

`\conductivity`{⟨*magnitude*⟩}

name	base	derived	alternate
`\conductivity`	$m^{-3} \cdot kg^{-1} \cdot s^3 \cdot A^2$	S / m	$(A / m^2) / (V / m)$

`\conventionalcurrent`{⟨*magnitude*⟩}

name	base	derived	alternate
`\conventionalcurrent`	A	C / s	A

`\current`{⟨*magnitude*⟩}

name	base	derived	alternate
`\current`	A	A	A

N 2021-02-24

`\currentdensity`{⟨*magnitude*⟩}
`\currentdensityvector`{⟨$c_1, \ldots, c_n$⟩}
`\vectorcurrentdensity`{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\currentdensity`	$\mathrm{m}^{-2} \cdot \mathrm{A}$	$\mathrm{C} \cdot \mathrm{s} / \mathrm{m}^2$	$\mathrm{A} / \mathrm{m}^2$

`\dielectricconstant`{⟨*magnitude*⟩}

name	base	derived	alternate
`\dielectricconstant`			

N 2021-02-24

`\displacement`{⟨*magnitude*⟩}
`\displacementvector`{⟨$c_1, \ldots, c_n$⟩}
`\vectordisplacement`{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\displacement`	m	m	m

`\duration`{⟨*magnitude*⟩}

name	base	derived	alternate
`\duration`	s	s	s

N 2021-02-24

`\electricdipolemoment`{⟨*magnitude*⟩}
`\electricdipolemomentvector`{⟨$c_1, \ldots, c_n$⟩}
`\vectorelectricdipolemoment`{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\electricdipolemoment`	$\mathrm{m} \cdot \mathrm{s} \cdot \mathrm{A}$	$\mathrm{C} \cdot \mathrm{m}$	$\mathrm{C} \cdot \mathrm{m}$

N 2021-02-24

`\electricfield`{⟨*magnitude*⟩}
`\electricfieldvector`{⟨$c_1, \ldots, c_n$⟩}
`\vectorelectricfield`{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\electricfield`	$\mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-3} \cdot \mathrm{A}^{-1}$	V / m	N / C

`\electricflux`{⟨*magnitude*⟩}

name	base	derived	alternate
`\electricflux`	$\mathrm{m}^3 \cdot \mathrm{kg} \cdot \mathrm{s}^{-3} \cdot \mathrm{A}^{-1}$	$\mathrm{V} \cdot \mathrm{m}$	$\mathrm{N} \cdot \mathrm{m}^2 / \mathrm{C}$

`\electricpotential`{⟨*magnitude*⟩}

name	base	derived	alternate
`\electricpotential`	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$	V	J / C

`\electroncurrent{⟨magnitude⟩}`

name	base	derived	alternate
`\electroncurrent`	s^{-1}	e / s	e / s

`\emf{⟨magnitude⟩}`

name	base	derived	alternate
`\emf`	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$	V	J / C

`\energy{⟨magnitude⟩}`

name	base	derived	alternate
`\energy`	$m^2 \cdot kg \cdot s^{-2}$	J	J

`\energydensity{⟨magnitude⟩}`

name	base	derived	alternate
`\energydensity`	$m^{-1} \cdot kg \cdot s^{-2}$	J / m^3	J / m^3

`\energyflux{⟨magnitude⟩}`
N 2021-02-24 `\energyfluxvector{⟨`$c_1, \ldots, c_n$`⟩}`
`\vectorenergyflux{⟨`$c_1, \ldots, c_n$`⟩}`

name	base	derived	alternate
`\energyflux`	$kg \cdot s^{-3}$	W / m^2	W / m^2

`\entropy{⟨magnitude⟩}`

name	base	derived	alternate
`\entropy`	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$	J / K	J / K

`\force{⟨magnitude⟩}`
N 2021-02-24 `\forcevector{⟨`$c_1, \ldots, c_n$`⟩}`
`\vectorforce{⟨`$c_1, \ldots, c_n$`⟩}`

name	base	derived	alternate
`\force`	$m \cdot kg \cdot s^{-2}$	N	N

`\frequency{⟨magnitude⟩}`

name	base	derived	alternate
`\frequency`	s^{-1}	Hz	Hz

`\gravitationalfield{⟨magnitude⟩}`
N 2021-02-24 `\gravitationalfieldvector{⟨c_1, ..., c_n⟩}`
`\vectorgravitationalfield{⟨c_1, ..., c_n⟩}`

name	base	derived	alternate
`\gravitationalfield`	$\mathrm{m} \cdot \mathrm{s}^{-2}$	N / kg	N / kg

`\gravitationalpotential{⟨magnitude⟩}`

name	base	derived	alternate
`\gravitationalpotential`	$\mathrm{m}^2 \cdot \mathrm{s}^{-2}$	J / kg	J / kg

`\impulse{⟨magnitude⟩}`
N 2021-02-24 `\impulsevector{⟨c_1, ..., c_n⟩}`
`\vectorimpulse{⟨c_1, ..., c_n⟩}`

name	base	derived	alternate
`\impulse`	$\mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$	N · s	N · s

`\indexofrefraction{⟨magnitude⟩}`

name	base	derived	alternate
`\indexofrefraction`			

`\inductance{⟨magnitude⟩}`

name	base	derived	alternate
`\inductance`	$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-2} \cdot \mathrm{A}^{-2}$	H	V · s / A

`\linearchargedensity{⟨magnitude⟩}`

name	base	derived	alternate
`\linearchargedensity`	$\mathrm{m}^{-1} \cdot \mathrm{s} \cdot \mathrm{A}$	C / m	C / m

`\linearmassdensity{⟨magnitude⟩}`

name	base	derived	alternate
`\linearmassdensity`	$\mathrm{m}^{-1} \cdot \mathrm{kg}$	kg / m	kg / m

`\luminous{⟨magnitude⟩}`

name	base	derived	alternate
`\luminous`	cd	cd	cd

`\magneticcharge{⟨magnitude⟩}`

name	base	derived	alternate
`\magneticcharge`	$\mathrm{m} \cdot \mathrm{A}$	$\mathrm{m} \cdot \mathrm{A}$	$\mathrm{m} \cdot \mathrm{A}$

N 2021-02-24

\magneticdipolemoment{⟨*magnitude*⟩}
\magneticdipolemomentvector{⟨$c_1, \ldots, c_n$⟩}
\vectormagneticdipolemoment{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\magneticdipolemoment`	$\mathrm{m}^2 \cdot \mathrm{A}$	$\mathrm{A} \cdot \mathrm{m}^2$	J / T

N 2021-02-24

\magneticfield{⟨*magnitude*⟩}
\magneticfieldvector{⟨$c_1, \ldots, c_n$⟩}
\vectormagneticfield{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\magneticfield`	$\mathrm{kg} \cdot \mathrm{s}^{-2} \cdot \mathrm{A}^{-1}$	T	$\mathrm{N} / \mathrm{C} \cdot (\mathrm{m} / \mathrm{s})$

\magneticflux{⟨*magnitude*⟩}

name	base	derived	alternate
`\magneticflux`	$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-2} \cdot \mathrm{A}^{-1}$	$\mathrm{T} \cdot \mathrm{m}^2$	$\mathrm{V} \cdot \mathrm{s}$

\mass{⟨*magnitude*⟩}

name	base	derived	alternate
`\mass`	kg	kg	kg

\mobility{⟨*magnitude*⟩}

name	base	derived	alternate
`\mobility`	$\mathrm{m}^2 \cdot \mathrm{kg} \cdot \mathrm{s}^{-4} \cdot \mathrm{A}^{-1}$	$\mathrm{m}^2 / \mathrm{V} \cdot \mathrm{s}$	$(\mathrm{m} / \mathrm{s}) / (\mathrm{N} / \mathrm{C})$

\momentofinertia{⟨*magnitude*⟩}

name	base	derived	alternate
`\momentofinertia`	$\mathrm{m}^2 \cdot \mathrm{kg}$	$\mathrm{J} \cdot \mathrm{s}^2$	$\mathrm{kg} \cdot \mathrm{m}^2$

N 2021-02-24

\momentum{⟨*magnitude*⟩}
\momentumvectordemo{⟨$c_1, \ldots, c_n$⟩}
\vectormomentum{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\momentum`	$\mathrm{m} \cdot \mathrm{kg} \cdot \mathrm{s}^{-1}$	$\mathrm{N} \cdot \mathrm{s}$	$\mathrm{kg} \cdot \mathrm{m} / \mathrm{s}$

N 2021-02-24

\momentumflux{⟨*magnitude*⟩}
\momentumfluxvector{⟨$c_1, \ldots, c_n$⟩}
\vectormomentumflux{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\momentumflux`	$m^{-1} \cdot kg \cdot s^{-2}$	N / m^2	N / m^2

`\numberdensity{⟨magnitude⟩}`

name	base	derived	alternate
`\numberdensity`	m^{-3}	$/ m^3$	$/ m^3$

`\permeability{⟨magnitude⟩}`

name	base	derived	alternate
`\permeability`	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$	$T \cdot m / A$	H / m

`\permittivity{⟨magnitude⟩}`

name	base	derived	alternate
`\permittivity`	$m^{-3} \cdot kg^{-1} \cdot s^{-4} \cdot A^2$	F / m	$C^2 / N \cdot m^2$

`\planeangle{⟨magnitude⟩}`

name	base	derived	alternate
`\planeangle`	$m \cdot m^{-1}$	rad	rad

`\polarizability{⟨magnitude⟩}`

name	base	derived	alternate
`\polarizability`	$kg^{-1} \cdot s^4 \cdot A^2$	$C \cdot m^2 / V$	$C \cdot m / (N / C)$

`\power{⟨magnitude⟩}`

name	base	derived	alternate
`\power`	$m^2 \cdot kg \cdot s^{-3}$	W	J / s

`\poynting{⟨magnitude⟩}`
N 2021-02-24 `\poyntingvector{⟨`$c_1, \ldots, c_n$`⟩}`
`\vectorpoynting{⟨`$c_1, \ldots, c_n$`⟩}`

name	base	derived	alternate
`\poynting`	$kg \cdot s^{-3}$	W / m^2	W / m^2

`\pressure{⟨magnitude⟩}`

name	base	derived	alternate
`\pressure`	$m^{-1} \cdot kg \cdot s^{-2}$	Pa	N / m^2

`\relativepermeability{⟨magnitude⟩}`

name	base	derived	alternate
`\relativepermeability`			

`\relativepermittivity`{⟨*magnitude*⟩}

name	base	derived	alternate
`\relativepermittivity`			

`\resistance`{⟨*magnitude*⟩}

name	base	derived	alternate
`\resistance`	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$	V / A	Ω

`\resistivity`{⟨*magnitude*⟩}

name	base	derived	alternate
`\resistivity`	$m^3 \cdot kg \cdot s^{-3} \cdot A^{-2}$	$\Omega \cdot m$	$(V / m) / (A / m^2)$

`\solidangle`{⟨*magnitude*⟩}

name	base	derived	alternate
`\solidangle`	$m^2 \cdot m^{-2}$	sr	sr

`\specificheatcapacity`{⟨*magnitude*⟩}

name	base	derived	alternate
`\specificheatcapacity`	$m^2 \cdot s^{-2} \cdot K^{-1}$	$J / K \cdot kg$	$J / K \cdot kg$

`\springstiffness`{⟨*magnitude*⟩}

name	base	derived	alternate
`\springstiffness`	$kg \cdot s^{-2}$	N / m	N / m

`\springstretch`{⟨*magnitude*⟩}

name	base	derived	alternate
`\springstretch`	m	m	m

`\stress`{⟨*magnitude*⟩}

name	base	derived	alternate
`\stress`	$m^{-1} \cdot kg \cdot s^{-2}$	Pa	N / m^2

`\strain`{⟨*magnitude*⟩}

name	base	derived	alternate
`\strain`			

\temperature{⟨*magnitude*⟩}

name	base	derived	alternate
\temperature	K	K	K

\torque{⟨*magnitude*⟩}
N 2021-02-24 \torquevector{⟨$c_1, \ldots, c_n$⟩}
\vectortorque{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
\torque	$\mathrm{m^2 \cdot kg \cdot s^{-2}}$	$\mathrm{N \cdot m}$	$\mathrm{N \cdot m}$

\velocity{⟨*magnitude*⟩}
N 2021-02-24 \velocityvector{⟨$c_1, \ldots, c_n$⟩}
\vectorvelocity{⟨$c_1, \ldots, c_n$⟩}
\velocityc{⟨*magnitude*⟩}
N 2021-02-24 \velocitycvector{⟨$c_1, \ldots, c_n$⟩}
\vectorvelocityc{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
\velocity	$\mathrm{m \cdot s^{-1}}$	m / s	m / s

name	base	derived	alternate
\velocityc	c		c

\volume{⟨*magnitude*⟩}

name	base	derived	alternate
\volume	$\mathrm{m^3}$	$\mathrm{m^3}$	$\mathrm{m^3}$

\volumechargedensity{⟨*magnitude*⟩}

name	base	derived	alternate
\volumechargedensity	$\mathrm{m^{-3} \cdot s \cdot A}$	$\mathrm{C / m^3}$	$\mathrm{C / m^3}$

\volumemassdensity{⟨*magnitude*⟩}

name	base	derived	alternate
\volumemassdensity	$\mathrm{m^{-3} \cdot kg}$	$\mathrm{kg / m^3}$	$\mathrm{kg / m^3}$

\wavelength{⟨*magnitude*⟩}

name	base	derived	alternate
\wavelength	m	m	m

\wavenumber{⟨*magnitude*⟩}
N 2021-02-24 \wavenumbervector{⟨$c_1, \ldots, c_n$⟩}
\vectorwavenumber{⟨$c_1, \ldots, c_n$⟩}

name	base	derived	alternate
`\wavenumber`	m^{-1}	/ m	/ m

\work{⟨*magnitude*⟩}

name	base	derived	alternate
`\work`	$m^2 \cdot kg \cdot s^{-2}$	J	N · m

\youngsmodulus{⟨*magnitude*⟩}

name	base	derived	alternate
`\youngsmodulus`	$m^{-1} \cdot kg \cdot s^{-2}$	Pa	N / m^2

3.1.4 Defining and Redefining Your Own Physical Quantities

N 2021-02-16 \newscalarquantity{⟨*name*⟩}{⟨*base units*⟩}[⟨*derived units*⟩][⟨*alternate units*⟩]
N 2021-02-21 \renewscalarquantity{⟨*name*⟩}{⟨*base units*⟩}[⟨*derived units*⟩][⟨*alternate units*⟩]

Command to define/redefine a new/existing scalar quantity. If the derived or alternate units are omitted, they are defined to be the same as the base units. Do not use both this command and `\newvectorquantity` or `\renewvectorquantity` to define/redefine a quantity.

N 2021-02-16 \newvectorquantity{⟨*name*⟩}{⟨*base units*⟩}[⟨*derived units*⟩][⟨*alternate units*⟩]
N 2021-02-21 \renewvectorquantity{⟨*name*⟩}{⟨*base units*⟩}[⟨*derived units*⟩][⟨*alternate units*⟩]

Command to define/redefine a new/existing vector quantity. If the derived or alternate units are omitted, they are defined to be the same as the base units. Do not use both this command and `\newscalarquantity` or `\renewscalarquantity` to define/redefine a quantity.

3.1.5 Predefined Units and Constructs

\per
\usk
\unit{⟨*magnitude*⟩}{⟨*unit*⟩}
\emptyunit
\ampere
\atomicmassunit
\candela
\coulomb
\degree
\electronvolt
\farad
\henry
\hertz
\joule
\kelvin
\kilogram
\lightspeed
\meter

`\metre`	
`\mole`	
`\newton`	
`\ohm`	
`\pascal`	
`\radian`	
`\second`	
`\siemens`	
`\steradian`	
`\tesla`	
`\volt`	
`\watt`	
`\weber`	
`\tothetwo`	(postfix)
`\tothethree`	(postfix)
`\tothefour`	(postfix)
`\inverse`	(postfix)
`\totheinversetwo`	(postfix)
`\totheinversethree`	(postfix)
`\totheinversefour`	(postfix)

```
\per                            \\
\usk                            \\
\unit{3}{\meter\per\second}     \\
\emptyunit                      \\
\ampere                         \\
\atomicmassunit                 \\
\candela                        \\
\coulomb                        \\
\degree                         \\
\electronvolt                   \\
\farad                          \\
\henry                          \\
\hertz                          \\
\joule                          \\
\kelvin                         \\
\kilogram                       \\
\lightspeed                     \\
\meter                          \\
\metre                          \\
\mole                           \\
\newton                         \\
\ohm                            \\
\pascal                         \\
\radian                         \\
\second                         \\
\siemens                        \\
\steradian                      \\
\tesla                          \\
\volt                           \\
\watt                           \\
\weber                          \\
\emptyunit\tothetwo             \\
\emptyunit\tothethree           \\
\emptyunit\tothefour            \\
\emptyunit\inverse              \\
\emptyunit\totheinversetwo      \\
\emptyunit\totheinversethree \\
\emptyunit\totheinversefour
```

/
.
3 m / s
□
A
u
cd
C
°
eV
F
H
Hz
J
K
kg
c
m
m
mol
N
Ω
Pa
rad
s
S
sr
T
V
W
Wb
$\square^{2}$
$\square^{3}$
$\square^{4}$
$\square^{-1}$
$\square^{-2}$
$\square^{-3}$
$\square^{-4}$

3.1.6 Changing Units

U 2021-02-26 `\alwaysusebaseunits`
U 2021-02-26 `\alwaysusederivedunits`
U 2021-02-26 `\alwaysusealternateunits`

Modal commands (switches) for setting the default unit form for the entire document. When mandi is loaded, one of these three commands is executed depending on whether the optional `units` key is provided. See the section on loading the package for details. Alternate units are the default because they are the most likely ones to be seen in introductory physics textbooks.

