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This is the new **mandi** package (v3.0.0a dated 2021-01-04), which creates a habitat specifically for introductory physics students. It provides consistent notation conventions that align with ISO 80000-2 recommendations. This document is a demonstration for the new package and should not be taken as official documentation. Features are not necessarily final and are still subject to change.

1 Fonts

1.1 Text Mode Fonts

1.1.1 Default Text Font Parameters

To begin with, let's look at the fonts we have at our disposal. Let's look at the default text mode font parameters first.

| | |
|-------------------------------|------|
| <code>\encodingdefault</code> | TU |
| <code>\familydefault</code> | lmr |
| <code>\seriesdefault</code> | m |
| <code>\shapedefault</code> | n |
| <code>\rmdefault</code> | lmr |
| <code>\sfdefault</code> | lmss |
| <code>\ttdefault</code> | lmtt |
| <code>\bfdefault</code> | b |
| <code>\updefault</code> | up |
| <code>\itdefault</code> | it |
| <code>\mddefault</code> | m |
| <code>\sldefault</code> | sl |
| <code>\scdefault</code> | sc |

1.1.2 Text Mode Font Commands

Now let's look at the text mode commands for changing fonts and their accompanying results. Note that these commands require braced arguments and work only within the scope of the braces.

Text Mode Commands

The default normal text is `\textnormal{...}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get roman letters, use `\textrm{...}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get san serif letters, use `\textsf{...}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get typewriter letters, use `\texttt{...}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get medium letters, use `\textmd{...}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get boldface letters, use `\textbf{...}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Text up `\textup{...}`

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get italic letters, use `\textit{...}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get slanted letters, use `\textsl{...}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get small capital letters, use `\textsc{...}`.

ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789

Some of those text mode commands may seem redundant to you, and there are some you will never need to use, so don't worry if they look confusing. Remember that `\textnormal{...}` is the default and all you have to do to get it is start typing; no command is necessary unless you have changed something (and that's usually difficult to do). These text font commands can be used together if you remember to nest the braces correctly. Look at the following table.

Combined Text Mode Commands

To get boldface san serif letters, use `\textbf{\textsf{...}}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get boldface italic letters, use `\textbf{\textit{...}}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

To get boldface slanted letters, use `\textbf{\textsl{...}}`.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

1.1.3 Emphasizing Words in Text Mode

For semantic reasons, it's important to use `\emph{...}` when you want to emphasize a word. Use `\emph{vector}` to emphasize the word *vector* or `\emph{momentum}` to emphasize the word *momentum*. In most documents, `\emph{...}` defaults to italics, but it may default to something else when using a different document class. Let the document class do its work and you will have fewer things to remember.

1.1.4 Text Modal Font Commands

Next, let's look at the various text modal commands you can use. I like to think of them as *switches* rather than *commands* because they take effect immediately and stay in effect until you explicitly turn them off by activating another one, much like a light switch. As so, they do not take braced arguments, or indeed, any arguments at all. Look at the following table.

Text Modal Commands

Use `\normalfont` to switch to the default normal font.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Use `\rmfamily` to switch to roman letters.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Use `\sffamily` to switch to sans serif letters.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Use `\ttfamily` to switch to typewriter letters.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Use `\mdseries` to switch to medium letters.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Use `\bfseries` to switch to boldface letters.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Use `\upshape` to switch to upright letters.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Use `\itshape` to switch to italic letters.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Use `\slshape` to switch to slanted letters.

abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789

Use `\scshape` to switch to small capital letters.

ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz0123456789

To illustrate how these switches work, the following unindented paragraph is in the default text font (it's just filler text). Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis egestas urna et dolor posuere, accumsan faucibus justo viverra. Pellentesque libero neque, maximus vitae placerat eu, luctus sit amet sapien. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos himenaeos. Aenean vel nisl massa. Sed id velit tellus. Vivamus eu elit a erat aliquam auctor nec sed mi. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Cras ut consequat purus. Fusce imperdiet scelerisque sagittis. Etiam maximus sagittis sapien. Proin mi metus, cursus a ex eget, maximus laoreet sapien. In hac habitasse platea dictumst. Morbi eget est dui. Cras posuere nisl quis leo facilisis, vel viverra augue sagittis. Nullam posuere, ex id efficitur mollis, velit nisi tincidunt augue, vel tempor orci nisi a justo.

The following unindented paragraph is the same filler text, but now preceded by the `\sffamily` switch.

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Duis egestas urna et dolor posuere, accumsan faucibus justo viverra. Pellentesque libero neque, maximus vitae placerat eu, luctus sit amet sapien. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos himenaeos. Aenean vel nisl massa. Sed id velit tellus. Vivamus eu elit a erat aliquam auctor nec sed mi. Orci varius natoque penatibus et magnis dis parturient montes, nascetur ridiculus mus. Cras ut consequat purus. Fusce imperdiet scelerisque sagittis. Etiam maximus sagittis sapien. Proin mi metus, cursus a ex eget, maximus laoreet sapien. In hac habitasse platea dictumst. Morbi eget est dui. Cras posuere nisl quis leo facilisis, vel viverra augue sagittis. Nullam posuere, ex id efficitur mollis, velit nisi tincidunt augue, vel tempor orci nisi a justo.

Note that this (the current) paragraph is still typeset in sans serif letters because the `\sffamily` switch is still activated. We can deactivate it by activating another switch, like `\normalfont` to get back to normal default text, or like `\bfseries` to get bold letters, or even like `\itshape` to get italic letters. *Note that we got both bold and italic letters in that last phrase, and in this sentence, because the `\bfseries` switch was still activated when we activated the `\itshape` switch. Activated switches can accumulate to give us new combinations of letter styles and shapes. We can return to the normal default font by activating the `\normalfont` switch just like this.* Now everything is back to normal.