U 2021-02-26 `\hereusebaseunits{⟨content⟩}`
U 2021-02-26 `\hereusederivedunits{⟨content⟩}`
U 2021-02-26 `\hereusedalternateunits{⟨content⟩}`

Commands for setting the unit form on the fly for a single instance. The example uses momentum and the Coulomb constant, but they work for any defined quantity and constant.

```
\hereusebaseunits{\momentum{5}}      \\
\hereusederivedunits{\momentum{5}}   \\
\hereusealternateunits{\momentum{5}} \\
\hereusebaseunits{\oofpez}           \\
\hereusederivedunits{\oofpez}        \\
\hereusealternateunits{\oofpez}
```

$5\,\mathrm{m}\cdot\mathrm{kg}\cdot\mathrm{s}^{-1}$
$5\,\mathrm{N}\cdot\mathrm{s}$
$5\,\mathrm{kg}\cdot\mathrm{m}\,/\,\mathrm{s}$
$9\times10^{9}\,\mathrm{m}^{3}\cdot\mathrm{kg}\cdot\mathrm{s}^{-4}\cdot\mathrm{A}^{-2}$
$9\times10^{9}\,\mathrm{m}\,/\,\mathrm{F}$
$9\times10^{9}\,\mathrm{N}\cdot\mathrm{m}^{2}\,/\,\mathrm{C}^{2}$

U 2021-02-26 `\begin{usebaseunits}` (use base units)
`⟨environment content⟩`
`\end{usebaseunits}`
U 2021-02-26 `\begin{usederivedunits}` (use derived units)
`⟨environment content⟩`
`\end{usederivedunits}`
U 2021-02-26 `\begin{usealternateunits}` (use alternate units)
`⟨environment content⟩`
`\end{usealternateunits}`

Inside these environments units are changed for the duration of the environment regardless of the global default setting.

```
\momentum{5}   \\
\oofpez        \\
\begin{usebaseunits}
  \momentum{5} \\
  \oofpez      \\
\end{usebaseunits}
\begin{usederivedunits}
  \momentum{5} \\
  \oofpez      \\
\end{usederivedunits}
\begin{usealternateunits}
  \momentum{5} \\
  \oofpez
\end{usealternateunits}
```

$5\,\mathrm{kg}\cdot\mathrm{m}\,/\,\mathrm{s}$
$9\times10^{9}\,\mathrm{N}\cdot\mathrm{m}^{2}\,/\,\mathrm{C}^{2}$
$5\,\mathrm{m}\cdot\mathrm{kg}\cdot\mathrm{s}^{-1}$
$9\times10^{9}\,\mathrm{m}^{3}\cdot\mathrm{kg}\cdot\mathrm{s}^{-4}\cdot\mathrm{A}^{-2}$
$5\,\mathrm{N}\cdot\mathrm{s}$
$9\times10^{9}\,\mathrm{m}\,/\,\mathrm{F}$
$5\,\mathrm{kg}\cdot\mathrm{m}\,/\,\mathrm{s}$
$9\times10^{9}\,\mathrm{N}\cdot\mathrm{m}^{2}\,/\,\mathrm{C}^{2}$

3.2 Physical Constants

3.2.1 Typesetting Physical Constants

Take the quantity $\frac{1}{4\pi\epsilon_o}$, sometimes called the Coulomb constant, as the prototypical physical constant in an introductory physics course. Here are all the ways to access this quantity in mandi. As you can see, these commands are almost identical to the corresponding commands for physical quantities.

`\oofpez`

Command for the Coulomb constant. The constant's numerical precision and default units will depend on the options passed to mandi at load time. Alternate units and approximate numerical values are the defaults. Other units can be forced as demonstrated.

```
\oofpez                    \\
\oofpezapproximatevalue    \\
\oofpezprecisevalue        \\
\oofpezmathsymbol          \\
\oofpezbaseunits           \\
\oofpezderivedunits        \\
\oofpezalternateunits      \\
\oofpezonlybaseunits       \\
\oofpezonlyderivedunits    \\
\oofpezonlyalternateunits
```

$9 \times 10^9\,\mathrm{N\cdot m^2 / C^2}$
9×10^9
8.987551787×10^9
$\frac{1}{4\pi\epsilon_o}$
$9 \times 10^9\,\mathrm{m^3\cdot kg\cdot s^{-4}\cdot A^{-2}}$
$9 \times 10^9\,\mathrm{m / F}$
$9 \times 10^9\,\mathrm{N\cdot m^2 / C^2}$
$\mathrm{m^3\cdot kg\cdot s^{-4}\cdot A^{-2}}$
$\mathrm{m / F}$
$\mathrm{N\cdot m^2 / C^2}$

3.2.2 Checking Physical Constants

U 2021-02-26 `\checkconstant{⟨name⟩}`

Command to check and typeset the constant's name, base units, derived units, alternate units, mathematical symbol, approximate value, and precise value.

3.2.3 Commands For Predefined Physical Constants

Every other defined physical constant can be treated similarly. Just replace `oofpez` with the constant's name. Unfortunately, there is no universal agreement on the names of every constant so consult the next section for the names that have been used. Here are all the physical constants, with all their units, defined in mandi. The constants `\coulombconstant`→P. 23 and `\biotsavartconstant` are defined as semantic aliases for, respectively, `\oofpez`→P. 25 and `\mzofp`→P. 25.

`\avogadro`

name	base	derived	alternate
`\avogadro`	$\mathrm{mol^{-1}}$	$\mathrm{/\,mol}$	$\mathrm{/\,mol}$
symbol	approximate	precise	
$\mathrm{N_A}$	6×10^{23}	$6.02214076 \times 10^{23}$	

N 2021-02-02 `\biotsavartconstant`

name	base	derived	alternate
\biotsavartconstant	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$	$H\,/\,m$	$T \cdot m\,/\,A$
symbol	approximate	precise	
$\frac{\mu_o}{4\pi}$	10^{-7}	10^{-7}	

\bohrradius

name	base	derived	alternate
\bohrradius	m	m	m
symbol	approximate	precise	
a_o	5.3×10^{-11}	$5.2917721067 \times 10^{-11}$	

\boltzmann

name	base	derived	alternate
\boltzmann	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$	$J\,/\,K$	$J\,/\,K$
symbol	approximate	precise	
k_B	1.4×10^{-23}	1.380649×10^{-23}	

N 2021-02-02

\coulombconstant

name	base	derived	alternate
\coulombconstant	$m^3 \cdot kg \cdot s^{-4} \cdot A^{-2}$	$m\,/\,F$	$N \cdot m^2\,/\,C^2$
symbol	approximate	precise	
$\frac{1}{4\pi\epsilon_o}$	9×10^{9}	$8.9875517873681764 \times 10^{9}$	

\earthmass

name	base	derived	alternate
\earthmass	kg	kg	kg
symbol	approximate	precise	
M_{Earth}	6.0×10^{24}	5.97237×10^{24}	

\earthmoondistance

name	base	derived	alternate
\earthmoondistance	m	m	m
symbol	approximate	precise	
d_{EM}	3.8×10^{8}	3.81550×10^{8}	

\earthradius

name	base	derived	alternate
\earthradius	m	m	m
symbol	approximate	precise	
R_{Earth}	6.4×10^{6}	6.371×10^{6}	

\earthsundistance

name	base	derived	alternate
\earthsundistance	m	m	m
symbol	approximate	precise	
d_{ES}	1.5×10^{11}	1.496×10^{11}	

\electroncharge

name	base	derived	alternate
\electroncharge	$A \cdot s$	C	C
symbol	approximate	precise	
q_e	-1.6×10^{-19}	$-1.602176634 \times 10^{-19}$	

\electronCharge

name	base	derived	alternate
\electronCharge	$A \cdot s$	C	C
symbol	approximate	precise	
Q_e	-1.6×10^{-19}	$-1.602176634 \times 10^{-19}$	

\electronmass

name	base	derived	alternate
\electronmass	kg	kg	kg
symbol	approximate	precise	
m_e	9.1×10^{-31}	$9.10938356 \times 10^{-31}$	

\elementarycharge

name	base	derived	alternate
\elementarycharge	$A \cdot s$	C	C
symbol	approximate	precise	
e	1.6×10^{-19}	$1.602176634 \times 10^{-19}$	

\finestructure

name	base	derived	alternate
\finestructure			
symbol	approximate	precise	
α	$\frac{1}{137}$	$7.2973525664 \times 10^{-3}$	

\hydrogenmass

name	base	derived	alternate
\hydrogenmass	kg	kg	kg
symbol	approximate	precise	
m_H	1.7×10^{-27}	$1.6737236 \times 10^{-27}$	

\moonearthdistance

name	base	derived	alternate
\moonearthdistance	m	m	m
symbol	approximate	precise	
d_{ME}	3.8×10^{8}	3.81550×10^{8}	

\moonmass

name	base	derived	alternate
\moonmass	kg	kg	kg
symbol	approximate	precise	
M_{Moon}	7.3×10^{22}	7.342×10^{22}	

\moonradius

name	base	derived	alternate
\moonradius	m	m	m
symbol	approximate	precise	
R_{Moon}	1.7×10^{6}	1.7371×10^{6}	

\mzofp

name	base	derived	alternate
\mzofp	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$	H / m	$T \cdot m / A$
symbol	approximate	precise	
$\frac{\mu_o}{4\pi}$	10^{-7}	10^{-7}	

\neutronmass

name	base	derived	alternate
\neutronmass	kg	kg	kg
symbol	approximate	precise	
m_n	1.7×10^{-27}	$1.674927471 \times 10^{-27}$	

\oofpez

name	base	derived	alternate
\oofpez	$m^3 \cdot kg \cdot s^{-4} \cdot A^{-2}$	m / F	$N \cdot m^2 / C^2$
symbol	approximate	precise	
$\frac{1}{4\pi\epsilon_o}$	9×10^{9}	$8.987551787 \times 10^{9}$	

\oofpezcs

name	base	derived	alternate
\oofpezcs	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$	$T \cdot m^2$	$N \cdot s^2 / C^2$
symbol	approximate	precise	
$\frac{1}{4\pi\epsilon_o c^2}$	10^{-7}	10^{-7}	

\planck

name	base	derived	alternate
\planck	$m^2 \cdot kg \cdot s^{-1}$	$J \cdot s$	$J \cdot s$
symbol	approximate	precise	
h	6.6×10^{-34}	$6.62607015 \times 10^{-34}$	

\planckbar

name	base	derived	alternate
\planckbar	$m^2 \cdot kg \cdot s^{-1}$	$J \cdot s$	$J \cdot s$
symbol	approximate	precise	
$\hbar$	1.1×10^{-34}	$1.054571817 \times 10^{-34}$	

\planckc

name	base	derived	alternate
\planckc	$m^3 \cdot kg \cdot s^{-2}$	$J \cdot m$	$J \cdot m$
symbol	approximate	precise	
hc	2.0×10^{-25}	$1.98644586 \times 10^{-25}$	

\protoncharge

name	base	derived	alternate
\protoncharge	$A \cdot s$	C	C
symbol	approximate	precise	
q_p	$+1.6 \times 10^{-19}$	$+1.602176634 \times 10^{-19}$	

\protonCharge

name	base	derived	alternate
\protonCharge	$A \cdot s$	C	C
symbol	approximate	precise	
Q_p	$+1.6 \times 10^{-19}$	$+1.602176634 \times 10^{-19}$	

\protonmass

name	base	derived	alternate
\protonmass	kg	kg	kg
symbol	approximate	precise	
m_p	1.7×10^{-27}	$1.672621898 \times 10^{-27}$	

\rydberg

name	base	derived	alternate
\rydberg	m^{-1}	m^{-1}	m^{-1}
symbol	approximate	precise	
R_∞	1.1×10^7	$1.0973731568508 \times 10^7$	

\speedoflight

name	base	derived	alternate
\speedoflight	$\mathrm{m \cdot s^{-1}}$	$\mathrm{m / s}$	$\mathrm{m / s}$
symbol	approximate	precise	
c	3×10^{8}	2.99792458×10^{8}	

\stefanboltzmann

name	base	derived	alternate
\stefanboltzmann	$\mathrm{kg \cdot s^{-3} \cdot K^{-4}}$	$\mathrm{W / m^{2} \cdot K^{4}}$	$\mathrm{W / m^{2} \cdot K^{4}}$
symbol	approximate	precise	
σ	5.7×10^{-8}	5.670367×10^{-8}	

\sunearthdistance

name	base	derived	alternate
\sunearthdistance	m	m	m
symbol	approximate	precise	
$\mathrm{d_{SE}}$	1.5×10^{11}	1.496×10^{11}	

\sunradius

name	base	derived	alternate
\sunradius	m	m	m
symbol	approximate	precise	
$\mathrm{R_{Sun}}$	7.0×10^{8}	6.957×10^{8}	

\surfacegravfield

name	base	derived	alternate
\surfacegravfield	$\mathrm{m \cdot s^{-2}}$	$\mathrm{N / kg}$	$\mathrm{N / kg}$
symbol	approximate	precise	
g	9.8	9.807	

\universalgrav

name	base	derived	alternate
\universalgrav	$\mathrm{m^{3} \cdot kg^{-1} \cdot s^{-2}}$	$\mathrm{N \cdot m^{2} / kg^{2}}$	$\mathrm{N \cdot m^{2} / kg^{2}}$
symbol	approximate	precise	
G	6.7×10^{-11}	6.67408×10^{-11}	

\vacuumpermeability

name	base	derived	alternate
\vacuumpermeability	$\mathrm{m \cdot kg \cdot s^{-2} \cdot A^{-2}}$	$\mathrm{H / m}$	$\mathrm{T \cdot m / A}$
symbol	approximate	precise	
μ_{o}	$4\pi \times 10^{-7}$	$4\pi \times 10^{-7}$	

`\vacuumpermittivity`

name	base	derived	alternate
`\vacuumpermittivity`	$m^{-3} \cdot kg^{-1} \cdot s^{4} \cdot A^{2}$	F / m	$C^{2} / N \cdot m^{2}$
symbol	approximate	precise	
ϵ_o	9×10^{-12}	$8.854187817 \times 10^{-12}$	

3.2.4 Defining and Redefining Your Own Physical Constants

N 2021-02-16 `\newphysicalconstant {⟨name⟩}{⟨symbol⟩}{⟨approximate value⟩}{⟨precise value⟩}{⟨base units⟩} [⟨derived units⟩] [⟨alternate units⟩]`

N 2021-02-21 `\renewphysicalconstant {⟨name⟩}{⟨symbol⟩}{⟨approximate value⟩}{⟨precise value⟩}{⟨base units⟩} [⟨derived units⟩] [⟨alternate units⟩]`

Command to define/redefine a new/existing physical constant. If the derived or alternate units are omitted, they are defined to be the same as the base units.

3.2.5 Changing Precision

N 2021-02-16 `\alwaysuseapproximateconstants`

N 2021-02-16 `\alwaysusepreciseconstants`

Modal commands (switches) for setting the default precision for the entire document. The default with the package is loaded is set by the presence or absence of the `preciseconstants` → P. 6 key.

N 2021-02-16 `\hereuseapproximateconstants{⟨content⟩}`

N 2021-02-16 `\hereusepreciseconstants{⟨content⟩}`

Commands for setting the precision on the fly for a single instance.

```
\hereuseapproximateconstants{\oofpez} \\
\hereusepreciseconstants{\oofpez}
```

$9 \times 10^{9}\ N \cdot m^{2} / C^{2}$
$8.987551787 \times 10^{9}\ N \cdot m^{2} / C^{2}$

N 2021-02-16 `\begin{useapproximateconstants}` (use approximate constants)
`⟨environment content⟩`
`\end{useapproximateconstants}`

N 2021-02-16 `\begin{usepreciseconstants}` (use precise constants)
`⟨environment content⟩`
`\end{usepreciseconstants}`

Inside these environments precision is changed for the duration of the environment regardless of the global default setting.

```
\oofpez        \\
\begin{useapproximateconstants}
  \oofpez      \\
\end{useapproximateconstants}
\begin{usepreciseconstants}
  \oofpez      \\
\end{usepreciseconstants}
\oofpez
```

$9 \times 10^{9}\ N \cdot m^{2} / C^{2}$
$9 \times 10^{9}\ N \cdot m^{2} / C^{2}$
$8.987551787 \times 10^{9}\ N \cdot m^{2} / C^{2}$
$9 \times 10^{9}\ N \cdot m^{2} / C^{2}$

4 GlowScript and VPython Program Listings

4.1 The glowscriptblock Environment

U 2021-02-26

```
\begin{glowscriptblock}[⟨options⟩](⟨link⟩){⟨caption⟩}
  ⟨GlowScript code⟩
\end{glowscriptblock}
```

Code placed here is nicely formatted and optionally linked to its source on GlowScript.org. Clicking anywhere in the code window will open the link in the default browser. A caption is mandatory, and a label is internally generated. The listing always begins on a new page. A URL shortening utility is recommended to keep the URL from getting unruly. For convenience, `https://` is automatically prepended to the URL and can thus be omitted.

```
\begin{glowscriptblock}(tinyurl.com/y3lnqyn3){A \texttt{GlowScript} Program}
GlowScript 3.0 vpython

scene.width = 400
scene.height = 760
# constants and data
g = 9.8       # m/s^2
mball = 0.03  # kg
Lo = 0.26     # m
ks = 1.8      # N/m
deltat = 0.01 # s

# objects (origin is at ceiling)
ceiling = box(pos=vector(0,0,0), length=0.2, height=0.01,
              width=0.2)
ball = sphere(pos=vector(0,-0.3,0),radius=0.025,
              color=color.orange)
spring = helix(pos=ceiling.pos, axis=ball.pos-ceiling.pos,
               color=color.cyan,thickness=0.003,coils=40,
               radius=0.010)

# initial values
pball = mball * vector(0,0,0)      # kg m/s
Fgrav = mball * g * vector(0,-1,0) # N
t = 0

# improve the display
scene.autoscale = False        # turn off automatic camera zoom
scene.center = vector(0,-Lo,0) # move camera down
scene.waitfor('click')         # wait for a mouse click

# initial calculation loop
# calculation loop
while t < 10:
    rate(100)
    # we need the stretch
    s = mag(ball.pos) - Lo
    # we need the spring force
    Fspring = ks * s * -norm(spring.axis)
    Fnet = Fgrav + Fspring
    pball = pball + Fnet * deltat
    ball.pos = ball.pos + (pball / mball) * deltat
    spring.axis = ball.pos - ceiling.pos
    t = t + deltat
\end{glowscriptblock}
```

GlowScript Program 1: A GlowScript program

```python
GlowScript 3.0 vpython

scene.width = 400
scene.height = 760
# constants and data
g = 9.8        # m/s^2
mball = 0.03   # kg
Lo = 0.26      # m
ks = 1.8       # N/m
deltat = 0.01 # s

# objects (origin is at ceiling)
ceiling = box(pos=vector(0,0,0), length=0.2, height=0.01,
              width=0.2)
ball = sphere(pos=vector(0,-0.3,0),radius=0.025,
              color=color.orange)
spring = helix(pos=ceiling.pos, axis=ball.pos-ceiling.pos,
               color=color.cyan,thickness=0.003,coils=40,
               radius=0.010)

# initial values
pball = mball * vector(0,0,0)      # kg m/s
Fgrav = mball * g * vector(0,-1,0) # N
t = 0

# improve the display
scene.autoscale = False         # turn off automatic camera zoom
scene.center = vector(0,-Lo,0) # move camera down
scene.waitfor('click')          # wait for a mouse click

# initial calculation loop
# calculation loop
while t < 10:
    rate(100)
    # we need the stretch
    s = mag(ball.pos) - Lo
    # we need the spring force
    Fspring = ks * s * -norm(spring.axis)
    Fnet = Fgrav + Fspring
    pball = pball + Fnet * deltat
    ball.pos = ball.pos + (pball / mball) * deltat
    spring.axis = ball.pos - ceiling.pos
    t = t + deltat
```

```latex
\GlowScript\ program \ref{gs:1} is nice.
It's called \nameref{gs:1} and is on page \pageref{gs:1}.
```

GlowScript program 1 is nice. It's called A GlowScript program and is on page 31.

4.2 The `vpythonfile` Command

U 2021-02-26 `\vpythonfile[⟨options⟩]{⟨file⟩}{⟨caption⟩}`

Command to load and typeset a `VPython` program. The file is read from `{⟨file⟩}`. Clicking anywhere in the code window can optionally open a link, passed as an option, in the default browser. A caption is mandatory, and a label is internally generated. The listing always begins on a new page. A URL shortening utility is recommended to keep the URL from getting unruly. For convenience, `https://` is automatically prepended to the URL and can thus be omitted.

```
\vpythonfile[hyperurl interior = https://vpython.org]{vdemo.py}
  {A \VPython\ program}
```

VPython Program 1: A VPython program

```
from vpython import *

scene.width = 400
scene.height = 760
# constants and data
g = 9.8       # m/s^2
mball = 0.03  # kg
Lo = 0.26     # m
ks = 1.8      # N/m
deltat = 0.01 # s

# objects (origin is at ceiling)
ceiling = box(pos=vector(0,0,0), length=0.2, height=0.01,
              width=0.2)
ball = sphere(pos=vector(0,-0.3,0),radius=0.025,
              color=color.orange)
spring = helix(pos=ceiling.pos, axis=ball.pos-ceiling.pos,
               color=color.cyan,thickness=0.003,coils=40,
               radius=0.010)

# initial values
pball = mball * vector(0,0,0)      # kg m/s
Fgrav = mball * g * vector(0,-1,0) # N
t = 0

# improve the display
scene.autoscale = False        # turn off automatic camera zoom
scene.center = vector(0,-Lo,0) # move camera down
scene.waitfor('click')         # wait for a mouse click

# initial calculation loop
# calculation loop
while t < 10:
    rate(100)
    # we need the stretch
    s = mag(ball.pos) - Lo
    # we need the spring force
    Fspring = ks * s * -norm(spring.axis)
    Fnet = Fgrav + Fspring
    pball = pball + Fnet * deltat
    ball.pos = ball.pos + (pball / mball) * deltat
    spring.axis = ball.pos - ceiling.pos
    t = t + deltat
```

```
\VPython\ program \ref{vp:1} is nice.
It's called \nameref{vp:1} and is on page \pageref{vp:1}.
```

VPython program 1 is nice. It's called A VPython program and is on page 33.

4.3 The `glowscriptinline` and `vpythoninline` Commands

U 2021-02-26 **\glowscriptinline**{⟨*GlowScript code*⟩}

U 2021-02-26 **\vpythoninline**{⟨*VPython code*⟩}

Typesets a small, in-line snippet of code. The snippet should be less than one line long.

```
\GlowScript\ programs begin with \glowscriptinline{GlowScript 3.0 VPython}
and \VPython\ programs begin with \vpythoninline{from vpython import *}.
```

`GlowScript` programs begin with `GlowScript 3.0 VPython` and `VPython` programs begin with `from vpython import *`.

5 Commands for Writing Physics Problem Solutions

In addition to the glowscriptblock→P. 29 environment and the \vpythonfile→P. 32 command, the \glowscriptinline→P. 34 command, and \vpythoninline→P. 34 command mandi provides a collection of commands physics students can use for writing problem solutions. This new version focuses on the most frequently needed tools. These commands should always be used in math mode.

5.1 Traditional Vector Notation

\vec{⟨symbol⟩}[⟨labels⟩] (use this variant for boldface notation)
\vec*{⟨symbol⟩}[⟨labels⟩] (use this variant for arrow notation)

Powerful and intelligent command for symbolic vector notation. The mandatory argument is the symbol for the vector quantity. The optional label(s) consists of superscripts and/or subscripts and can be mathematical or textual in nature. If textual, be sure to wrap them in `\symup{...}` for proper typesetting. The starred variant gives arrow notation whereas without the star you get boldface notation. Subscript and superscript labels can be arbitrarily mixed, and order doesn't matter.

```
\( \vec{p} \)                                  \\
\( \vec{p}_{2} \)                              \\
\( \vec{p}^{\symup{ball}} \)                   \\
\( \vec{p}_{\symup{final}} \)                  \\
\( \vec{p}^{\symup{ball}}_{\symup{final}} \) \\
\( \vec{p}^{\symup{final}}_{\symup{ball}} \) \\
\( \vec*{p} \)
```

$\boldsymbol{p}$
$\boldsymbol{p}_2$
$\boldsymbol{p}^{\mathrm{ball}}$
$\boldsymbol{p}_{\mathrm{final}}$
$\boldsymbol{p}^{\mathrm{ball}}_{\mathrm{final}}$
$\boldsymbol{p}^{\mathrm{final}}_{\mathrm{ball}}$
$\vec{p}$

\dirvec{⟨symbol⟩}[⟨labels⟩] (use this variant for boldface notation)
\dirvec*{⟨symbol⟩}[⟨labels⟩] (use this variant for arrow notation)

Powerful and intelligent command for typesetting the direction of a vector. The options are the same as those for \vec.

```
\( \dirvec{p} \)                                  \\
\( \dirvec{p}_{2} \)                              \\
\( \dirvec{p}^{\symup{ball}} \)                   \\
\( \dirvec{p}_{\symup{final}} \)                  \\
\( \dirvec{p}^{\symup{ball}}_{\symup{final}} \) \\
\( \dirvec{p}^{\symup{final}}_{\symup{ball}} \) \\
\( \dirvec*{p} \)
```

$\widehat{\boldsymbol{p}}$
$\widehat{\boldsymbol{p}}_2$
$\widehat{\boldsymbol{p}}^{\mathrm{ball}}$
$\widehat{\boldsymbol{p}}_{\mathrm{final}}$
$\widehat{\boldsymbol{p}}^{\mathrm{ball}}_{\mathrm{final}}$
$\widehat{\boldsymbol{p}}^{\mathrm{final}}_{\mathrm{ball}}$
$\widehat{p}$

\zerovec (use this variant for boldface notation)
\zerovec* (use this variant for arrow notation)

Command for typesetting the zero vector. The starred variant gives arrow notation. Without the star you get boldface notation.

```
\( \zerovec  \) \\
\( \zerovec* \)
```

$\mathbf{0}$
$\vec{0}$

\mivector[⟨*delimiter*⟩]{⟨$c_1, \ldots, c_n$⟩}[⟨*units*⟩]

Typesets a vector as either numeric or symbolic components with an optional unit (for numerical components only). There can be more than three components. The delimiter used in the list of components can be specified; the default is a comma. The notation mirrors that of *Matter & Interactions*.

```
\mivector{p_0,p_1,p_2,p_3}                          \\
\mivector{\gamma m v_x,\gamma m v_y,\gamma m v_z} \\
\mivector{\frac{Q_1Q_2}{x^2},0,0}                   \\
\mivector{-1,0,0}                                   \\
\mivector{-1,0,0}[\velocityonlyderivedunits]        \\
\mivector{-1,0,0}[\meter\per\second]                \\
\velocity{\mivector{-1,0,0}}
```

$\langle p_0, p_1, p_2, p_3 \rangle$
$\left\langle \gamma m v_x, \gamma m v_y, \gamma m v_z \right\rangle$
$\left\langle \frac{Q_1 Q_2}{x^2}, 0, 0 \right\rangle$
$\langle -1, 0, 0 \rangle$
$\langle -1, 0, 0 \rangle$ m / s
$\langle -1, 0, 0 \rangle$ m / s
$\langle -1, 0, 0 \rangle$ m / s

N 2021-02-21 **\direction**[⟨*delimiter*⟩]{⟨$c_1, \ldots, c_n$⟩}
N 2021-02-21 **\unitvector**[⟨*delimiter*⟩]{⟨$c_1, \ldots, c_n$⟩}

Semantic aliases for \mivector.

```
\direction{\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}} \\
\unitvector{\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}},\frac{1}{\sqrt{3}}}
```

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

\changein

Semantic alias for `\Delta`.

```
\( \changein t \) \\
\( \changein \vec{p} \)
```

Δt
$\Delta \boldsymbol{p}$

N 2021-02-21 **\doublebars**[⟨*size*⟩]{⟨*quantity*⟩} (double bars)
N 2021-02-21 **\doublebars***[⟨*size*⟩]{⟨*quantity*⟩} (double bars for fractions)
N 2021-02-21 **\singlebars**[⟨*size*⟩]{⟨*quantity*⟩} (single bars)
N 2021-02-21 **\singlebars***[⟨*size*⟩]{⟨*quantity*⟩} (single bars for fractions)
N 2021-02-21 **\anglebrackets**[⟨*size*⟩]{⟨*quantity*⟩} (angle brackets)
N 2021-02-21 **\anglebrackets***[⟨*size*⟩]{⟨*quantity*⟩} (angle brackets for fractions)
N 2021-02-21 **\parentheses**[⟨*size*⟩]{⟨*quantity*⟩} (parentheses)
N 2021-02-21 **\parentheses***[⟨*size*⟩]{⟨*quantity*⟩} (parentheses for fractions)
N 2021-02-21 **\squarebrackets**[⟨*size*⟩]{⟨*quantity*⟩} (square brackets)
N 2021-02-21 **\squarebrackets***[⟨*size*⟩]{⟨*quantity*⟩} (square brackets for fractions)
N 2021-02-21 **\curlybraces**[⟨*size*⟩]{⟨*quantity*⟩} (curly braces)

N 2021-02-21

`\curlybraces*[⟨size⟩]{⟨quantity⟩}` (curly braces for fractions)

If no argument is given, a placeholder is provided. Sizers like `\big`,`\Big`,`\bigg`, and `\Bigg` can be optionally specified. Beginners are encouraged not to use them. See the mathtools package documentation for details.

```
\[ \doublebars{} \]
\[ \doublebars{\vec{a}} \]
\[ \doublebars*{\frac{\vec{a}}{3}} \]
\[ \doublebars[\Bigg]{\frac{\vec{a}}{3}} \]
```

$$\lVert \cdot \rVert$$

$$\lVert \boldsymbol{a} \rVert$$

$$\left\lVert \frac{\boldsymbol{a}}{3} \right\rVert$$

$$\Bigg\lVert \frac{\boldsymbol{a}}{3} \Bigg\rVert$$

```
\[ \singlebars{} \]
\[ \singlebars{x} \]
\[ \singlebars*{\frac{x}{3}} \]
\[ \singlebars[\Bigg]{\frac{x}{3}} \]
```

$$\lvert \cdot \rvert$$

$$\lvert x \rvert$$

$$\left\lvert \frac{x}{3} \right\rvert$$

$$\Bigg\lvert \frac{x}{3} \Bigg\rvert$$

```
\[ \anglebrackets{} \]
\[ \anglebrackets{\vec{a}} \]
\[ \anglebrackets*{\frac{\vec{a}}{3}} \]
\[ \anglebrackets[\Bigg]{\frac{\vec{a}}{3}} \]
```

$$\langle \cdot \rangle$$

$$\langle \boldsymbol{a} \rangle$$

$$\left\langle \frac{\boldsymbol{a}}{3} \right\rangle$$

$$\Bigg\langle \frac{\boldsymbol{a}}{3} \Bigg\rangle$$

```
\[ \parentheses{} \]
\[ \parentheses{x} \]
\[ \parentheses*{\frac{x}{3}} \]
\[ \parentheses[\Bigg]{\frac{x}{3}} \]
```

$$(\cdot)$$

$$(x)$$

$$\left(\frac{x}{3} \right)$$

$$\Bigg(\frac{x}{3} \Bigg)$$

```
\[ \squarebrackets{} \]
\[ \squarebrackets{x} \]
\[ \squarebrackets*{\frac{x}{3}} \]
\[ \squarebrackets[\Bigg]{\frac{x}{3}} \]
```

$$[\,\cdot\,]$$
$$[x]$$
$$\left[\frac{x}{3}\right]$$
$$\Bigg[\frac{x}{3}\Bigg]$$

```
\[ \curlybraces{} \]
\[ \curlybraces{x} \]
\[ \curlybraces*{\frac{x}{3}} \]
\[ \curlybraces[\Bigg]{\frac{x}{3}} \]
```

$$\{\,\cdot\,\}$$
$$\{x\}$$
$$\left\{\frac{x}{3}\right\}$$
$$\Bigg\{\frac{x}{3}\Bigg\}$$

N 2021-02-21 `\magnitude[⟨size⟩]{⟨quantity⟩}` (alias for double bars)
N 2021-02-21 `\magnitude*[⟨size⟩]{⟨quantity⟩}` (alias for double bars for fractions)
N 2021-02-21 `\norm[⟨size⟩]{⟨quantity⟩}` (alias for double bars)
N 2021-02-21 `\norm*[⟨size⟩]{⟨quantity⟩}` (alias for double bars for fractions)
N 2021-02-21 `\absolutevalue[⟨size⟩]{⟨quantity⟩}` (alias for single bars)
N 2021-02-21 `\absolutevalue*[⟨size⟩]{⟨quantity⟩}` (alias for single bars for fractions)

Semantic aliases. Use `\magnitude` or `\magnitude*` to typeset the magnitude of a vector.

```
\[ \magnitude{\vec{p}} \]
\[ \magnitude{\vec*{p}} \]
\[ \magnitude*{\vec{p}_{\symup{final}}} \]
\[ \magnitude*{\vec*{p}_{\symup{final}}} \]
```

$$\|\boldsymbol{p}\|$$
$$\|\vec{p}\|$$
$$\left\|\boldsymbol{p}_{\mathrm{final}}\right\|$$
$$\left\|\vec{p}_{\mathrm{final}}\right\|$$

`\colvec[⟨delimiter⟩]{⟨c_1, …, c_n⟩}`
`\rowvec[⟨delimiter⟩]{⟨c_1, …, c_n⟩}`

Typesets column vectors and row vectors as numeric or symbolic components. There can be more than three components. The delimiter used in the list of components can be specified; the default is a comma. Units are not supported, so these are mainly for symbolic work.

```
\[ \colvec{1,2,3} \]
\[ \rowvec{1,2,3} \]
\[ \colvec{x_0,x_1,x_2,x_3} \]
\[ \rowvec{x^0,x^1,x^2,x^3} \]
```

$$\begin{pmatrix}1\\2\\3\end{pmatrix}$$

$$\begin{pmatrix}1 & 2 & 3\end{pmatrix}$$

$$\begin{pmatrix}x_0\\x_1\\x_2\\x_3\end{pmatrix}$$

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

\tento{⟨*number*⟩}
\timestento{⟨*number*⟩}
\xtento{⟨*number*⟩}

Commands for powers of ten and scientific notation.

```
\( \tento{-4} \)      \\
\( 3\timestento{8} \) \\
\( 3\xtento{8} \)
```

10^{-4}
3×10^{8}
3×10^{8}

5.2 Coordinate-Free and Index Notation

Beyond the current level of introductory physics, we need intelligent commands for typesetting vector and tensor symbols and components suitable for both coordinate-free and index notations.