1.2 Math Mode Fonts

Now we need to discuss math mode fonts, which are considerably more complicated than text mode fonts. There are math mode font *commands*, but there are no math mode font *switches*. Math mode fonts sometimes include lowercase and/or uppercase Greek letters, which are frequently used in mathematical notation. Math mode fonts go into effect whenever you enter in-line math mode with `\(...\)` or display math mode with `\[...\]`. Many \LaTeX tutorials use `$...$` for in-line math mode and `$$...$$` for display math mode. For various technical reasons, these are not recommended so please do not use them. Please consistently use `\(...\)` for in-line math mode and `\[...\]` for display math mode.

1.2.1 Unicode Math Mode Font Commands

In math mode, we use the `unicode-math` package to create new font combinations that allow for greater flexibility than otherwise available. There is a tradeoff, and that is documents must be processed with the \Lua\LaTeX engine. The math mode Unicode font commands available to you in this habitat are given in the following table. Note that all of these commands begin with `\sym<...>`. You may assume that characters not shown are not supported.

$\backslash(\dots\backslash)$ or $\backslash[\dots\backslash]$ or $\backslash\mathrm{symnormal}\{\dots\}$ give the default math mode font. Use this for vector index notation.
 $abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789$
 $\alpha\beta\gamma\delta\epsilon\zeta\eta\theta\iota\kappa\lambda\mu\nu\xi\omicron\pi\rho\sigma\tau\upsilon\phi\chi\psi\omega\Delta\Gamma\Theta\Lambda\Xi\P\S\Upsilon\Phi\Psi\Omega$
 $\backslash\mathrm{symbf}\{\dots\}$ gives boldface italic. Use this for coordinate-free vectors and matrices.
 $\mathbf{abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ}$
 $\alpha\beta\gamma\delta\epsilon\zeta\eta\theta\iota\kappa\lambda\mu\nu\xi\omicron\pi\rho\sigma\tau\upsilon\phi\chi\psi\omega\Delta\Gamma\Theta\Lambda\Xi\P\S\Upsilon\Phi\Psi\Omega$
 $\backslash\mathrm{symup}\{\dots\}$ gives upright (roman) serif. Use this to name particles. $\backslash\mathrm{symup}\{\Omega\}$ (Ω) represents the ohm.
 $abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789$
 $\alpha\beta\gamma\delta\epsilon\zeta\eta\theta\iota\kappa\lambda\mu\nu\xi\omicron\pi\rho\sigma\tau\upsilon\phi\chi\psi\omega\Delta\Gamma\Theta\Lambda\Xi\P\S\Upsilon\Phi\Psi\Omega$
 $\backslash\mathrm{symbfup}\{\dots\}$ gives boldface upright serif.
 $\mathbf{abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789}$
 $\alpha\beta\gamma\delta\epsilon\zeta\eta\theta\iota\kappa\lambda\mu\nu\xi\omicron\pi\rho\sigma\tau\upsilon\phi\chi\psi\omega\Delta\Gamma\Theta\Lambda\Xi\P\S\Upsilon\Phi\Psi\Omega$
 $\backslash\mathrm{symsfup}\{\dots\}$ gives sans serif upright. Use this for physical dimensions.
 $abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789$
 $\backslash\mathrm{symbfsfup}\{\dots\}$ gives boldface sans serif upright.
 $\mathbf{abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789}$
 $\alpha\beta\gamma\delta\epsilon\zeta\eta\theta\iota\kappa\lambda\mu\nu\xi\omicron\pi\rho\sigma\tau\upsilon\phi\chi\psi\omega\Delta\Gamma\Theta\Lambda\Xi\P\S\Upsilon\Phi\Psi\Omega$
 $\backslash\mathrm{symsfit}\{\dots\}$ gives sans serif italic. Use this for tensor index notation.
 $abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ$
 $\backslash\mathrm{symbfsfit}\{\dots\}$ gives boldface sans serif italic. Use this for coordinate-free tensors.
 $\mathbf{abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ}$
 $\backslash\mathrm{symcal}\{\dots\}$ and $\backslash\mathrm{symbfcal}\{\dots\}$ give calligraphic. Use these for points on a manifold or naming coordinate systems.
 $ABCDEFGHIJKLMNOPQRSTUVWXYZ$
 $\mathbf{ABCDEFGHIJKLMNOPQRSTUVWXYZ}$
 $\backslash\mathrm{symscr}\{\dots\}$ and $\backslash\mathrm{symbfscr}\{\dots\}$ give script. Use these for naming spacetime events.
 $abcdefghijklmnopqrstuvwxyz\mathcal{A}\mathcal{B}\mathcal{C}\mathcal{D}\mathcal{E}\mathcal{F}\mathcal{G}\mathcal{H}\mathcal{I}\mathcal{J}\mathcal{K}\mathcal{L}\mathcal{M}\mathcal{N}\mathcal{O}\mathcal{P}\mathcal{Q}\mathcal{R}\mathcal{S}\mathcal{T}\mathcal{U}\mathcal{V}\mathcal{W}\mathcal{X}\mathcal{Y}\mathcal{Z}$
 $\mathbf{abcdefghijklmnopqrstuvwxyz\mathcal{A}\mathcal{B}\mathcal{C}\mathcal{D}\mathcal{E}\mathcal{F}\mathcal{G}\mathcal{H}\mathcal{I}\mathcal{J}\mathcal{K}\mathcal{L}\mathcal{M}\mathcal{N}\mathcal{O}\mathcal{P}\mathcal{Q}\mathcal{R}\mathcal{S}\mathcal{T}\mathcal{U}\mathcal{V}\mathcal{W}\mathcal{X}\mathcal{Y}\mathcal{Z}}$
 $\backslash\mathrm{symtt}\{\dots\}$ gives typewriter.
 $abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789$
 $\backslash\mathrm{symfrac}\{\dots\}$ and $\backslash\mathrm{symbffrac}\{\dots\}$ give Fraktur.
 $abcdefghijklmnopqrstuvwxyz\mathfrak{A}\mathfrak{B}\mathfrak{C}\mathfrak{D}\mathfrak{E}\mathfrak{F}\mathfrak{G}\mathfrak{H}\mathfrak{I}\mathfrak{J}\mathfrak{K}\mathfrak{L}\mathfrak{M}\mathfrak{N}\mathfrak{O}\mathfrak{P}\mathfrak{Q}\mathfrak{R}\mathfrak{S}\mathfrak{T}\mathfrak{U}\mathfrak{V}\mathfrak{W}\mathfrak{X}\mathfrak{Y}\mathfrak{Z}$
 $\mathbf{abcdefghijklmnopqrstuvwxyz\mathfrak{A}\mathfrak{B}\mathfrak{C}\mathfrak{D}\mathfrak{E}\mathfrak{F}\mathfrak{G}\mathfrak{H}\mathfrak{I}\mathfrak{J}\mathfrak{K}\mathfrak{L}\mathfrak{M}\mathfrak{N}\mathfrak{O}\mathfrak{P}\mathfrak{Q}\mathfrak{R}\mathfrak{S}\mathfrak{T}\mathfrak{U}\mathfrak{V}\mathfrak{W}\mathfrak{X}\mathfrak{Y}\mathfrak{Z}}$
 $\backslash\mathrm{symbb}\{\dots\}$ gives blackboard.
 $\mathbf{abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789}$
 $\backslash\mathrm{symbbit}\{\dots\}$ gives blackboard italic. I have no idea why it's defined for only five letters.
 \mathbf{deijD}