\veccomp{⟨*symbol*⟩} (use this variant for coordinate-free vector notation)
\veccomp*{⟨*symbol*⟩} (use this variant for index vector notation)
\tencomp{⟨*symbol*⟩} (use this variant for coordinate-free tensor notation)
\tencomp*{⟨*symbol*⟩} (use this variant for index tensor notation)

Conforms to ISO 80000-2 notation.

```
\( \veccomp{r}  \) \\
\( \veccomp*{r} \) \\
\( \tencomp{r}  \) \\
\( \tencomp*{r} \)
```

$\boldsymbol{r}$
r
$\boldsymbol{\mathsf{r}}$
r

\valence{⟨*index*⟩}{⟨*index*⟩}
\valence*{⟨*index*⟩}{⟨*index*⟩}

Typesets tensor valence. The starred variant typesets it horizontally.

```
A vector is a \( \valence{1}{0}  \) tensor. \\
A vector is a \( \valence*{1}{0} \) tensor.
```

A vector is a $\binom{1}{0}$ tensor.
A vector is a $(1,0)$ tensor.

`\contraction{⟨slot,slot⟩}`
`\contraction*{⟨slot,slot⟩}`

Typesets tensor contraction in coordinate-free notation. There is no standard on this so we assert one here.

```
\( \contraction{1,2}  \) \\
\( \contraction*{1,2} \)
```

$\mathbb{C}_{1,2}$
$\mathsf{C}_{1,2}$

`\slot[⟨vector⟩]`
`\slot*[⟨vector⟩]`

An intelligent slot command for coordinate-free vector and tensor notation. The starred variants suppress the underscore.

```
\( (\slot)  \)          \\
\( (\slot[\vec{a}])  \) \\
\( (\slot*) \)          \\
\( (\slot*[\vec{a}]) \)
```

$(\underline{\quad})$
$(\underline{\boldsymbol{a}})$
$(\quad)$
$(\boldsymbol{a})$

5.3 Problems and Annotated Problem Solutions

N 2021-02-03 `\begin{physicsproblem}{⟨title⟩}` (use this variant for vertical lists)
  ⟨*problem*⟩
`\end{physicsproblem}`

N 2021-02-03 `\begin{physicsproblem*}{⟨title⟩}` (use this variant for in-line lists)
  ⟨*problem*⟩
`\end{physicsproblem*}`

N 2021-02-03 `\begin{parts}{⟨title⟩}` (provides problem parts)
  ⟨*problem*⟩
`\end{parts}`

Provides an environment for stating physics problems. Each problem will begin on a new page. See the examples for how to handle single and multiple part problems.

N 2012-02-03 `\problempart`

Denotes a part of a problem within a `parts` environment.

```
\begin{physicsproblem}{Problem 1}
  This is a physics problem with no parts.
\end{physicsproblem}
```

Problem 1

This is a physics problem with no parts.

```
\begin{physicsproblem}{Problem 2}
  This is a physics problem with multiple parts.
  The list is vertical.
  \begin{parts}
    \problempart This is the first part.
    \problempart This is the second part.
    \problempart This is the third part.
  \end{parts}
\end{physicsproblem}
```

Problem 2

This is a physics problem with multiple parts. The list is vertical.

(a) This is the first part.

(b) This is the second part.

(c) This is the third part.

```
\begin{physicsproblem*}{Problem 3}
  This is a physics problem with multiple parts.
  The list is in-line.
  \begin{parts}
    \problempart This is the first part.
    \problempart This is the second part.
    \problempart This is the third part.
  \end{parts}
\end{physicsproblem*}
```

Problem 3

This is a physics problem with multiple parts. The list is in-line. **(a)** This is the first part. **(b)** This is the second part. **(c)** This is the third part.

U 2021-02-26 `\begin{physicssolution}` (use this variant for numbered steps)
⟨*solution steps*⟩
`\end{physicssolution}`

U 2021-02-26 `\begin{physicssolution*}` (use this variant for unnumbered steps)
⟨*solution steps*⟩
`\end{physicssolution*}`

This environment is only for mathematical solutions. The starred variant omits numbering of steps. See the examples.

```
\begin{physicssolution}
  x &= y + z \\
  z &= x - y \\
  y &= x - z
\end{physicssolution}
\begin{physicssolution*}
  x &= y + z \\
  z &= x - y \\
  y &= x - z
\end{physicssolution*}
```

$$x = y + z \tag{1}$$
$$z = x - y \tag{2}$$
$$y = x - z \tag{3}$$

$$x = y + z$$
$$z = x - y$$
$$y = x - z$$

U 2012-02-26

\reason{⟨*reason*⟩}

Provides an annotation in a step-by-step solution. Keep reasons short and to the point. Wrap mathematical content in math mode.

```
\begin{physicssolution}
  x &= y + z \reason{This is a reason.}     \\
  z &= x - y \reason{This is a reason too.} \\
  y &= x - z \reason{final answer}
\end{physicssolution}
\begin{physicssolution*}
  x &= y + z \reason{This is a reason.}     \\
  z &= x - y \reason{This is a reason too.} \\
  y &= x - z \reason{final answer}
\end{physicssolution*}
```

$$x = y + z \quad \text{This is a reason.} \tag{4}$$
$$z = x - y \quad \text{This is a reason too.} \tag{5}$$
$$y = x - z \quad \text{final answer} \tag{6}$$

$$x = y + z \quad \text{This is a reason.}$$
$$z = x - y \quad \text{This is a reason too.}$$
$$y = x - z \quad \text{final answer}$$

When writing solutions, remember that the physicssolution→P. 41 environment is *only* for mathematical content, not textual content or explanations.

```
\begin{physicsproblem}{Combined Problem and Solution}
  This is an interesting physics problem.
  \begin{physicssolution}
    The solution goes here.
  \end{physicssolution}
\end{physicsproblem}
```

```
\begin{physicsproblem}{Combined Multipart Problem with Solutions}
  This is a physics problem with multiple parts.
  \begin{parts}
    \problempart This is the first part.
      \begin{physicssolution}
        The solution goes here.
      \end{physicssolution}
    \problempart This is the second part.
      \begin{physicssolution}
        The solution goes here.
      \end{physicssolution}
    \problempart This is the third part.
      \begin{physicssolution}
        The solution goes here.
      \end{physicssolution}
  \end{parts}
\end{physicsproblem}
```

N 2021-02-06 **\hilite**[⟨*color*⟩]{⟨*target*⟩}[⟨*shape*⟩]

Hilites the desired target, which can be an entire mathematical expression or a part thereof. The default color is magenta and the default shape is a rectangle.

```
\begin{align*}
  (\Delta s)^2 &= -(\Delta t)^2 + (\Delta x)^2 + (\Delta y)^2 +
                  (\Delta z)^2 \\
  (\Delta s)^2 &= \hilite{-(\Delta t)^2 + (\Delta x)^2}[rounded rectangle] +
                  (\Delta y)^2 + (\Delta z)^2 \\
  (\Delta s)^2 &= \hilite{-(\Delta t)^2 + (\Delta x)^2}[rectangle] +
                  (\Delta y)^2 + (\Delta z)^2 \\
  (\Delta s)^2 &= \hilite{-(\Delta t)^2 + (\Delta x)^2}[ellipse] +
                  (\Delta y)^2 + (\Delta z)^2 \\
  (\Delta s)^{\hilite{2}[circle]} &= \hilite[green]{-}[circle]
              (\Delta t)^{\hilite[cyan]{2}[circle]}+
              (\Delta x)^{\hilite[orange]{2}[circle]} +
              (\Delta y)^{\hilite[blue!50]{2}[circle]} +
              (\Delta z)^{\hilite[violet!45]{2}[circle]}
\end{align*}
```

$$
\begin{aligned}
(\Delta s)^2 &= -(\Delta t)^2 + (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2 \\
(\Delta s)^2 &= -(\Delta t)^2 + (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2 \\
(\Delta s)^2 &= \boxed{-(\Delta t)^2 + (\Delta x)^2} + (\Delta y)^2 + (\Delta z)^2 \\
(\Delta s)^2 &= -(\Delta t)^2 + (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2 \\
(\Delta s)^2 &= -(\Delta t)^2 + (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2
\end{aligned}
$$

```
\begin{align*}
  \Delta\vec{p} &= \vec{F}_{\sumup{net}}\,\Delta t \\
  \hilite[orange]{\Delta\vec{p}}[circle] &= \vec{F}_{\symup{net}}\,\Delta t \\
  \Delta\vec{p} &= \hilite[yellow!50]{\vec{F}_{\symup{net}}}
                   [rounded rectangle]\,\Delta t \\
  \Delta\vec{p} &= \vec{F}_{\symup{net}}\,\hilite[olive!50]
                   {\Delta t}[rectangle] \\
  \Delta\vec{p} &= \hilite[cyan!50]{\vec{F}_{\symup{net}}\,\Delta t}
                   [ellipse] \\
  \hilite{\Delta\vec{p}}[rectangle] &= \vec{F}_{\symup{net}}\,\Delta t
\end{align*}
```

$$\begin{aligned}
\Delta\boldsymbol{p} &= \boldsymbol{F}_{\mathrm{net}}\,\Delta t \\
\Delta\boldsymbol{p} &= \boldsymbol{F}_{\mathrm{net}}\,\Delta t \\
\Delta\boldsymbol{p} &= \boldsymbol{F}_{\mathrm{net}}\,\Delta t \\
\Delta\boldsymbol{p} &= \boldsymbol{F}_{\mathrm{net}}\,\Delta t \\
\Delta\boldsymbol{p} &= \boldsymbol{F}_{\mathrm{net}}\,\Delta t \\
\Delta\boldsymbol{p} &= \boldsymbol{F}_{\mathrm{net}}\,\Delta t
\end{aligned}$$

U 2021-02-26 **\image**[⟨*options*⟩]{⟨*caption*⟩}{⟨*label*⟩}{⟨*image*⟩}

Simplified interface for importing an image. The images are treated as floats, so they may not appear at the most logically intuitive place.

```
\image[scale=0.20]{example-image-1x1}
  {Image shown 20 percent actual size.}{reffig1}
```

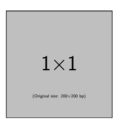

Figure 1: Image shown 20 percent actual size.

```
Figure \ref{reffig1} is nice.
It's captioned \nameref{reffig1} and is on page \pageref{reffig1}.
```

Figure 1 is nice. It's captioned Image shown 20 percent actual size and is on page 44.

```
\image[scale=0.20,angle=45]{example-image-1x1}
{Image shown 20 percent actual size and rotated.}{reffig1}
```

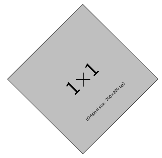

Figure 2: Image shown 20 percent actual size and rotated.

```
Figure \ref{reffig2} is nice.
It's captioned \nameref{reffig2} and is on page \pageref{reffig2}.
```

Figure 2 is nice. It's captioned Image shown 20 percent actual size and rotated and is on page 45.

6 Commands Specific to *Matter & Interactions*

mandi comes with an accessory package mandiexp which includes commands specific to *Matter & Interactions*[2]. The commands are primarily for typesetting mathematical expressions used in the text. Use of mandiexp is optional and so must be manually loaded by including the line `\usepackage{mandiexp}` in your document's preamble.

6.1 The Momentum Principle

`\lhsmomentumprinciple`	(LHS of delta form, bold vectors)
`\rhsmomentumprinciple`	(RHS of delta form, bold vectors)
`\lhsmomentumprincipleupdate`	(LHS of update form, bold vectors)
`\rhsmomentumprincipleupdate`	(RHS of update form, bold vectors)
`\momentumprinciple`	(delta form, bold vectors)
`\momentumprincipleupdate`	(update form, bold vectors)
`\lhsmomentumprinciple*`	(LHS of delta form, arrow vectors)
`\rhsmomentumprinciple*`	(RHS of delta form, arrow vectors)
`\lhsmomentumprincipleupdate*`	(LHS of update form, arrow vectors)
`\rhsmomentumprincipleupdate*`	(RHS of update form, arrow vectors)
`\momentumprinciple*`	(delta form, arrow vectors)
`\momentumprincipleupdate*`	(update form, arrow vectors)

Variants of command for typesetting the momentum principle. Use starred variants to get arrow notation for vectors.

```
\( \lhsmomentumprinciple \)         \\
\( \rhsmomentumprinciple \)         \\
\( \lhsmomentumprincipleupdate \)   \\
\( \rhsmomentumprincipleupdate \)   \\
\( \momentumprinciple \)            \\
\( \momentumprincipleupdate \)      \\
\( \lhsmomentumprinciple* \)        \\
\( \rhsmomentumprinciple* \)        \\
\( \lhsmomentumprincipleupdate* \)  \\
\( \rhsmomentumprincipleupdate* \)  \\
\( \momentumprinciple* \)           \\
\( \momentumprincipleupdate* \)
```

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

6.2 The Energy Principle

`\lhsenergyprinciple`	(LHS of delta form)
`\rhsenergyprinciple[⟨+process...⟩]`	(RHS of delta form)
`\lhsenergyprincipleupdate`	(LHS of update form)

[2]See *Matter & Interactions* and https://matterandinteractions.org/ for details

`\rhsenergyprincipleupdate[⟨+process...⟩]` (RHS of update form)
`\energyprinciple[⟨+process...⟩]` (delta form)
`\energyprincipleupdate[⟨+process...⟩]` (update form)

Variants of command for typesetting the energy principle.

```
\( \lhsenergyprinciple \)           \\
\( \rhsenergyprinciple \)           \\
\( \rhsenergyprinciple[+Q] \)       \\
\( \energyprinciple \)              \\
\( \energyprinciple[+Q] \)          \\
\( \lhsenergyprincipleupdate \)     \\
\( \rhsenergyprincipleupdate \)     \\
\( \rhsenergyprincipleupdate[+Q] \) \\
\( \energyprincipleupdate \)        \\
\( \energyprincipleupdate[+Q] \)
```

$\mathit{\Delta} E_{\text{sys}}$
W_{ext}
$W_{\text{ext}} + Q$
$\mathit{\Delta} E_{\text{sys}} = W_{\text{ext}}$
$\mathit{\Delta} E_{\text{sys}} = W_{\text{ext}} + Q$
$E_{\text{sys,final}}$
$E_{\text{sys,initial}} + W_{\text{ext}}$
$E_{\text{sys,initial}} + W_{\text{ext}} + Q$
$E_{\text{sys,final}} = E_{\text{sys,initial}} + W_{\text{ext}}$
$E_{\text{sys,final}} = E_{\text{sys,initial}} + W_{\text{ext}} + Q$

6.3 The Angular Momentum Principle

`\lhsangularmomentumprinciple` (LHS of delta form, bold vectors)
`\rhsangularmomentumprinciple` (RHS of delta form, bold vectors)
`\lhsangularmomentumprincipleupdate` (LHS of update form, bold vectors)
`\rhsangularmomentumprincipleupdate` (RHS of update form, bold vectors)
`\angularmomentumprinciple` (delta form, bold vectors)
`\angularmomentumprincipleupdate` (update form, bold vectors)
`\lhsangularmomentumprinciple*` (LHS of delta form, arrow vectors)
`\rhsangularmomentumprinciple*` (RHS of delta form, arrow vectors)
`\lhsangularmomentumprincipleupdate*` (LHS of update form, arrow vectors)
`\rhsangularmomentumprincipleupdate*` (RHS of update form, arrow vectors)
`\angularmomentumprinciple*` (delta form, arrow vectors)
`\angularmomentumprincipleupdate*` (update form, arrow vectors)

Variants of command for typesetting the angularmomentum principle. Use starred variants to get arrow notation for vectors.

```
\( \lhsangularmomentumprinciple \)        \\
\( \rhsangularmomentumprinciple \)        \\
\( \lhsangularmomentumprincipleupdate \)  \\
\( \rhsangularmomentumprincipleupdate \)  \\
\( \angularmomentumprinciple \)           \\
\( \angularmomentumprincipleupdate \)     \\
\( \lhsangularmomentumprinciple* \)       \\
\( \rhsangularmomentumprinciple* \)       \\
\( \lhsangularmomentumprincipleupdate* \) \\
\( \rhsangularmomentumprincipleupdate* \) \\
\( \angularmomentumprinciple* \)          \\
\( \angularmomentumprincipleupdate* \)
```

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

6.4 Other Expressions

N 2021-02-13 **\energyof**{⟨*label*⟩}[⟨*label*⟩]

Generic symbol for the energy of some entity.

```
\( \energyof{\symup{electron}} \) \\
\( \energyof{\symup{electron}}[\symup{final}] \)
```

E_{electron}
$E_{\text{electron,final}}$

N 2021-02-13 **\systemenergy**[⟨*label*⟩]

Symbol for system energy.

```
\( \systemenergy \) \\
\( \systemenergy[\symup{final}] \)
```

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

N 2021-02-13 **\particleenergy**[⟨*label*⟩]

Symbol for particle energy.

```
\( \particleenergy \) \\
\( \particleenergy[\symup{final}] \)
```

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

N 2021-02-13 **\restenergy**[⟨*label*⟩]

Symbol for rest energy.

```
\( \restenergy \) \\
\( \restenergy[\symup{final}] \)
```

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

N 2021-02-13 `\internalenergy[⟨label⟩]`

Symbol for internal energy.

```
\( \internalenergy \) \\
\( \internalenergy[\symup{final}] \)
```

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

N 2021-02-13 `\chemicalenergy[⟨label⟩]`

Symbol for chemical energy.

```
\( \chemicalenergy \) \\
\( \chemicalenergy[\symup{final}] \)
```

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

N 2021-02-13 `\thermalenergy[⟨label⟩]`

Symbol for thermal energy.

```
\( \thermalenergy \) \\
\( \thermalenergy[\symup{final}] \)
```

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

N 2021-02-13 `\photonenergy[⟨label⟩]`

Symbol for photon energy.

```
\( \photonenergy \) \\
\( \photonenergy[\symup{final}] \)
```

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

N 2021-02-13 `\translationalkineticenergy[⟨label⟩]`
N 2021-02-13 `\translationalkineticenergy*[⟨label⟩]`

Symbol for translational kinetic energy. The starred variant gives E notation.

```
\( \translationalkineticenergy \) \\
\( \translationalkineticenergy[\symup{initial}] \) \\
\( \translationalkineticenergy* \) \\
\( \translationalkineticenergy*[\symup{initial}] \)
```

K_{trans}
$K_{\text{trans,initial}}$
E_{K}
$E_{\text{K,initial}}$

N 2021-02-13 `\rotationalkineticenergy[⟨label⟩]`
N 2021-02-13 `\rotationalkineticenergy*[⟨label⟩]`

Symbol for rotational kinetic energy. The starred variant gives E notation.

```
\( \rotationalkineticenergy \) \\
\( \rotationalkineticenergy[\symup{initial}] \) \\
\( \rotationalkineticenergy* \) \\
\( \rotationalkineticenergy*[\symup{initial}] \)
```

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

N 2021-02-13 `\vibrationalkineticenergy[⟨label⟩]`
N 2021-02-13 `\vibrationalkineticenergy*[⟨label⟩]`

Symbol for vibrational kinetic energy. The starred variant gives E notation.

```
\( \vibrationalkineticenergy \) \\
\( \vibrationalkineticenergy[\symup{initial}] \) \\
\( \vibrationalkineticenergy* \) \\
\( \vibrationalkineticenergy*[\symup{initial}] \)
```

K_{vib}
$K_{\mathrm{vib,initial}}$
E_{vib}
$E_{\mathrm{vib,initial}}$

N 2021-02-13 `\gravitationalpotentialenergy[⟨label⟩]`

Symbol for gravitational potential energy.

```
\( \gravitationalpotentialenergy \) \\
\( \gravitationalpotentialenergy[\symup{final}] \)
```

U_{g}
$U_{\mathrm{g,final}}$

N 2021-02-13 `\electricpotentialenergy[⟨label⟩]`

Symbol for electric potential energy.

```
\( \electricpotentialenergy \) \\
\( \electricpotentialenergy[\symup{final}] \)
```

U_{e}
$U_{\mathrm{e,final}}$

N 2021-02-13 `\springpotentialenergy[⟨label⟩]`

Symbol for spring potential energy.

```
\( \springpotentialenergy \) \\
\( \springpotentialenergy[\symup{final}] \)
```

U_{s}
$U_{\mathrm{s,final}}$

7 Source Code

Definine the package version and date for global use, exploiting the fact that in a .sty file there is now no need for `\makeatletter` and `\makeatother`. This simplifies defining internal commands, with `@` in the name, that are not for the user to know about.

```
\def\mandi@Version{3.0.0i}
\def\mandi@Date{2021-03-18}
\NeedsTeXFormat{LaTeX2e}[1999/12/01]
\providecommand\DeclareRelease[3]{}
\providecommand\DeclareCurrentRelease[2]{}
\DeclareRelease{v3.0.0i}{2021-03-18}{mandi.sty}
\DeclareCurrentRelease{v\mandi@Version}{\mandi@Date}
\ProvidesPackage{mandi}
  [\mandi@Date\space v\mandi@Version\space Macros for introductory physics]
```

Define a convenient package version command.

```
\newcommand*{\mandiversion}{v\mandi@Version\space dated \mandi@Date}
```

Set up the fonts to be consistent with ISO 80000-2 notation. The unicode-math package loads the fontspec and xparse packages. Note that xparse is now part of the LaTeX kernel. Because unicode-math is required, all documents using mandi must be compiled with an engine that supports Unicode. We recommend LuaLaTeX.

```
\RequirePackage{unicode-math}
\unimathsetup{math-style=ISO}
\unimathsetup{warnings-off={mathtools-colon,mathtools-overbracket}}
\setmathfont[Scale=MatchLowercase]{TeX Gyre DejaVu Math} % single-storey g.
```

Use normal math letters from Latin Modern Math for familiarity with textbooks.

```
\setmathfont[Scale=MatchLowercase,range=it/]{Latin Modern Math}
```

Borrow `mathscr` and `mathbfscr` from XITS Math.
See https://tex.stackexchange.com/a/120073/218142.

```
\setmathfont[Scale=MatchLowercase,range={\mathscr,\mathbfscr}]{XITS Math}
```

Get original and bold `mathcal` fonts.
See https://tex.stackexchange.com/a/21742/218142.

```
\setmathfont[Scale=MatchLowercase,range={\mathcal,\mathbfcal},StylisticSet=1]{XITS Math}
```

Borrow Greek letters from Latin Modern Math.

```
\setmathfont[Scale=MatchLowercase,range=    it/{greek,Greek}]{Latin Modern Math}
\setmathfont[Scale=MatchLowercase,range=  bfit/{greek,Greek}]{Latin Modern Math}
\setmathfont[Scale=MatchLowercase,range=    up/{greek,Greek}]{Latin Modern Math}
\setmathfont[Scale=MatchLowercase,range=  bfup/{greek,Greek}]{Latin Modern Math}
\setmathfont[Scale=MatchLowercase,range=bfsfup/{greek,Greek}]{Latin Modern Math}
```

Load third party packages, documenting why each one is needed.

```
\RequirePackage{amsmath}              % AMS goodness (don't load amssymb or amsfonts)
\RequirePackage[inline]{enumitem}     % needed for physicsproblem environment
\RequirePackage{eso-pic}              % needed for \hilite
\RequirePackage[g]{esvect}            % needed for nice vector arrow, style g
\RequirePackage{pgfopts}              % needed for key-value interface
\RequirePackage{array}                % needed for \checkquantity and \checkconstant
\RequirePackage{iftex}                % needed for requiring LuaLaTeX
\RequirePackage{makebox}              % needed for consistent \dirvect; \makebox
\RequirePackage{mathtools}            % needed for paired delimiters; extends amsmath
\RequirePackage{nicematrix}           % needed for column and row vectors
\RequirePackage[most]{tcolorbox}      % needed for program listings
\RequirePackage{tensor}               % needed for index notation
\RequirePackage{tikz}                 % needed for \hilite
```

```
\usetikzlibrary{shapes,fit,tikzmark} % needed for \hilite
\RequirePackage{hyperref}            % load last
\RequireLuaTeX                       % require this engine
```

Need to tweak the esvect package fonts to get the correct font size. Code provided by @egreg. See https://tex.stackexchange.com/a/566676.

```
\DeclareFontFamily{U}{esvect}{}
\DeclareFontShape{U}{esvect}{m}{n}{%
  <-5.5> vect5
  <5.5-6.5> vect6
  <6.5-7.5> vect7
  <7.5-8.5> vect8
  <8.5-9.5> vect9
  <9.5-> vect10
}{}%
```

```
\directlua{%
 luaotfload.add_colorscheme("colordigits",
   {["8000FF"] = {"one","two","three","four","five","six","seven","eight","nine","zero"}})
}%
\newfontfamily\colordigits{DejaVuSansMono}[RawFeature={color=colordigits}]
```

Set up a color scheme and a new code environment for listings. The new colors are more restful on the eye. All listing commands now use tcolorbox.
See https://tex.stackexchange.com/a/529421/218142.

```
\newfontfamily{\gsfontfamily}{DejaVuSansMono}    % new font for listings
\definecolor{gsbggray}     {rgb}{0.90,0.90,0.90} % background gray
\definecolor{gsgray}       {rgb}{0.30,0.30,0.30} % gray
\definecolor{gsgreen}      {rgb}{0.00,0.60,0.00} % green
\definecolor{gsorange}     {rgb}{0.80,0.45,0.12} % orange
\definecolor{gspeach}      {rgb}{1.00,0.90,0.71} % peach
\definecolor{gspearl}      {rgb}{0.94,0.92,0.84} % pearl
\definecolor{gsplum}       {rgb}{0.74,0.46,0.70} % plum
\lstdefinestyle{vpython}{%                       % style for listings
  backgroundcolor=\color{gsbggray},%             % background color
  basicstyle=\colordigits\footnotesize,%         % default style
  breakatwhitespace=true%                        % break at whitespace
  breaklines=true,%                              % break long lines
  captionpos=b,%                                 % position caption
  classoffset=1,%                                % STILL DON'T UNDERSTAND THIS
  commentstyle=\color{gsgray},%                  % font for comments
  deletekeywords={print},%                       % delete keywords from the given language
  emph={self,cls,@classmethod,@property},%       % words to emphasize
  emphstyle=\color{gsorange}\itshape,%           % font for emphasis
  escapeinside={(*@}{@*)},%                      % add LaTeX within your code
  frame=tb,%                                     % frame style
  framerule=2.0pt,%                              % frame thickness
  framexleftmargin=5pt,%                         % extra frame left margin
  %identifierstyle=\sffamily,%                    % style for identifiers
  keywordstyle=\gsfontfamily\color{gsplum},%     % color for keywords
  language=Python,%                              % select language
  linewidth=\linewidth,%                         % width of listings
  morekeywords={%                                % VPython/GlowScript specific keywords
    __future__,abs,acos,align,ambient,angle,append,append_to_caption,%
    append_to_title,arange,arrow,asin,astuple,atan,atan2,attach_arrow,%
    attach_trail,autoscale,axis,background,billboard,bind,black,blue,border,%
    bounding_box,box,bumpaxis,bumpmap,bumpmaps,camera,canvas,caption,capture,%
    ceil,center,clear,clear_trail,click,clone,CoffeeScript,coils,color,combin,%
    comp,compound,cone,convex,cos,cross,curve,cyan,cylinder,data,degrees,del,%
```

```
    delete,depth,descender,diff_angle,digits,division,dot,draw_complete,%
    ellipsoid,emissive,end_face_color,equals,explog,extrusion,faces,factorial,%
    False,floor,follow,font,format,forward,fov,frame,gcurve,gdisplay,gdots,%
    get_library,get_selected,ghbars,global,GlowScript,graph,graphs,green,gvbars,%
    hat,headlength,headwidth,height,helix,hsv_to_rgb,index,interval,keydown,%
    keyup,label,length,lights,line,linecolor,linewidth,logx,logy,lower_left,%
    lower_right,mag,mag2,magenta,make_trail,marker_color,markers,material,%
    max,min,mouse,mousedown,mousemove,mouseup,newball,norm,normal,objects,%
    offset,one,opacity,orange,origin,path,pause,pi,pixel_to_world,pixels,plot,%
    points,pos,pow,pps,print,print_function,print_options,proj,purple,pyramid,%
    quad,radians,radius,random,rate,ray,read_local_file,readonly,red,redraw,%
    retain,rgb_to_hsv,ring,rotate,round,scene,scroll,shaftwidth,shape,shapes,%
    shininess,show_end_face,show_start_face,sign,sin,size,size_units,sleep,%
    smooth,space,sphere,sqrt,start,start_face_color,stop,tan,text,textpos,%
    texture,textures,thickness,title,trail_color,trail_object,trail_radius,%
    trail_type,triangle,trigger,True,twist,unbind,up,upper_left,upper_right,%
    userpan,userspin,userzoom,vec,vector,vertex,vertical_spacing,visible,%
    visual,vpython,VPython,waitfor,white,width,world,xtitle,yellow,yoffset,%
    ytitle%
  },%
  morekeywords={print,None,TypeError},%      % additional keywords
  morestring=[b]{"""},%                      % treat triple quotes as strings
  numbers=left,%                             % where to put line numbers
  numbersep=10pt,%                           % how far line numbers are from code
  numberstyle=\bfseries\tiny,%               % set to 'none' for no line numbers
  showstringspaces=false,%                   % show spaces in strings
  showtabs=false,%                           % show tabs within strings
  stringstyle=\gsfontfamily\color{gsgreen},% % color for strings
  upquote=true,%                             % how to typeset quotes
}%
```

Introduce a new, more intelligent `glowscriptblock`→P. 29 environment.

```
\NewTCBListing[auto counter,list inside=gsprogs]{glowscriptblock}
  { O{} D(){glowscript.org} m }{%
  breakable,%
  center,%
  code = \newpage,%
  %derivpeach,%
  enhanced,%
  hyperurl interior = https://#2,%
  label = {gs:\thetcbcounter},%
  left = 8mm,%
  list entry = \thetcbcounter~~~~~#3,%
  listing only,%
  listing style = vpython,%
  nameref = {#3},%
  title = \texttt{GlowScript} Program \thetcbcounter: #3,%
  width = 0.9\textwidth,%
  {#1},
}%
```

A new command for generating a list of `GlowScript` programs.

```
\NewDocumentCommand{\listofglowscriptprograms}{}{\tcblistof[\section*]{gsprogs}
  {List of \texttt{GlowScript} Programs}}%
```

Introduce a new, more intelligent `\vpythonfile`→P. 32 command.

```
\NewTCBInputListing[auto counter,list inside=vpprogs]{\vpythonfile}
  { O{} m m }{%
  breakable,%
```

```
  center,%
  code = \newpage,%
  %derivgray,%
  enhanced,%
  hyperurl interior = https://,%
  label = {vp:\thetcbcounter},%
  left = 8mm,%
  list entry = \thetcbcounter~~~~~#3,%
  listing file = {#2},%
  listing only,%
  listing style = vpython,%
  nameref = {#3},%
  title = \texttt{VPython} Program \thetcbcounter: #3,%
  width = 0.9\textwidth,%
  {#1},%
}%
```

A new command for generating a list of `VPython` programs.

```
\NewDocumentCommand{\listofvpythonprograms}{}{\tcblistof[\section*]{vpprogs}
  {List of \texttt{VPython} Programs}}%
```

Introduce a new `\glowscriptinline`→P. 34 command.

```
\DeclareTotalTCBox{\glowscriptinline}{ m }{%
  bottom = 0pt,%
  bottomrule = 0.0mm,%
  boxsep = 1.0mm,%
  colback = gsbggray,%
  colframe = gsbggray,%
  left = 0pt,%
  leftrule = 0.0mm,%
  nobeforeafter,%
  right = 0pt,%
  rightrule = 0.0mm,%
  sharp corners,%
  tcbox raise base,%
  top = 0pt,%
  toprule = 0.0mm,%
}{\lstinline[style = vpython]{#1}}%
```

Define `\vpythoninline`→P. 34, a semantic alias for `VPython` in-line listings.

```
\NewDocumentCommand{\vpythoninline}{}{\glowscriptinline}%
```