The zero vector is $\backslash\mathrm{symbfup}\{0\}$ or $\mathbf{0}$. It is aliased as $\backslash\mathrm{zerovector}$, which also gives $\mathbf{0}$. As you can see, many more characters are available using the Unicode commands. Also, notice the semantic naming of each typeface and style.

1.2.2 A Few More Mathematical Symbols

There's a handful of other mathematical symbols you will need, and here they are. Don't worry if you've never seen any or all of these before. The third row of symbols is unique to *mandi*.

$$\nabla \square \partial \otimes \times \cdot \cdot$$

$$\nabla \partial$$

$$\nabla_{\boldsymbol{u}} \nabla_{\boldsymbol{u}}$$

$$\text{---} \text{---} \boldsymbol{a} \mathbb{C}_{(1,2)} \mathbb{C}_{(1,3)(2,4)} \mathbb{C}_{(1,2)} \mathbb{C}_{(1,3)(2,4)}$$

1.2.3 Unicode Input

With Unicode support, you can use characters direction from your keyboard. It is important to remember that the glyphs (characters) you use must be present in the font you use for your document or they will not display correctly, if at all.

There is an intelligent exterior derivative operator.

$$\mathbf{d}\omega$$

2 The Unit Engine

The seven fundamental SI quantities are displacement (3 m), duration (3 s), mass (3 kg), electric current (3 A), thermodynamic temperature (3 K), amount (3 mol), and luminous intensity (3 cd).

$4 \text{ m} \cdot \text{kg} \cdot \text{s}^{-1}$, $4 \text{ N} \cdot \text{s}$, $4 \text{ kg} \cdot \text{m/s}$
 $4 \text{ m} \cdot \text{s}^{-2}$, 4 N/kg , 4 m/s^2
 $4 \text{ kg} \cdot \text{s}^{-2} \cdot \text{A}^{-1}$, 4 T , $4 \text{ N/C} \cdot (\text{m/s})$
 $4 \text{ m} \cdot \text{kg} \cdot \text{s}^{-1}$, $4 \text{ m} \cdot \text{s}^{-2}$, $4 \text{ kg} \cdot \text{s}^{-2} \cdot \text{A}^{-1}$
 $4 \text{ N} \cdot \text{s}$, 4 N/kg , 4 T
 $4 \text{ kg} \cdot \text{m/s}$, 4 m/s^2 , $4 \text{ N/C} \cdot (\text{m/s})$
 $\text{m} \cdot \text{kg} \cdot \text{s}^{-1}$, $\text{N} \cdot \text{s}$, $\text{kg} \cdot \text{m/s}$

| | | | |
|----------------------|--|---------------------------------------|--|
| name | base | derived | alternate |
| \acceleration | $\text{m} \cdot \text{s}^{-2}$ | N/kg | m/s^2 |
| name | base | derived | alternate |
| \amount | mol | mol | mol |
| name | base | derived | alternate |
| \angularvelocity | $\text{rad} \cdot \text{s}^{-1}$ | rad/s | rad/s |
| name | base | derived | alternate |
| \angularacceleration | $\text{rad} \cdot \text{s}^{-2}$ | rad/s^2 | rad/s^2 |
| name | base | derived | alternate |
| \angularfrequency | $\text{rad} \cdot \text{s}^{-1}$ | rad/s | rad/s |
| name | base | derived | alternate |
| \angularimpulse | $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$ | J · s | $\text{N} \cdot \text{m} \cdot \text{s}$ |
| name | base | derived | alternate |
| \angularmomentum | $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-1}$ | $\text{kg} \cdot \text{m}^2/\text{s}$ | $\text{N} \cdot \text{m} \cdot \text{s}$ |
| name | base | derived | alternate |
| \area | m^2 | m^2 | m^2 |
| name | base | derived | alternate |
| \areamassdensity | $\text{m}^{-2} \cdot \text{kg}$ | kg/m^2 | kg/m^2 |
| name | base | derived | alternate |
| \areachargedensity | $\text{m}^{-2} \cdot \text{s} \cdot \text{A}$ | C/m^2 | C/m^2 |
| name | base | derived | alternate |
| \capacitance | $\text{m}^{-2} \cdot \text{kg}^{-1} \cdot \text{s}^4 \cdot \text{A}^2$ | F | C/V |
| name | base | derived | alternate |
| \charge | A · s | C | C |

| | | | |
|-------------------------------|--|--------------------------------------|-----------------------------------|
| name \cmagneticfield | base $\text{m} \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-1}$ | derived N/C | alternate V/m |
| name \conductance | base $\text{m}^{-2} \cdot \text{kg}^{-1} \cdot \text{s}^3 \cdot \text{A}^2$ | derived A/V | alternate S |
| name \conductivity | base $\text{m}^{-3} \cdot \text{kg}^{-1} \cdot \text{s}^3 \cdot \text{A}^2$ | derived (A/m ²)/(V/m) | alternate S/m |
| name \conventionalcurrent | base A | derived A | alternate C/s |
| name \current | base A | derived A | alternate A |
| name \currentdensity | base $\text{m}^{-2} \cdot \text{A}$ | derived A/m ² | alternate C · s/m ² |
| name \dielectricconstant | base | derived | alternate |
| name \displacement | base m | derived m | alternate m |
| name \duration | base s | derived s | alternate s |
| name \electricdipolemoment | base $\text{m} \cdot \text{s} \cdot \text{A}$ | derived C · m | alternate C · m |
| name \electricfield | base $\text{m} \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-1}$ | derived N/C | alternate V/m |
| name \electricflux | base $\text{m}^3 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-1}$ | derived N · m ² /C | alternate V · m |
| name \electricpotential | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-1}$ | derived V | alternate J/C |
| name \electroncurrent | base s ⁻¹ | derived e/s | alternate e/s |
| name \emf | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-1}$ | derived V | alternate J/C |
| name \energy | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2}$ | derived J | alternate N · m |

| | | | |
|---------------------------------|--|--|--|
| name \energydensity | base $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$ | derived J/m^3 | alternate J/m^3 |
| name \energyflux | base $\text{kg} \cdot \text{s}^{-3}$ | derived W/m^2 | alternate W/m^2 |
| name \entropy | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{K}^{-1}$ | derived J/K | alternate J/K |
| name \frequency | base s^{-1} | derived Hz | alternate Hz |
| name \force | base $\text{m} \cdot \text{kg} \cdot \text{s}^{-2}$ | derived N | alternate N |
| name \gravitationalfield | base $\text{m} \cdot \text{s}^{-2}$ | derived N/kg | alternate N/kg |
| name \gravitationalpotential | base $\text{m}^2 \cdot \text{s}^{-2}$ | derived J/kg | alternate J/kg |
| name \impulse | base $\text{m} \cdot \text{kg} \cdot \text{s}^{-1}$ | derived $\text{N} \cdot \text{s}$ | alternate $\text{N} \cdot \text{s}$ |
| name \indexofrefraction | base | derived | alternate |
| name \inductance | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{A}^{-2}$ | derived H | alternate $\text{V} \cdot \text{s}/\text{A}$ |
| name \linearchargedensity | base $\text{m}^{-1} \cdot \text{s} \cdot \text{A}$ | derived C/m | alternate C/m |
| name \linearmassdensity | base $\text{m}^{-1} \cdot \text{kg}$ | derived kg/m | alternate kg/m |
| name \luminous | base cd | derived cd | alternate cd |
| name \magneticcharge | base $\text{m} \cdot \text{A}$ | derived $\text{m} \cdot \text{A}$ | alternate $\text{m} \cdot \text{A}$ |
| name \magneticdipolemoment | base $\text{m}^2 \cdot \text{A}$ | derived $\text{A} \cdot \text{m}^2$ | alternate J/T |
| name \magneticfield | base $\text{kg} \cdot \text{s}^{-2} \cdot \text{A}^{-1}$ | derived T | alternate $\text{N}/\text{C} \cdot (\text{m}/\text{s})$ |

| | | | |
|-------------------------------|---|---|---|
| name \magneticflux | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{A}^{-1}$ | derived $\text{T} \cdot \text{m}^2$ | alternate $\text{V} \cdot \text{s}$ |
| name \mass | base kg | derived kg | alternate kg |
| name \mobility | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-4} \cdot \text{A}^{-1}$ | derived $\text{m}^2/\text{V} \cdot \text{s}$ | alternate $(\text{m/s})/(\text{N/C})$ |
| name \momentum | base $\text{m} \cdot \text{kg} \cdot \text{s}^{-1}$ | derived $\text{N} \cdot \text{s}$ | alternate $\text{kg} \cdot \text{m/s}$ |
| name \momentumflux | base $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$ | derived N/m^2 | alternate N/m^2 |
| name \momentofinertia | base $\text{m}^2 \cdot \text{kg}$ | derived $\text{m}^2 \cdot \text{kg}$ | alternate $\text{J} \cdot \text{s}^2$ |
| name \numberdensity | base m^{-3} | derived $/\text{m}^3$ | alternate $/\text{m}^3$ |
| name \permeability | base $\text{m} \cdot \text{kg} \cdot \text{s}^{-2} \cdot \text{A}^{-2}$ | derived $\text{T} \cdot \text{m}/\text{A}$ | alternate H/m |
| name \permittivity | base $\text{m}^{-3} \cdot \text{kg}^{-1} \cdot \text{s}^{-4} \cdot \text{A}^2$ | derived $\text{C}^2/\text{N} \cdot \text{m}^2$ | alternate F/m |
| name \planeangle | base $\text{m} \cdot \text{m}^{-1}$ | derived rad | alternate rad |
| name \polarizability | base $\text{kg}^{-1} \cdot \text{s}^4 \cdot \text{A}^2$ | derived $\text{C} \cdot \text{m}^2/\text{V}$ | alternate $\text{C} \cdot \text{m}/(\text{N/C})$ |
| name \power | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3}$ | derived W | alternate J/s |
| name \pressure | base $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$ | derived Pa | alternate N/m^2 |
| name \relativepermeability | base | derived | alternate |
| name \relativepermittivity | base | derived | alternate |
| name \resistance | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-2}$ | derived Ω | alternate V/A |