Define units to be used with the unit engine. All single letter macros are now gone. We basically absorbed and adapted the now outdated SIunits package. We make use of `\symup{...}` from the unicode-math package.

```
\NewDocumentCommand{\per}{}{\ensuremath{\,/\,}}
\NewDocumentCommand{\usk}{}{\ensuremath{\,\cdot\,}}
\NewDocumentCommand{\unit}{ m m }{\ensuremath{{#1}\;{#2}}}
\NewDocumentCommand{\ampere}{}{\ensuremath{\symup{A}}}
\NewDocumentCommand{\atomicmassunit}{}{\ensuremath{\symup{u}}}
\NewDocumentCommand{\candela}{}{\ensuremath{\symup{cd}}}
\NewDocumentCommand{\coulomb}{}{\ensuremath{\symup{C}}}
\NewDocumentCommand{\degree}{}{\ensuremath{^{\circ}}}
\NewDocumentCommand{\electronvolt}{}{\ensuremath{\symup{eV}}}
\NewDocumentCommand{\farad}{}{\ensuremath{\symup{F}}}
\NewDocumentCommand{\henry}{}{\ensuremath{\symup{H}}}
\NewDocumentCommand{\hertz}{}{\ensuremath{\symup{Hz}}}
\NewDocumentCommand{\joule}{}{\ensuremath{\symup{J}}}
\NewDocumentCommand{\kelvin}{}{\ensuremath{\symup{K}}}
\NewDocumentCommand{\kilogram}{}{\ensuremath{\symup{kg}}}
```

```
\NewDocumentCommand{\lightspeed}{}{\ensuremath{\symup{c}}}
\NewDocumentCommand{\meter}{}{\ensuremath{\symup{m}}}
\NewDocumentCommand{\metre}{}{\meter}
\NewDocumentCommand{\mole}{}{\ensuremath{\symup{mol}}}
\NewDocumentCommand{\newton}{}{\ensuremath{\symup{N}}}
\NewDocumentCommand{\ohm}{}{\ensuremath{\symup\Omega}}
\NewDocumentCommand{\pascal}{}{\ensuremath{\symup{Pa}}}
\NewDocumentCommand{\radian}{}{\ensuremath{\symup{rad}}}
\NewDocumentCommand{\second}{}{\ensuremath{\symup{s}}}
\NewDocumentCommand{\siemens}{}{\ensuremath{\symup{S}}}
\NewDocumentCommand{\steradian}{}{\ensuremath{\symup{sr}}}
\NewDocumentCommand{\tesla}{}{\ensuremath{\symup{T}}}
\NewDocumentCommand{\volt}{}{\ensuremath{\symup{V}}}
\NewDocumentCommand{\watt}{}{\ensuremath{\symup{W}}}
\NewDocumentCommand{\weber}{}{\ensuremath{\symup{Wb}}}
\NewDocumentCommand{\tothetwo}{}{\ensuremath{^2}}             % postfix  2
\NewDocumentCommand{\tothethree}{}{\ensuremath{^3}}           % postfix  3
\NewDocumentCommand{\tothefour}{}{\ensuremath{^4}}            % postfix  4
\NewDocumentCommand{\inverse}{}{\ensuremath{^{-1}}}           % postfix -1
\NewDocumentCommand{\totheinversetwo}{}{\ensuremath{^{-2}}}   % postfix -2
\NewDocumentCommand{\totheinversethree}{}{\ensuremath{^{-3}}} % postfix -3
\NewDocumentCommand{\totheinversefour}{}{\ensuremath{^{-4}}}  % postfix -4
\NewDocumentCommand{\emptyunit}{}{\ensuremath{\mdlgwhtsquare}}
```

The core unit engine has been completely rewritten in expl3 for both clarity and power.
Generic internal selectors.

```
\newcommand*{\mandi@selectunits}{}
\newcommand*{\mandi@selectprecision}{}
```

Specific internal selectors.

```
\newcommand*{\mandi@selectapproximate}[2]{#1}    % really \@firstoftwo
\newcommand*{\mandi@selectprecise}[2]{#2}        % really \@secondoftwo
\newcommand*{\mandi@selectbaseunits}[3]{#1}      % really \@firstofthree
\newcommand*{\mandi@selectderivedunits}[3]{#2}   % really \@secondofthree
\newcommand*{\mandi@selectalternateunits}[3]{#3} % really \@thirdofthree
```

Document level global switches.

```
\NewDocumentCommand{\alwaysusebaseunits}{}
  {\renewcommand*{\mandi@selectunits}{\mandi@selectbaseunits}}%
\NewDocumentCommand{\alwaysusederivedunits}{}
  {\renewcommand*{\mandi@selectunits}{\mandi@selectderivedunits}}%
\NewDocumentCommand{\alwaysusealternateunits}{}
  {\renewcommand*{\mandi@selectunits}{\mandi@selectalternateunits}}%
\NewDocumentCommand{\alwaysuseapproximateconstants}{}
  {\renewcommand*{\mandi@selectprecision}{\mandi@selectapproximate}}%
\NewDocumentCommand{\alwaysusepreciseconstants}{}
  {\renewcommand*{\mandi@selectprecision}{\mandi@selectprecise}}%
```

Document level localized variants.

```
\NewDocumentCommand{\hereusebaseunits}{ m }{\begingroup\alwaysusebaseunits#1\endgroup}%
\NewDocumentCommand{\hereusederivedunits}{ m }{\begingroup\alwaysusederivedunits#1\endgroup}%
\NewDocumentCommand{\hereusealternateunits}{ m }{\begingroup\alwaysusealternateunits#1\endgroup}%
\NewDocumentCommand{\hereuseapproximateconstants}{ m }{\begingroup\alwaysuseapproximateconstants#1\endgroup}%
\NewDocumentCommand{\hereusepreciseconstants}{ m }{\begingroup\alwaysusepreciseconstants#1\endgroup}%
```

Document level environments.

```
\NewDocumentEnvironment{usebaseunits}{}{\alwaysusebaseunits}{}%
\NewDocumentEnvironment{usederivedunits}{}{\alwaysusederivedunits}{}%
\NewDocumentEnvironment{usealternateunits}{}{\alwaysusealternateunits}{}%
```

```
\NewDocumentEnvironment{useapproximateconstants}{}{\alwaysuseapproximateconstants}{}%
\NewDocumentEnvironment{usepreciseconstants}{}{\alwaysusepreciseconstants}{}%
```

Defining a new scalar quantity. I am very much aware that this family of commands doesn't yet correctly abide by the LaTeX3 concept of separating document commands from the programming layer. The problem is that current documentation is not completely understandable to me and getting help is difficult for non-experts.

```
\NewDocumentCommand{\newscalarquantity}{ m m O{#2} O{#2} }{%
  \expandafter\newcommand\csname #1\endcsname[1]{##1\,\mandi@selectunits{#2}{#3}{#4}}%
  \expandafter\newcommand\csname #1value\endcsname[1]{##1}%
  \expandafter\newcommand\csname #1baseunits\endcsname[1]{##1\,\mandi@selectbaseunits{#2}{#3}{#4}}%
  \expandafter\newcommand\csname #1derivedunits\endcsname[1]{##1\,\mandi@selectderivedunits{#2}{#3}{#4}}%
  \expandafter\newcommand\csname #1alternateunits\endcsname[1]{##1\,\mandi@selectalternateunits{#2}{#3}{#4}}%
  \expandafter\newcommand\csname #1onlybaseunits\endcsname{\mandi@selectbaseunits{#2}{#3}{#4}}%
  \expandafter\newcommand\csname #1onlyderivedunits\endcsname{\mandi@selectderivedunits{#2}{#3}{#4}}%
  \expandafter\newcommand\csname #1onlyalternateunits\endcsname{\mandi@selectalternateunits{#2}{#3}{#4}}%
}%
```

Redefining a new scalar quantity.

```
\NewDocumentCommand{\renewscalarquantity}{ m m O{#2} O{#2} }{%
  \expandafter\renewcommand\csname #1\endcsname[1]{##1\,\mandi@selectunits{#2}{#3}{#4}}%
  \expandafter\renewcommand\csname #1value\endcsname[1]{##1}%
  \expandafter\renewcommand\csname #1baseunits\endcsname[1]{##1\,\mandi@selectbaseunits{#2}{#3}{#4}}%
  \expandafter\renewcommand\csname #1derivedunits\endcsname[1]{##1\,\mandi@selectderivedunits{#2}{#3}{#4}}%
  \expandafter\renewcommand\csname #1alternateunits\endcsname[1]{##1\,\mandi@selectalternateunits{#2}{#3}{#4}}%
  \expandafter\renewcommand\csname #1onlybaseunits\endcsname{\mandi@selectbaseunits{#2}{#3}{#4}}%
  \expandafter\renewcommand\csname #1onlyderivedunits\endcsname{\mandi@selectderivedunits{#2}{#3}{#4}}%
  \expandafter\renewcommand\csname #1onlyalternateunits\endcsname{\mandi@selectalternateunits{#2}{#3}{#4}}%
}%
```

Defining a new vector quantity. Note that a corresponding scalar is also defined.

```
\NewDocumentCommand{\newvectorquantity}{ m m O{#2} O{#2} }{%
  \newscalarquantity{#1}{#2}[#3][#4]
  \expandafter\newcommand\csname vector#1\endcsname[1]{\expandafter\csname #1\endcsname{\mivector{##1}}}%
  \expandafter\newcommand\csname #1vector\endcsname[1]{\expandafter\csname #1\endcsname{\mivector{##1}}}%
}%
```

Redefining a new vector quantity. Note that a corresponding scalar is also redefined.

```
\NewDocumentCommand{\renewvectorquantity}{ m m O{#2} O{#2} }{%
  \renewscalarquantity{#1}{#2}[#3][#4]
  \expandafter\renewcommand\csname vector#1\endcsname[1]{\expandafter\csname #1\endcsname{\mivector{##1}}}%
  \expandafter\renewcommand\csname #1vector\endcsname[1]{\expandafter\csname #1\endcsname{\mivector{##1}}}%
}%
```

Defining a new physical constant.

```
\NewDocumentCommand{\newphysicalconstant}{ m m m m m O{#5} O{#5} }{%
  \expandafter\newcommand\csname #1\endcsname
    {\mandi@selectprecision{#3}{#4}\,\mandi@selectunits{#5}{#6}{#7}}%
  \expandafter\newcommand\csname #1mathsymbol\endcsname{\ensuremath{#2}}%
  \expandafter\newcommand\csname #1approximatevalue\endcsname{\ensuremath{#3}}%
  \expandafter\newcommand\csname #1precisevalue\endcsname{\ensuremath{#4}}%
  \expandafter\newcommand\csname #1baseunits\endcsname
    {\mandi@selectprecision{#3}{#4}\,\mandi@selectbaseunits{#5}{#6}{#7}}%
  \expandafter\newcommand\csname #1derivedunits\endcsname
    {\mandi@selectprecision{#3}{#4}\,\mandi@selectderivedunits{#5}{#6}{#7}}%
  \expandafter\newcommand\csname #1alternateunits\endcsname
    {\mandi@selectprecision{#3}{#4}\,\mandi@selectalternateunits{#5}{#6}{#7}}%
  \expandafter\newcommand\csname #1onlybaseunits\endcsname
    {\mandi@selectbaseunits{#5}{#6}{#7}}%
  \expandafter\newcommand\csname #1onlyderivedunits\endcsname
```

```
    {\mandi@selectderivedunits{#5}{#6}{#7}}%
  \expandafter\newcommand\csname #1onlyalternateunits\endcsname
    {\mandi@selectalternateunits{#5}{#6}{#7}}%
}%
```

Redefining a new physical constant.

```
\NewDocumentCommand{\renewphysicalconstant}{ m m m m m O{#5} O{#5} }{%
  \expandafter\renewcommand\csname #1\endcsname
    {\mandi@selectprecision{#3}{#4}\,\mandi@selectunits{#5}{#6}{#7}}%
  \expandafter\renewcommand\csname #1mathsymbol\endcsname{\ensuremath{#2}}%
  \expandafter\renewcommand\csname #1approximatevalue\endcsname{\ensuremath{#3}}%
  \expandafter\renewcommand\csname #1precisevalue\endcsname{\ensuremath{#4}}%
  \expandafter\renewcommand\csname #1baseunits\endcsname
    {\mandi@selectprecision{#3}{#4}\,\mandi@selectbaseunits{#5}{#6}{#7}}%
  \expandafter\renewcommand\csname #1derivedunits\endcsname
    {\mandi@selectprecision{#3}{#4}\,\mandi@selectderivedunits{#5}{#6}{#7}}%
  \expandafter\renewcommand\csname #1alternateunits\endcsname
    {\mandi@selectprecision{#3}{#4}\,\mandi@selectalternateunits{#5}{#6}{#7}}%
  \expandafter\renewcommand\csname #1onlybaseunits\endcsname
    {\mandi@selectbaseunits{#5}{#6}{#7}}%
  \expandafter\renewcommand\csname #1onlyderivedunits\endcsname
    {\mandi@selectderivedunits{#5}{#6}{#7}}%
  \expandafter\renewcommand\csname #1onlyalternateunits\endcsname
    {\mandi@selectalternateunits{#5}{#6}{#7}}%
}%
```

mandi now has a key-value interface, implemented with pgfopts and pgfkeys. There are two options:
`units` → P. 6, with values `base`, `derived`, or `alternate` selects the default form of units
`preciseconstants` → P. 6, with values `true` and `false`, selects precise numerical values for constants rather than approximate values.

First, define the keys. The key handlers require certain commands defined by the unit engine, and thus must be defined and processed after the unit engine code.

```
\newif\ifusingpreciseconstants
\pgfkeys{%
  /mandi/options/.cd,
  initial@setup/.style={%
    /mandi/options/buffered@units/.initial=alternate,%
  },%
  initial@setup,%
  preciseconstants/.is if=usingpreciseconstants,%
  units/.is choice,%
  units/.default=derived,%
  units/alternate/.style={/mandi/options/buffered@units=alternate},%
  units/base/.style={/mandi/options/buffered@units=base},%
  units/derived/.style={/mandi/options/buffered@units=derived},%
}%
```

Process the options.

```
\ProcessPgfPackageOptions{/mandi/options}
```

Write a banner to the console showing the options in use. The value of the `units` → P. 6 key is used in situ to set the default units.

```
\newcommand*{\mandi@linetwo}{\typeout{mandi: Loadtime options...}}
\newcommand*{\mandi@do@setup}{%
  \typeout{}%
  \typeout{mandi: You are using mandi \mandiversion.}%
  \mandi@linetwo
  \csname alwaysuse\pgfkeysvalueof{/mandi/options/buffered@units}units\endcsname%
  \typeout{mandi: You will get \pgfkeysvalueof{/mandi/options/buffered@units}\space units.}%
```

```
  \ifusingpreciseconstants
    \alwaysusepreciseconstants
    \typeout{mandi: You will get precise constants.}%
  \else
    \alwaysuseapproximateconstants
    \typeout{mandi: You will get approximate constants.}%
  \fi
  \typeout{}%
}%
\mandi@do@setup
```

Define a setup command that overrides the loadtime options when called with new options. A new banner is written to the console.

```
\NewDocumentCommand{\mandisetup}{ m }{%
  \IfValueT{#1}{%
    \pgfqkeys{/mandi/options}{#1}
    \renewcommand*{\mandi@linetwo}{\typeout{mandi: mandisetup options...}}
    \mandi@do@setup
  }%
}%
```