| | | | |
|---|--|--|--|
| name <code>\resistivity</code> | base $\text{m}^3 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-2}$ | derived $\Omega \cdot \text{m}$ | alternate $(\text{V}/\text{m})/(\text{A}/\text{m}^2)$ |
| name <code>\solidangle</code> | base $\text{m}^2 \cdot \text{m}^{-2}$ | derived sr | alternate sr |
| name <code>\specificeatcapacity</code> | base $\text{m}^2 \cdot \text{s}^{-2} \cdot \text{K}^{-1}$ | derived $\text{J}/\text{K} \cdot \text{kg}$ | alternate $\text{J}/\text{K} \cdot \text{kg}$ |
| name <code>\springstiffness</code> | base $\text{kg} \cdot \text{s}^{-2}$ | derived N/m | alternate N/m |
| name <code>\springstretch</code> | base m | derived m | alternate m |
| name <code>\stress</code> | base $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$ | derived Pa | alternate N/m^2 |
| name <code>\strain</code> | base | derived | alternate |
| name <code>\temperature</code> | base K | derived K | alternate K |
| name <code>\torque</code> | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2}$ | derived $\text{N} \cdot \text{m}$ | alternate $\text{N} \cdot \text{m}$ |
| name <code>\velocity</code> | base $\text{m} \cdot \text{s}^{-1}$ | derived $\text{m} \cdot \text{s}^{-1}$ | alternate m/s |
| name <code>\volume</code> | base m^3 | derived m^3 | alternate m^3 |
| name <code>\volumechargedensity</code> | base $\text{m}^{-3} \cdot \text{s} \cdot \text{A}$ | derived C/m^3 | alternate C/m^3 |
| name <code>\volumemassdensity</code> | base $\text{m}^{-3} \cdot \text{kg}$ | derived kg/m^3 | alternate kg/m^3 |
| name <code>\wavelength</code> | base m | derived m | alternate m |
| name <code>\wavenumber</code> | base m^{-1} | derived /m | alternate /m |
| name <code>\work</code> | base $\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2}$ | derived J | alternate $\text{N} \cdot \text{m}$ |
| name <code>\youngsmodulus</code> | base $\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$ | derived Pa | alternate N/m^2 |

3 Column and Row Vectors

3.1 Column Vectors

$$\begin{pmatrix} 0 \\ 1 \\ 2 \\ 3 \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_2 \end{pmatrix}$$

3.2 Row Vectors

$$(0 \ 1 \ 2 \ 3)(a_1 \ a_2 \ a_2)$$

4 Symbolic Vectors

4.1 Notation Conventions

Typesetting symbolic vectors is ubiquitous in physics, yet most sources are not consistent in notation compared to other sources. Using arrows to denote vector quantities, as with `\vec{*}{p}` (note the `*`), which gives \vec{p} , seems the standard in introductory physics courses, but this isn't seen in higher level resources, and certainly not in published articles. The standard, which doesn't seem to be observed, is that vectors are typeset in boldface italic, as with `\vec{p}`, which gives \mathbf{p} . Physics teachers know students struggle with using arrows to denote vector quantities, and most students never correctly learn it. After all, why should they learn something that isn't used consistently, or even at all? There is really just one practical reason for using arrows rather than boldface, and that is the quaint notion of writing on a whiteboard (or a chalkboard if anyone remembers those). We really should move with the times and enforce the professional convention for our students. So in `mandi` we do exactly this, but allow flexibility in notation for those who insist upon having it. By default, the standard L^AT_EX `\vec{...}` command is redefined to, by default, typeset symbols for vector quantities in boldface italic. The starred form of the command, `\vec{*}{...}`, typesets them with arrows. Note that getting arrow notation is a bit more difficult (because you must type the `*`) than the default boldface italic notation, and this is a subtle psychological tactic on my part; the new notation takes less effort.

4.2 Symbolic Notation

The command `\direct{...}` typesets the symbol for a vector's direction. `\direct{r}` gives \hat{r} and as you might expect by now `\direct{*}{r}` gives \widehat{r} . A vector's magnitude is typeset with `\norm{...}`. As you may predict, `\norm{\vec{r}}` gives $\|\mathbf{r}\|$ and `\norm{\vec{*}{r}}` gives $\|\vec{r}\|$. Any vector can be *factored* into its magnitude and direction. So $\mathbf{p} = \|\mathbf{p}\|\hat{p}$ or $\vec{p} = \|\vec{p}\|\widehat{p}$.

The command `\magvect{...}` typesets the symbol for a vector's magnitude. `\magvect{r}` gives $\|\mathbf{r}\|$ and of course `\magvect{*}{r}` gives $\|\vec{r}\|$.

Finally, the command `\Dvect{...}` typesets the symbol for the change in a vector. `\Dvect{r}` gives $\Delta\mathbf{r}$. For arrow notation, use the starred form. `\Dvect{*}{r}` gives $\Delta\vec{r}$.

4.3 Embellishments

Again, I state that notation should help the reader and for physics students, unambiguously help guide one's thinking. This frequently requires use of embellishments, or additions to basic notation. For example, consider a rock moving through space. One can speak of the rock's momentum, and notate it as \vec{p}_{rock} , which gives

$$\mathbf{p}_{\text{rock}}$$

as predicted. But wait, the subscript doesn't look right. It is typeset in italic when it shouldn't be. So instead, we write $\vec{p}_{\text{\textup{rock}}}$, which gives

$$\mathbf{p}_{\text{rock}}$$

which looks much better. Why does this make a difference? The answer is that the $\vec{\dots}$ command internally takes place in *math mode*, which means all characters are, by default, typeset in italic. Words are not intended to be written in math mode. So if we want to typeset an actual piece of text, you must mark it up as such using a $\text{\textup{\dots}}$ command.

So now you can correctly typeset an initial momentum and final momentum symbolically as $\vec{p}_{\text{\textup{initial}}}$ and $\vec{p}_{\text{\textup{final}}}$, which give

$$\mathbf{p}_{\text{\textup{initial}}} \text{ and } \mathbf{p}_{\text{\textup{final}}}$$

exactly as expected. If you want something other than actual text as a subscript, just supply it without additional markup. So you could write, for example, \vec{p}_1 and get

$$\mathbf{p}_1$$

as expected. The braces around the subscript are strictly not required if the subscript is just one character, but it is a good habit to write them all the time, so I do.