Define every quantity we need in introductory physics, alphabetically for convenience. This is really the core feature of mandi that no other package offers. There are commands for quantities that have no dimensions or units, and these quantities are defined for semantic completeness.

```
\newvectorquantity{acceleration}%
  {\meter\usk\second\totheinversetwo}%
  [\newton\per\kilogram]%
  [\meter\per\second\tothetwo]%
\newscalarquantity{amount}%
  {\mole}%
\newvectorquantity{angularacceleration}%
  {\radian\usk\second\totheinversetwo}%
  [\radian\per\second\tothetwo]%
  [\radian\per\second\tothetwo]%
\newscalarquantity{angularfrequency}%
  {\radian\usk\second\inverse}%
  [\radian\per\second]%
  [\radian\per\second]%
%\ifmandi@rotradians
%  \newphysicalquantity{angularimpulse}%
%    {\meter\tothetwo\usk\kilogram\usk\second\inverse\usk\radian\inverse}%
%    [\joule\usk\second\per\radian]%
%    [\newton\usk\meter\usk\second\per\radian]%
%  \newphysicalquantity{angularmomentum}%
%    {\meter\tothetwo\usk\kilogram\usk\second\inverse\usk\radian\inverse}%
%    [\kilogram\usk\meter\tothetwo\per(\second\usk\radian)]%
%    [\newton\usk\meter\usk\second\per\radian]%
%\else
  \newvectorquantity{angularimpulse}%
    {\meter\tothetwo\usk\kilogram\usk\second\inverse}%
    [\kilogram\usk\meter\tothetwo\per\second]% % also \joule\usk\second
    [\kilogram\usk\meter\tothetwo\per\second]% % also \newton\usk\meter\usk\second
  \newvectorquantity{angularmomentum}%
    {\meter\tothetwo\usk\kilogram\usk\second\inverse}%
    [\kilogram\usk\meter\tothetwo\per\second]% % also \joule\usk\second
    [\kilogram\usk\meter\tothetwo\per\second]% % also \newton\usk\meter\usk\second
%\fi
\newvectorquantity{angularvelocity}%
  {\radian\usk\second\inverse}%
```

```
  [\radian\per\second]%
  [\radian\per\second]%
\newscalarquantity{area}%
  {\meter\tothetwo}%
\newscalarquantity{areamassdensity}%
  {\meter\totheinversetwo\usk\kilogram}%
  [\kilogram\per\meter\tothetwo]%
  [\kilogram\per\meter\tothetwo]%
\newscalarquantity{areachargedensity}%
  {\meter\totheinversetwo\usk\second\usk\ampere}%
  [\coulomb\per\meter\tothetwo]%
  [\coulomb\per\meter\tothetwo]%
\newscalarquantity{capacitance}%
  {\meter\totheinversetwo\usk\kilogram\inverse\usk\second\tothefour\usk\ampere\tothetwo}%
  [\farad]%
  [\coulomb\per\volt]% % also \coulomb\tothetwo\per\newton\usk\meter, \second\per\ohm
\newscalarquantity{charge}%
  {\ampere\usk\second}%
  [\coulomb]%
  [\coulomb]% % also \farad\usk\volt
\newvectorquantity{cmagneticfield}%
  {\meter\usk\kilogram\usk\second\totheinversethree\usk\ampere\inverse}%
  [\volt\per\meter]%
  [\newton\per\coulomb]%
\newscalarquantity{conductance}%
  {\meter\totheinversetwo\usk\kilogram\inverse\usk\second\tothethree\usk\ampere\tothetwo}%
  [\siemens]%
  [\ampere\per\volt]%
\newscalarquantity{conductivity}%
  {\meter\totheinversethree\usk\kilogram\inverse\usk\second\tothethree\usk\ampere\tothetwo}%
  [\siemens\per\meter]%
  [(\ampere\per\meter\tothetwo)\per(\volt\per\meter)]%
\newscalarquantity{conventionalcurrent}%
  {\ampere}%
  [\coulomb\per\second]%
  [\ampere]%
\newscalarquantity{current}%
  {\ampere}%
\newscalarquantity{currentdensity}%
  {\meter\totheinversetwo\usk\ampere}%
  [\coulomb\usk\second\per\meter\tothetwo]%
  [\ampere\per\meter\tothetwo]%
\newscalarquantity{dielectricconstant}%
  {}%
\newvectorquantity{displacement}%
  {\meter}
\newscalarquantity{duration}%
  {\second}%
\newvectorquantity{electricdipolemoment}%
  {\meter\usk\second\usk\ampere}%
  [\coulomb\usk\meter]%
  [\coulomb\usk\meter]%
\newvectorquantity{electricfield}%
  {\meter\usk\kilogram\usk\second\totheinversethree\usk\ampere\inverse}%
  [\volt\per\meter]%
  [\newton\per\coulomb]%
\newscalarquantity{electricflux}%
  {\meter\tothethree\usk\kilogram\usk\second\totheinversethree\usk\ampere\inverse}%
  [\volt\usk\meter]%
```

```
  [\newton\usk\meter\tothetwo\per\coulomb]%
\newscalarquantity{electricpotential}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversethree\usk\ampere\inverse}%
  [\volt]%
  [\joule\per\coulomb]%
\newscalarquantity{electroncurrent}%
  {\second\inverse}%
  [\ensuremath{\symup{e}}\per\second]%
  [\ensuremath{\symup{e}}\per\second]%
\newscalarquantity{emf}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversethree\usk\ampere\inverse}%
  [\volt]%
  [\joule\per\coulomb]%
\newscalarquantity{energy}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversetwo}%
  [\joule]% % also \newton\usk\meter
  [\joule]%
\newscalarquantity{energydensity}%
  {\meter\inverse\usk\kilogram\usk\second\totheinversetwo}%
  [\joule\per\meter\tothethree]%
  [\joule\per\meter\tothethree]%
\newscalarquantity{energyflux}%
  {\kilogram\usk\second\totheinversethree}%
  [\watt\per\meter\tothetwo]%
  [\watt\per\meter\tothetwo]%
\newscalarquantity{entropy}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversetwo\usk\kelvin\inverse}%
  [\joule\per\kelvin]%
  [\joule\per\kelvin]%
\newvectorquantity{force}%
  {\meter\usk\kilogram\usk\second\totheinversetwo}%
  [\newton]%
  [\newton]% % also \kilogram\usk\meter\per\second\tothetwo
\newscalarquantity{frequency}%
  {\second\inverse}%
  [\hertz]%
  [\hertz]%
\newvectorquantity{gravitationalfield}%
  {\meter\usk\second\totheinversetwo}%
  [\newton\per\kilogram]%
  [\newton\per\kilogram]%
\newscalarquantity{gravitationalpotential}%
  {\meter\tothetwo\usk\second\totheinversetwo}%
  [\joule\per\kilogram]%
  [\joule\per\kilogram]%
\newvectorquantity{impulse}%
  {\meter\usk\kilogram\usk\second\inverse}%
  [\newton\usk\second]%
  [\newton\usk\second]%
\newscalarquantity{indexofrefraction}%
  {}%
\newscalarquantity{inductance}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversetwo\usk\ampere\totheinversetwo}%
  [\henry]%
  [\volt\usk\second\per\ampere]% % also \square\meter\usk\kilogram\per\coulomb\tothetwo, \Wb\per\ampere
\newscalarquantity{linearchargedensity}%
  {\meter\inverse\usk\second\usk\ampere}%
  [\coulomb\per\meter]%
  [\coulomb\per\meter]%
```

```
\newscalarquantity{linearmassdensity}%
  {\meter\inverse\usk\kilogram}%
  [\kilogram\per\meter]%
  [\kilogram\per\meter]%
\newscalarquantity{luminous}%
  {\candela}%
\newscalarquantity{magneticcharge}%
  {\meter\usk\ampere}%
\newvectorquantity{magneticdipolemoment}%
  {\meter\tothetwo\usk\ampere}%
  [\ampere\usk\meter\tothetwo]%
  [\joule\per\tesla]%
\newvectorquantity{magneticfield}%
  {\kilogram\usk\second\totheinversetwo\usk\ampere\inverse}%
  [\tesla]%
  [\newton\per\coulomb\usk(\meter\per\second)]% % also \Wb\per\meter\tothetwo
\newscalarquantity{magneticflux}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversetwo\usk\ampere\inverse}%
  [\tesla\usk\meter\tothetwo]%
  [\volt\usk\second]% % also \Wb and \joule\per\ampere
\newscalarquantity{mass}%
  {\kilogram}%
\newscalarquantity{mobility}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversefour\usk\ampere\inverse}%
  [\meter\tothetwo\per\volt\usk\second]%
  [(\meter\per\second)\per(\newton\per\coulomb)]%
\newscalarquantity{momentofinertia}%
  {\meter\tothetwo\usk\kilogram}%
  [\joule\usk\second\tothetwo]%
  [\kilogram\usk\meter\tothetwo]%
\newvectorquantity{momentum}%
  {\meter\usk\kilogram\usk\second\inverse}%
  [\newton\usk\second]%
  [\kilogram\usk\meter\per\second]%
\newvectorquantity{momentumflux}%
  {\meter\inverse\usk\kilogram\usk\second\totheinversetwo}%
  [\newton\per\meter\tothetwo]%
  [\newton\per\meter\tothetwo]%
\newscalarquantity{numberdensity}%
  {\meter\totheinversethree}%
  [\per\meter\tothethree]%
  [\per\meter\tothethree]%
\newscalarquantity{permeability}%
  {\meter\usk\kilogram\usk\second\totheinversetwo\usk\ampere\totheinversetwo}%
  [\tesla\usk\meter\per\ampere]%
  [\henry\per\meter]%
\newscalarquantity{permittivity}%
  {\meter\totheinversethree\usk\kilogram\inverse\usk\second\totheinversefour\usk\ampere\tothetwo}%
  [\farad\per\meter]%
  [\coulomb\tothetwo\per\newton\usk\meter\tothetwo]%
\newscalarquantity{planeangle}%
  {\meter\usk\meter\inverse}%
  [\radian]%
  [\radian]%
\newscalarquantity{polarizability}%
  {\kilogram\inverse\usk\second\tothefour\usk\ampere\tothetwo}%
  [\coulomb\usk\meter\tothetwo\per\volt]%
  [\coulomb\usk\meter\per(\newton\per\coulomb)]%
\newscalarquantity{power}%
```

```
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversethree}%
  [\watt]%
  [\joule\per\second]%
\newvectorquantity{poynting}%
  {\kilogram\usk\second\totheinversethree}%
  [\watt\per\meter\tothetwo]%
  [\watt\per\meter\tothetwo]%
\newscalarquantity{pressure}%
  {\meter\inverse\usk\kilogram\usk\second\totheinversetwo}%
  [\pascal]%
  [\newton\per\meter\tothetwo]%
\newscalarquantity{relativepermeability}
  {}%
\newscalarquantity{relativepermittivity}%
  {}%
\newscalarquantity{resistance}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversethree\usk\ampere\totheinversetwo}%
  [\volt\per\ampere]%
  [\ohm]%
\newscalarquantity{resistivity}%
  {\meter\tothethree\usk\kilogram\usk\second\totheinversethree\usk\ampere\totheinversetwo}%
  [\ohm\usk\meter]%
  [(\volt\per\meter)\per(\ampere\per\meter\tothetwo)]%
\newscalarquantity{solidangle}%
  {\meter\tothetwo\usk\meter\totheinversetwo}%
  [\steradian]%
  [\steradian]%
\newscalarquantity{specificheatcapacity}%
  {\meter\tothetwo\usk\second\totheinversetwo\usk\kelvin\inverse}%
  [\joule\per\kelvin\usk\kilogram]%
  [\joule\per\kelvin\usk\kilogram]
\newscalarquantity{springstiffness}%
  {\kilogram\usk\second\totheinversetwo}%
  [\newton\per\meter]%
  [\newton\per\meter]%
\newscalarquantity{springstretch}% % This is really just a displacement.
  {\meter}%
\newscalarquantity{stress}%
  {\meter\inverse\usk\kilogram\usk\second\totheinversetwo}%
  [\pascal]%
  [\newton\per\meter\tothetwo]%
\newscalarquantity{strain}%
  {}%
\newscalarquantity{temperature}%
  {\kelvin}%
%\ifmandi@rotradians
%  \newphysicalquantity{torque}%
%    {\meter\tothetwo\usk\kilogram\usk\second\totheinversetwo\usk\radian\inverse}%
%    [\newton\usk\meter\per\radian]%
%    [\newton\usk\meter\per\radian]%
%\else
  \newvectorquantity{torque}%
    {\meter\tothetwo\usk\kilogram\usk\second\totheinversetwo}%
    [\newton\usk\meter]%
    [\newton\usk\meter]%
%\fi
\newvectorquantity{velocity}%
  {\meter\usk\second\inverse}%
  [\meter\per\second]%
```

```
  [\meter\per\second]%
\newvectorquantity{velocityc}%
  {\lightspeed}%
  []%
  [\lightspeed]%
\newscalarquantity{volume}%
  {\meter\tothethree}%
\newscalarquantity{volumechargedensity}%
  {\meter\totheinversethree\usk\second\usk\ampere}%
  [\coulomb\per\meter\tothethree]%
  [\coulomb\per\meter\tothethree]%
\newscalarquantity{volumemassdensity}%
  {\meter\totheinversethree\usk\kilogram}%
  [\kilogram\per\meter\tothethree]%
  [\kilogram\per\meter\tothethree]%
\newscalarquantity{wavelength}% % This is really just a displacement.
  {\meter}%
\newvectorquantity{wavenumber}%
  {\meter\inverse}%
  [\per\meter]%
  [\per\meter]%
\newscalarquantity{work}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversetwo}%
  [\joule]%
  [\newton\usk\meter]%
\newscalarquantity{youngsmodulus}% % This is really just a stress.
  {\meter\inverse\usk\kilogram\usk\second\totheinversetwo}%
  [\pascal]%
  [\newton\per\meter\tothetwo]%
```

Define physical constants for introductory physics, again alphabetically for convenience.

```
\newphysicalconstant{avogadro}%
  {\symup{N_A}}%
  {6\timestento{23}}{6.02214076\timestento{23}}%
  {\mole\inverse}%
  [\per\mole]%
  [\per\mole]%
\newphysicalconstant{biotsavartconstant}% % alias for \mzofp
  {\symup{\frac{\mu_o}{4\pi}}}%
  {\tento{-7}}{\tento{-7}}%
  {\meter\usk\kilogram\usk\second\totheinversetwo\usk\ampere\totheinversetwo}%
  [\henry\per\meter]%
  [\tesla\usk\meter\per\ampere]%
\newphysicalconstant{bohrradius}%
  {\symup{a_o}}%
  {5.3\timestento{-11}}{5.2917721067\timestento{-11}}%
  {\meter}%
\newphysicalconstant{boltzmann}%
  {\symup{k_B}}%
  {1.4\timestento{-23}}{1.380649\timestento{-23}}%
  {\meter\tothetwo\usk\kilogram\usk\second\totheinversetwo\usk\kelvin\inverse}%
  [\joule\per\kelvin]%
  [\joule\per\kelvin]%
\newphysicalconstant{coulombconstant}% % alias for \oofpez
  {\symup{\frac{1}{4\pi\epsilon_o}}}%
  {9\timestento{9}}{8.9875517873681764\timestento{9}}%
  {\meter\tothethree\usk\kilogram\usk\second\totheinversefour\usk\ampere\totheinversetwo}%
  [\meter\per\farad]%
  [\newton\usk\meter\tothetwo\per\coulomb\tothetwo]%
```

```
\newphysicalconstant{earthmass}%
  {\symup{M_{Earth}}}%
  {6.0\timestento{24}}{5.97237\timestento{24}}%
  {\kilogram}%
\newphysicalconstant{earthmoondistance}%
  {\symup{d_{EM}}}%
  {3.8\timestento{8}}{3.81550\timestento{8}}%
  {\meter}%
\newphysicalconstant{earthradius}%
  {\symup{R_{Earth}}}%
  {6.4\timestento{6}}{6.371\timestento{6}}%
  {\meter}%
\newphysicalconstant{earthsundistance}%
  {\symup{d_{ES}}}%
  {1.5\timestento{11}}{1.496\timestento{11}}%
  {\meter}%
\newphysicalconstant{electroncharge}%
  {\symup{q_e}}%
  {-\elementarychargeapproximatevalue}{-\elementarychargeprecisevalue}%
  {\ampere\usk\second}%
  [\coulomb]%
  [\coulomb]%
\newphysicalconstant{electronCharge}%
  {\symup{Q_e}}%
  {-\elementarychargeapproximatevalue}{-\elementarychargeprecisevalue}%
  {\ampere\usk\second}%
  [\coulomb]%
  [\coulomb]%
\newphysicalconstant{electronmass}%
  {\symup{m_e}}%
  {9.1\timestento{-31}}{9.10938356\timestento{-31}}%
  {\kilogram}%
\newphysicalconstant{elementarycharge}%
  {\symup{e}}%
  {1.6\timestento{-19}}{1.602176634\timestento{-19}}%
  {\ampere\usk\second}%
  [\coulomb]%
  [\coulomb]%
\newphysicalconstant{finestructure}%
  {\symup{\alpha}}%
  {\frac{1}{137}}{7.2973525664\timestento{-3}}%
  {}%
\newphysicalconstant{hydrogenmass}%
  {\symup{m_H}}%
  {1.7\timestento{-27}}{1.6737236\timestento{-27}}%
  {\kilogram}%
\newphysicalconstant{moonearthdistance}%
  {\symup{d_{ME}}}%
  {3.8\timestento{8}}{3.81550\timestento{8}}%
  {\meter}%
\newphysicalconstant{moonmass}%
  {\symup{M_{Moon}}}%
  {7.3\timestento{22}}{7.342\timestento{22}}%
  {\kilogram}%
\newphysicalconstant{moonradius}%
  {\symup{R_{Moon}}}%
  {1.7\timestento{6}}{1.7371\timestento{6}}%
  {\meter}%
\newphysicalconstant{mzofp}%
```

```
  {\symup{\frac{\mu_o}{4\pi}}}%
  {\tento{-7}}{\tento{-7}}%
  {\meter\usk\kilogram\usk\second\totheinversetwo\usk\ampere\totheinversetwo}%
  [\henry\per\meter]%
  [\tesla\usk\meter\per\ampere]%
\newphysicalconstant{neutronmass}%
  {\symup{m_n}}%
  {1.7\timestento{-27}}{1.674927471\timestento{-27}}%
  {\kilogram}%
\newphysicalconstant{oofpez}%
  {\symup{\frac{1}{4\pi\epsilon_o}}}%
  {9\timestento{9}}{8.987551787\timestento{9}}%
  {\meter\tothethree\usk\kilogram\usk\second\totheinversefour\usk\ampere\totheinversetwo}%
  [\meter\per\farad]%
  [\newton\usk\meter\tothetwo\per\coulomb\tothetwo]%
\newphysicalconstant{oofpezcs}%
  {\symup{\frac{1}{4\pi\epsilon_o c^2}}}%
  {\tento{-7}}{\tento{-7}}%
  {\meter\usk\kilogram\usk\second\totheinversetwo\usk\ampere\totheinversetwo}%
  [\tesla\usk\meter\tothetwo]%
  [\newton\usk\second\tothetwo\per\coulomb\tothetwo]%
\newphysicalconstant{planck}%
  {\symup{h}}%
  {6.6\timestento{-34}}{6.62607015\timestento{-34}}%
  {\meter\tothetwo\usk\kilogram\usk\second\inverse}%
  [\joule\usk\second]%
  [\joule\usk\second]%
```