You can add superscripts just as easily as you can add subscripts, using a caret (^) to denote the superscript. Writing $\vec{p}^{\text{\textup{rock}}}$ gives

$$\mathbf{p}^{\text{rock}}$$

just like that. All the comments about subscripts above apply to superscripts. The best part is that you can effortlessly mix subscripts and superscripts. Writing

$\vec{p}_{\text{\textup{final}}}^{\text{\textup{rock}}}$ or $\vec{p}^{\text{\textup{rock}}}_{\text{\textup{final}}}$ gives

$$\mathbf{p}_{\text{\textup{final}}}^{\text{rock}} \text{ and } \mathbf{p}_{\text{\textup{final}}}^{\text{rock}}$$

and note that the order of the flourishes doesn't matter. The underlying L^AT_EX3 programming layer makes this almost trivial to implement in **mandi** now. Using text to embellish a symbolic vector takes a bit more effort, which is a subtle warning to use it sparingly. Simply changing $\vec{\dots}$ to $\vec{*}\dots$ gives the same results with arrow notation and gives

$$\vec{p}_{\text{\textup{final}}}^{\text{rock}} \text{ and } \vec{p}_{\text{\textup{final}}}^{\text{rock}}$$

as expected.

It is very important to always that when in math mode, always, without exception, wrap words used in subscripts and superscripts in `\mathup{...}`. This does not apply to mathematical symbols, only to actual words or any text that is not mathematical notation.

Of course you can mix mathematical notation and text in the flourishes. As an example, one could represent an alpha particle's final momentum by writing `\vec{p}_{\symup{\alpha},\mathup{final}}` which typesets as

$$\boldsymbol{p}_{\alpha,\text{final}}$$

as beautifully as expected. If you want arrow notation, you would write `\vec{p}_{\symup{\alpha},\mathup{final}}` which typesets as

$$\vec{p}_{\alpha,\text{final}}$$

as expected. For many reasons, I think the boldface notation looks better. Finally, note that `\symup{...}` is used here since upright Greek letters are used to name subatomic particles.

$$\|\boldsymbol{p}_{\text{final}}\| \quad \left(\frac{1}{4\pi\epsilon_o} \right)$$

$$\Delta \boldsymbol{r} = \boldsymbol{r}_{\text{final}} - \boldsymbol{r}_{\text{initial}} \quad \text{definition} \quad (1)$$

$$\Delta \vec{r} = \vec{r}_{\text{final}} - \vec{r}_{\text{initial}} \quad \begin{array}{l} \text{Morbi auctor lorem non} \\ \text{justo. Nam lacus libero,} \\ \text{pretium at, lobortis vitae,} \\ \text{ultrices et, tellus. Donec} \\ \text{aliquet, tortor sed} \\ \text{accumsan bibendum, erat} \\ \text{ligula aliquet magna, vitae} \\ \text{ornare odio metus a mi.} \end{array} \quad (2)$$

$$\Delta \boldsymbol{r} = \boldsymbol{r}_{\text{final}} - \boldsymbol{r}_{\text{initial}} \quad \text{definition} \quad (3)$$

$$\Delta \boldsymbol{r} = \boldsymbol{r}_{\text{final}} - \boldsymbol{r}_{\text{initial}} \quad \text{definition} \quad (4)$$

$$\|\boldsymbol{r}\| = \sqrt{\boldsymbol{r} \cdot \boldsymbol{r}} \quad (5)$$

$$\begin{array}{ll}
\left(\frac{1}{4\pi\epsilon_o}\right) & (\cdot) \\
\left[\frac{1}{4\pi\epsilon_o}\right] & [\cdot] \\
\left|\frac{1}{4\pi\epsilon_o}\right| & |\cdot| \\
\left\|\frac{1}{4\pi\epsilon_o}\right\| & \|\cdot\| \\
\left(\frac{1}{4\pi\epsilon_o}\right) & (\cdot) \\
\left[\frac{1}{4\pi\epsilon_o}\right] & [\cdot] \\
\left|\frac{1}{4\pi\epsilon_o}\right| & |\cdot| \\
\left\|\frac{1}{4\pi\epsilon_o}\right\| & \|\cdot\|
\end{array}$$

4.4 Coordinate-Free Notation

The arrow notation used in introductory physics is a compromise between a notation that ostensibly helps students remember the quantity in question had an associate direction and a notation that is easily reproducible by hand on a whiteboard. As hard as we try, students rarely use arrow notation for vectors correctly, if at all. You don't find arrow notation for vectors much at all in the literature outside of introductory textbooks. Most sources use boldface, and while that is harder to use on a whiteboard, it's trivial to do in L^AT_EX so why not adopt it as the expectation?

Use the `\veccomp{...}` command to get coordinate-free notation for vectors. `\veccomp{p}` gives **p**. This notation isn't intended to be used with embellishments, but it can be done as long as you are in math mode.

4.5 Index Notation

Use the `\veccomp*{...}` command to get index notation for vectors. `\veccomp*{p}` gives p . Where is the index? You have to supply it using the `\indices{...}` command from the **tensor** package, which `mandi` loads for you. So to get the symbol for momentum in index notation you would use `\veccomp*{p}\indices{^i}` which gives p^i . Now, you may realize that `\veccomp*{p}^i` gives the same result, and it does indeed give p^i as expected, so why bother with the `\indices{...}` command? The answer is that the `\indices{...}` command plays an important role in tensor index notation, which includes vector index notation, and you need to be comfortable using it. Use `\veccomp{e}` to get a basis vector, which gives **e** as expected. Basis vectors must be labeled, and I recommend using the `\indices{...}` command, but both `\veccomp{e}\indices{_i}` and `\veccomp{e}_i` give the same result, e_i as expected. So to get the full symbol for a vector in a particular basis you would use

$\backslash\text{veccomp}\{p\}_i\backslash\text{veccomp}\{e\}^i$ or $\backslash\text{veccomp}\{p\}\backslash\text{indices}\{^i\}\backslash\text{veccomp}\{e\}\backslash\text{indices}\{_i\}$, both of which give $p^i e_i$.

5 Highlighting Mathematics

A new feature to **mandi** is a command for highlighting mathematics.

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

Here is another example.

$$\begin{aligned} \Delta p &= F_{\text{net,sys}} \Delta t \\ \Delta p &= F_{\text{net,sys}} \Delta t \\ \Delta p &= F_{\text{net,sys}} \Delta t \\ \Delta p &= F_{\text{net,sys}} \Delta t \\ \Delta p &= F_{\text{net,sys}} \Delta t \\ \Delta p &= F_{\text{net,sys}} \Delta t \end{aligned}$$

Highlighting also works in in-line math mode like $a^2 + b^2 = c^2$.

6 Tensor Notation

A tensor has a valence $\binom{m}{n}$ by definition. A vector is a $\binom{1}{0}$ tensor and a one-form is a $\binom{0}{1}$ tensor.

7 GlowScript and VPython Program Listings

7.1 The glowscriptblock Environment

GlowScript program listings are improved and look better. Clicking anywhere on the actual code takes the reader to the relevant source code on [GlowScript.org](https://www.glowscript.org) for read-only access using the URL provided by the user. To minimize the chances of a program being broken over a pagebreak, each listing begins on a new page. This is a big change from the previous version of **mandi** and may be annoying for small programs, but I think the clarity of beginning a new listing on a new page is important. I recommend using a URL shortening utility to keep the URL from getting unruly, and don't forget to manually prepend either `http://` or `https://` (preferably the latter) to the URL. Note that **GlowScript** ignores the `from vpython import *` line.

```

1 GlowScript 3.0 VPython
2 from vpython import *
3
4 scene.width = 400
5 scene.height = 760
6 # constants and data
7 g = 9.8      # m/s^2
8 mball = 0.03 # kg
9 Lo = 0.26    # m
10 ks = 1.8     # N/m
11 deltat = 0.01 #s
12
13 # objects (origin is at ceiling)
14 ceiling = box(pos=vector(0,0,0), length=0.2, height=0.01, width=0.2)
15 ball = sphere(pos=vector(0,-0.3,0), radius=0.025, color=color.orange)
16 spring = helix(pos=ceiling.pos, axis=ball.pos-ceiling.pos,
17               color=color.cyan, thickness=0.003, coils=40, radius=0.010)
18
19 # initial values
20 pball = mball * vector(0,0,0)      # kg m/s
21 Fgrav = mball * g * vector(0,-1,0) # N
22 t = 0
23
24 # improve the display
25 scene.autoscale = False      # turn off automatic camera zoom
26 scene.center = vector(0,-Lo,0) # move camera down
27 scene.waitfor('click')      # wait for a mouse click
28
29 # initial calculation loop
30 # calculation loop
31 while t < 10:
32     rate(100)
33     # we need the stretch
34     s = mag(ball.pos) - Lo
35     # we need the spring force
36     Fspring = ks * s * -norm(spring.axis)
37     Fnet = Fgrav + Fspring
38     pball = pball + Fnet * deltat
39     ball.pos = ball.pos + (pball / mball) * deltat
40     spring.axis = ball.pos - ceiling.pos
41     t = t + deltat

```

Listing 1: A GlowScript program.

nameref-link to listing: [A GlowScript program](#)

ref-link to listing: [1](#)

pageref-link to listing: [18](#)

autoref-link to listing: [Listing 1](#)

It may be annoying for a small program listing like this, but again, I think the clarity is important, especially for beginners.

```
1 123456789012345678901234567890123456789012345678901234567890123456789
2 123456789012345678901234567890123456789012345678901234567890123456789
```

Listing 2: 79 Columns

nameref-link to listing: [79 Columns](#)

ref-link to listing: [2](#)

pageref-link to listing: [20](#)

autoref-link to listing: [Listing 2](#)

7.2 The `glowscripblock` Environment With `VPython` Programs

`VPython` programs are also nicely formatted but lack the hyperlink capability because they live on the user's local computer and not online. Since the `glowscripblock` environment turns the code into a hyperlink, it makes no sense semantically to use this environment for `VPython` programs. Still, it is sometimes helpful to show a block of code this way without turning the code into a hyperlink. Use `glowscripblock` without the optional argument to typeset a block of `VPython` code. In this example, note that the `GlowScript 3.0 VPython` line is omitted because `VPython` does not ignore it.

```

1  from vpython import *
2
3  scene.width = 400
4  scene.height = 760
5  # constants and data
6  g = 9.8      # m/s^2
7  mball = 0.03 # kg
8  Lo = 0.26    # m
9  ks = 1.8     # N/m
10 deltata = 0.01 #s
11
12 # objects (origin is at ceiling)
13 ceiling = box(pos=vector(0,0,0), length=0.2, height=0.01, width=0.2)
14 ball = sphere(pos=vector(0,-0.3,0), radius=0.025, color=color.orange)
15 spring = helix(pos=ceiling.pos, axis=ball.pos-ceiling.pos,
16               color=color.cyan, thickness=0.003, coils=40, radius=0.010)
17
18 # initial values
19 pball = mball * vector(0,0,0)      # kg m/s
20 Fgrav = mball * g * vector(0,-1,0) # N
21 t = 0
22
23 # improve the display
24 scene.autoscale = False           # turn off automatic camera zoom
25 scene.center = vector(0,-Lo,0)   # move camera down
26 scene.waitfor('click')          # wait for a mouse click
27
28 # initial calculation loop
29 # calculation loop
30 while t < 10:
31     rate(100)
32     # we need the stretch
33     s = mag(ball.pos) - Lo
34     # we need the spring force
35     Fspring = ks * s * -norm(spring.axis)
36     Fnet = Fgrav + Fspring
37     pball = pball + Fnet * deltata
38     ball.pos = ball.pos + (pball / mball) * deltata
39     spring.axis = ball.pos - ceiling.pos
40     t = t + deltata

```

Listing 3: A VPython program

nameref-link to listing: [A VPython program](#)

ref-link to listing: [3](#)

pageref-link to listing: [21](#)

autoref-link to listing: [Listing 3](#)

7.3 In-line GlowScript and VPython Code

In-line code can be included as before using `\glowscripeline{...}` or `\vpythonline{...}`, depending on which is semantically appropriate. Using

`\glowscripeline{Earth = sphere(color=color.blue)}` gives

`Earth = sphere(pos=vector(1,1,1), radius=2, color=color.blue)` and

`\vpythonline{Sun = sphere(pos=vector(1,1,1), radius=2, color=color.yellow)}` gives

`Sun = sphere(pos=vector(1,1,1), radius=2, color=color.yellow)`.