See https://tex.stackexchange.com/a/448565/218142.

```
\newphysicalconstant{planckbar}%
  {\symup{\lower0.18ex\hbox{\mathchar"AF}\mkern-7mu h}}%
  {1.1\timestento{-34}}{1.054571817\timestento{-34}}%
  {\meter\tothetwo\usk\kilogram\usk\second\inverse}%
  [\joule\usk\second]%
  [\joule\usk\second]
\newphysicalconstant{planckc}%
  {\symup{hc}}%
  {2.0\timestento{-25}}{1.98644586\timestento{-25}}%
  {\meter\tothethree\usk\kilogram\usk\second\totheinversetwo}%
  [\joule\usk\meter]%
  [\joule\usk\meter]%
\newphysicalconstant{protoncharge}%
  {\symup{q_p}}%
  {+\elementarychargeapproximatevalue}{+\elementarychargeprecisevalue}%
  {\ampere\usk\second}%
  [\coulomb]%
  [\coulomb]%
\newphysicalconstant{protonCharge}%
  {\symup{Q_p}}%
  {+\elementarychargeapproximatevalue}{+\elementarychargeprecisevalue}%
  {\ampere\usk\second}%
  [\coulomb]%
  [\coulomb]%
\newphysicalconstant{protonmass}%
  {\symup{m_p}}%
  {1.7\timestento{-27}}{1.672621898\timestento{-27}}%
  {\kilogram}%
\newphysicalconstant{rydberg}%
  {\symup{R_{\infty}}}%
```

```
  {1.1\timestento{7}}{1.0973731568508\timestento{7}}%
  {\meter\inverse}%
\newphysicalconstant{speedoflight}%
  {\symup{c}}%
  {3\timestento{8}}{2.99792458\timestento{8}}%
  {\meter\usk\second\inverse}%
  [\meter\per\second]%
  [\meter\per\second]
\newphysicalconstant{stefanboltzmann}%
  {\symup{\sigma}}%
  {5.7\timestento{-8}}{5.670367\timestento{-8}}%
  {\kilogram\usk\second\totheinversethree\usk\kelvin\totheinversefour}%
  [\watt\per\meter\tothetwo\usk\kelvin\tothefour]%
  [\watt\per\meter\tothetwo\usk\kelvin\tothefour]
\newphysicalconstant{sunearthdistance}%
  {\symup{d_{SE}}}%
  {1.5\timestento{11}}{1.496\timestento{11}}%
  {\meter}%
\newphysicalconstant{sunmass}%
  {\symup{M_{Sun}}}%
  {2.0\timestento{30}}{1.98855\timestento{30}}%
  {\kilogram}%
\newphysicalconstant{sunradius}%
  {\symup{R_{Sun}}}%
  {7.0\timestento{8}}{6.957\timestento{8}}%
  {\meter}%
\newphysicalconstant{surfacegravfield}%
  {\symup{g}}%
  {9.8}{9.807}%
  {\meter\usk\second\totheinversetwo}%
  [\newton\per\kilogram]%
  [\newton\per\kilogram]%
\newphysicalconstant{universalgrav}%
  {\symup{G}}%
  {6.7\timestento{-11}}{6.67408\timestento{-11}}%
  {\meter\tothethree\usk\kilogram\inverse\usk\second\totheinversetwo}%
  [\newton\usk\meter\tothetwo\per\kilogram\tothetwo]% % also \joule\usk\meter\per\kilogram\tothetwo
  [\newton\usk\meter\tothetwo\per\kilogram\tothetwo]%
\newphysicalconstant{vacuumpermeability}%
  {\symup{\mu_o}}%
  {4\pi\timestento{-7}}{4\pi\timestento{-7}}%
  {\meter\usk\kilogram\usk\second\totheinversetwo\usk\ampere\totheinversetwo}%
  [\henry\per\meter]%
  [\tesla\usk\meter\per\ampere]%
\newphysicalconstant{vacuumpermittivity}%
  {\symup{\epsilon_o}}%
  {9\timestento{-12}}{8.854187817\timestento{-12}}%
  {\meter\totheinversethree\usk\kilogram\inverse\usk\second\tothefour\usk\ampere\tothetwo}%
  [\farad\per\meter]%
  [\coulomb\tothetwo\per\newton\usk\meter\tothetwo]%
```

A better, intelligent coordinate-free `\vec`→P. 35 command. Note the use of the `e{_^}` type of optional argument. This accounts for much of the flexibility and power of this command. Also note the use of the TEX primitives `\sb{}` and `\sp{}`. Why doesn't it work when I put spaces around `#3` or `#4`? Because outside of `\ExplSyntaxOn...\ExplSyntaxOff`, the `_` character has a different catcode and is treated as a mathematical entity.
See https://tex.stackexchange.com/q/554706/218142.
See also https://tex.stackexchange.com/a/531037/218142.

```
\RenewDocumentCommand{\vec}{ s m e{_^} }{%
  \ensuremath{%
```

```
    % Note the \, used to make superscript look better.
    \IfBooleanTF {#1}
      {\vv{#2}%      % * gives an arrow
         % Use \sp{} primitive for superscript.
         % Adjust superscript for the arrow.
         \sp{\IfValueT{#4}{\,#4}\vphantom{\smash[t]{\big|}}}
      }%
      {\symbfit{#2}  % no * gives us bold
         % Use \sp{} primitive for superscript.
         % No superscript adjustment needed.
         \sp{\IfValueT{#4}{#4}\vphantom{\smash[t]{\big|}}}
      }%
    % Use \sb{} primitive for subscript.
    \sb{\IfValueT{#3}{#3}\vphantom{\smash[b]{|}}}
  }%
}%
```

A command for the direction of a vector. We use a slight tweak is needed to get uniform hats that requires the makebox package.
See https://tex.stackexchange.com/a/391204/218142.

```
\NewDocumentCommand{\dirvec}{ s m e{_^} }{%
  \ensuremath{%
    \widehat{\makebox*{\(w\)}{\ensuremath{%
      \IfBooleanTF {#1}
        {%
          #2
        }%
        {%
          \symbfit{#2}
        }%
       }%
      }%
     }%
    \sb{\IfValueT{#3}{#3}\vphantom{\smash[b]{|}}}
    \sp{\IfValueT{#4}{\,#4}\vphantom{\smash[t]{\big|}}}
  }%
}%
```

The zero vector.

```
\NewDocumentCommand{\zerovec}{ s }{%
  \IfBooleanTF {#1}
    {\vv{0}}%
    {\symbfup{0}}%
}%
```

Notation for column and row vectors. `\mivector`→P. 36 is a workhorse command.
Orginal code provided by @egreg.
See https://tex.stackexchange.com/a/39054/218142.

```
\ExplSyntaxOn
\NewDocumentCommand{\mivector}{ O{,} m o }%
 {%
   \mi_vector:nn { #1 } { #2 }
   \IfValueT{#3}{\;{#3}}
 }%
\seq_new:N \l__mi_list_seq
\cs_new_protected:Npn \mi_vector:nn #1 #2
{%
  \ensuremath{%
    \seq_set_split:Nnn \l__mi_list_seq { , } { #2 }
```

```
    \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \left\langle }
    \seq_use:Nnnn \l__mi_list_seq { #1 } { #1 } { #1 }
    \int_compare:nF { \seq_count:N \l__mi_list_seq = 1 } { \right\rangle }
  }%
}%
\NewDocumentCommand{\colvec}{ O{,} m }{%
  \vector_main:nnnn { p } { \\ } { #1 } { #2 }
}%
\NewDocumentCommand{\rowvec}{ O{,} m }{%
  \vector_main:nnnn { p } { & } { #1 } { #2 }
}%
\seq_new:N \l__vector_arg_seq
\cs_new_protected:Npn \vector_main:nnnn #1 #2 #3 #4 {%
  \seq_set_split:Nnn \l__vector_arg_seq { #3 } { #4 }
  \begin{#1NiceMatrix}[r]
    \seq_use:Nnnn \l__vector_arg_seq { #2 } { #2 } { #2 }
  \end{#1NiceMatrix}
}%
\ExplSyntaxOff
```

```
\NewDocumentCommand{\changein}{}{\Delta}
```

Intelligent delimiters provided via the mathtools package. Use the starred variants for fractions. You can supply optional sizes. Note that default placeholders are used when the argument is empty.

```
\DeclarePairedDelimiterX{\doublebars}[1]{\lVert}{\rVert}{\ifblank{#1}{\:\cdot\:}{#1}}
\DeclarePairedDelimiterX{\singlebars}[1]{\lvert}{\rvert}{\ifblank{#1}{\:\cdot\:}{#1}}
\DeclarePairedDelimiterX{\anglebrackets}[1]{\langle}{\rangle}{\ifblank{#1}{\:\cdot\:}{#1}}
\DeclarePairedDelimiterX{\parentheses}[1]{(}{)}{\ifblank{#1}{\:\cdot\:}{#1}}
\DeclarePairedDelimiterX{\squarebrackets}[1]{\lbrack}{\rbrack}{\ifblank{#1}{\:\cdot\:}{#1}}
\DeclarePairedDelimiterX{\curlybraces}[1]{\lbrace}{\rbrace}{\ifblank{#1}{\:\cdot\:}{#1}}
```

Some semantic aliases. Because of the way `\vec`→ P. 35 and `\dirvec`→ P. 35 are defined, I reluctantly decided not to implement a `\magvec` command. It would require accounting for too mamy options. So `\magnitude`→ P. 38 is the new solution.

```
\NewDocumentCommand{\magnitude}{}{\doublebars}
\NewDocumentCommand{\norm}{}{\doublebars}
\NewDocumentCommand{\absolutevalue}{}{\singlebars}
\NewDocumentCommand{\direction}{}{\mivector}
\NewDocumentCommand{\unitvector}{}{\mivector}
```

Intelligent commands for typesetting vector and tensor symbols and components suitable for use with both coordinate-free and index notations. Use starred form for index notation, unstarred form for coordinate-free.

```
\NewDocumentCommand{\veccomp}{ s m }{%
  % Consider renaming this to \vectorsym.
  \IfBooleanTF{#1}
  {%
    \ensuremath{\symnormal{#2}}%
  }%
  {%
    \ensuremath{\symbfit{#2}}%
  }%
}%
\NewDocumentCommand{\tencomp}{ s m }{%
  % Consider renaming this to \tensororsym.
  \IfBooleanTF{#1}
  {%
    \ensuremath{\symsfit{#2}}%
  }%
  {%
```

```
    \ensuremath{\symbfsfit{#2}}%
  }%
}%
```

An environment for problem statements. The starred variant gives in-line lists.

```
\NewDocumentEnvironment{physicsproblem}{ m }{%
  \newpage%
  \section*{#1}%
  \newlist{parts}{enumerate}{2}%
  \setlist[parts]{label=\bfseries(\alph*)}}%
  {}%
\NewDocumentEnvironment{physicsproblem*}{ m }{%
  \newpage%
  \section*{#1}%
  \newlist{parts}{enumerate*}{2}%
  \setlist[parts]{label=\bfseries(\alph*)}}%
  {}%
\NewDocumentCommand{\problempart}{}{\item}%
```

An environment for problem solutions.

```
\NewDocumentEnvironment{physicssolution}{ +b }{%
  % Make equation numbering consecutive through the document.
  \begin{align}
    #1
  \end{align}
}{}%
\NewDocumentEnvironment{physicssolution*}{ +b }{%
  % Make equation numbering consecutive through the document.
  \begin{align*}
    #1
  \end{align*}
}{}%
```

A simplified command for importing images.

```
\NewDocumentCommand{\image}{ O{scale=1} m m m }{%
  \begin{figure}[ht!]
    \begin{center}%
      \includegraphics[#1]{#2}%
    \end{center}%
    \caption{#3}%
    \label{#4}%
  \end{figure}%
}%
```

See https://tex.stackexchange.com/q/570223/218142.

```
\NewDocumentCommand{\reason}{ O{4cm} m }
  {&&\begin{minipage}{#1}\raggedright\small #2\end{minipage}}
```

Commands for scientific notation.

```
\NewDocumentCommand{\tento}{ m }{\ensuremath{10^{#1}}}
\NewDocumentCommand{\timestento}{ m }{\ensuremath{\;\times\;\tento{#1}}}
\NewDocumentCommand{\xtento}{ m }{\ensuremath{\;\times\;\tento{#1}}}
```

Command for highlighting parts of, or entire, mathematical expressions.
Original code by anonymous user `@abcdefg`, modified by me.
See https://texample.net/tikz/examples/beamer-arrows/.
See also https://tex.stackexchange.com/a/406084/218142.
See also https://tex.stackexchange.com/a/570858/218142.
See also https://tex.stackexchange.com/a/570789/218142.

See also https://tex.stackexchange.com/a/79659/218142.
See also https://tex.stackexchange.com/q/375032/218142.
See also https://tex.stackexchange.com/a/571744/218142.

```
\newcounter{tikzhighlightnode}
\NewDocumentCommand{\hilite}{ O{magenta!60} m O{rectangle} }{%
  \stepcounter{tikzhighlightnode}%
  \tikzmarknode{highlighted-node-\number\value{tikzhighlightnode}}{#2}%
  \edef\temp{%
    \noexpand\AddToShipoutPictureBG{%
      \noexpand\begin{tikzpicture}[overlay,remember picture]%
      \noexpand\iftikzmarkoncurrentpage{highlighted-node-\number\value{tikzhighlightnode}}%
       \noexpand\node[inner sep=1.0pt,fill=#1,#3,fit=(highlighted-node-\number\value{tikzhighlightnode})]{};%
      \noexpand\fi
      \noexpand\end{tikzpicture}%
    }%
  }%
  \temp%
}%
```

Intelligent slot command for coordinate-free tensor notation.

```
\NewDocumentCommand{\slot}{ s d[] }{%
  % d[] must be used because of the way consecutive optional
  %  arguments are handled. See xparse docs for details.
  \IfBooleanTF{#1}
  {%
    \IfValueTF{#2}
    {% Insert a vector, but don't show the slot.
      \smash{\makebox[1.5em]{\ensuremath{#2}}}
    }%
    {% No vector, no slot.
      \smash{\makebox[1.5em]{\ensuremath{}}}
    }%
  }%
  {%
    \IfValueTF{#2}
    {% Insert a vector and show the slot.
      \underline{\smash{\makebox[1.5em]{\ensuremath{#2}}}}
    }%
    {% No vector; just show the slot.
      \underline{\smash{\makebox[1.5em]{\ensuremath{}}}}
    }%
  }%
}%
```

Intelligent notation for contraction on pairs of slots.

```
\NewDocumentCommand{\contraction}{ s m }{%
  \IfBooleanTF{#1}
  {\mathsf{C}}%
  {\symbb{C}}%
  _{#2}
}%
```

Intelligent differential (exterior derivative) operator.

```
\NewDocumentCommand{\dd}{ s }{%
  \mathop{}\!
  \IfBooleanTF{#1}
  {\symbfsfup{d}}%
  {\symsfup{d}}%
}%
```

Command to typeset tensor valence.

```
\NewDocumentCommand{\valence}{ s m m }{%
  \IfBooleanTF{#1}
    {(#2,#3)}
    {\binom{#2}{#3}}
}%
```

Diagnostic commands to provide sanity checks on commands that represent physical quantities and constants.

```
\NewDocumentCommand{\checkquantity}{ m }{%
  % Works for both scalar and vector quantities.
  \begin{center}
    \begin{tabular}{>{\centering}p{4cm} >{\centering}p{3cm} >{\centering}p{4cm} >{\centering}p{3cm}}
      name & base & derived & alternate \tabularnewline
      \ttfamily\small{\expandafter\string\csname #1\endcsname} &
      \small{\csname #1onlybaseunits\endcsname} &
      \small{\csname #1onlyderivedunits\endcsname} &
      \small{\csname #1onlyalternateunits\endcsname}
    \end{tabular}
  \end{center}
}%
\NewDocumentCommand{\checkconstant}{ m }{%
  \begin{center}
    \begin{tabular}{>{\centering}p{4cm} >{\centering}p{3cm} >{\centering}p{4cm} >{\centering}p{3cm}}
      name & base & derived & alternate \tabularnewline
      \ttfamily\small{\expandafter\string\csname #1\endcsname} &
      \small{\csname #1onlybaseunits\endcsname} &
      \small{\csname #1onlyderivedunits\endcsname} &
      \small{\csname #1onlyalternateunits\endcsname} \tabularnewline
      symbol & approximate & precise \tabularnewline
      \small{\csname #1mathsymbol\endcsname} &
      \small{\csname #1approximatevalue\endcsname} &
      \small{\csname #1precisevalue\endcsname} \tabularnewline
    \end{tabular}
  \end{center}
}%
```

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