7.4 Including a VPython File

A VPython file can be included using `\vpythonfile{...}{...}{...}`. The file should be in the same folder as the document being typeset, and a caption and a reference label must be provided. Again, the typeset listing begins on a new page. Note that this example contains the exact same code as the example above, but it is read from a file.

```

1  from vpython import *
2
3  scene.width = 400
4  scene.height = 760
5  # constants and data
6  g = 9.8      # m/s^2
7  mball = 0.03 # kg
8  Lo = 0.26    # m
9  ks = 1.8     # N/m
10 deltata = 0.01 #s
11
12 # objects (origin is at ceiling)
13 ceiling = box(pos=vector(0,0,0), length=0.2, height=0.01, width=0.2)
14 ball = sphere(pos=vector(0,-0.3,0), radius=0.025, color=color.orange)
15 spring = helix(pos=ceiling.pos, axis=ball.pos-ceiling.pos,
16               color=color.cyan, thickness=0.003, coils=40, radius=0.010)
17
18 # initial values
19 pball = mball * vector(0,0,0) # kg m/s
20 Fgrav = mball * g * vector(0,-1,0) # N
21 t = 0
22
23 # improve the display
24 scene.autoscale = False # turn off automatic camera zoom
25 scene.center = vector(0,-Lo,0) # move camera down
26 scene.waitfor('click') # wait for a mouse click
27
28 # initial calculation loop
29 # calculation loop
30 while t < 10:
31     rate(100)
32     # we need the stretch
33     s = mag(ball.pos) - Lo
34     # we need the spring force
35     Fspring = ks * s * -norm(spring.axis)
36     Fnet = Fgrav + Fspring
37     pball = pball + Fnet * deltata
38     ball.pos = ball.pos + (pball / mball) * deltata
39     spring.axis = ball.pos - ceiling.pos
40     t = t + deltata

```

Listing 4: Sample Program

nameref-link to listing: [Sample Program](#)

ref-link to listing: [4](#)

pageref-link to listing: [23](#)

autoref-link to listing: [Listing 4](#)

8 Commands Specific to *Matter & Interactions*

These commands are defined in an optional accessory package called `mandiexp`. That package's name is subject to change.

| | |
|---|--|
| $\Delta \mathbf{p}_{\text{sys}} = \mathbf{F}_{\text{sys,net}} \Delta t$ | momentum principle |
| $\mathbf{p}_{\text{sys,final}} = \mathbf{p}_{\text{sys,initial}} + \mathbf{F}_{\text{sys,net}} \Delta t$ | momentum principle, update form |
| $\Delta E_{\text{sys}} = W_{\text{ext}} + Q$ | energy principle |
| $E_{\text{sys,final}} = E_{\text{sys,initial}} + W_{\text{ext}} + Q$ | energy principle, update form |
| $\Delta \mathbf{L}_{A,\text{sys}} = \boldsymbol{\tau}_{A,\text{sys,net}} \Delta t$ | angular momentum principle |
| $\mathbf{L}_{A,\text{sys,final}} = \mathbf{L}_{A,\text{sys,initial}} + \boldsymbol{\tau}_{A,\text{sys,net}} \Delta t$ | angular momentum principle, update form |

| | | | |
|-----------------------|-----------------------------|-------------------------------|------------------------------|
| E_{sys} | $E_{\text{sys,final}}$ | $E_{\text{sys,initial}}$ | ΔE_{sys} |
| E_{particle} | $E_{\text{particle,final}}$ | $E_{\text{particle,initial}}$ | $\Delta E_{\text{particle}}$ |
| E_{rest} | $E_{\text{rest,final}}$ | $E_{\text{rest,initial}}$ | ΔE_{rest} |
| E_{internal} | $E_{\text{internal,final}}$ | $E_{\text{internal,initial}}$ | $\Delta E_{\text{internal}}$ |
| E_{chem} | $E_{\text{chem,final}}$ | $E_{\text{chem,initial}}$ | ΔE_{chem} |
| E_{therm} | $E_{\text{therm,final}}$ | $E_{\text{therm,initial}}$ | ΔE_{therm} |
| E_{photon} | $E_{\text{photon,final}}$ | $E_{\text{photon,initial}}$ | ΔE_{photon} |
| E_{electron} | $E_{\text{electron,final}}$ | $E_{\text{electron,initial}}$ | $\Delta E_{\text{electron}}$ |
| E_{β} | $E_{\beta,\text{final}}$ | $E_{\beta,\text{initial}}$ | ΔE_{β} |
| K_{trans} | $K_{\text{trans,final}}$ | $K_{\text{trans,initial}}$ | ΔK_{trans} |
| E_{K} | $E_{\text{K,final}}$ | $E_{\text{K,initial}}$ | ΔE_{K} |
| K_{rot} | $K_{\text{rot,final}}$ | $K_{\text{rot,initial}}$ | ΔK_{rot} |
| E_{rot} | $E_{\text{rot,final}}$ | $E_{\text{rot,initial}}$ | ΔE_{rot} |
| K_{vib} | $K_{\text{vib,final}}$ | $K_{\text{vib,initial}}$ | ΔK_{vib} |
| E_{vib} | $E_{\text{vib,final}}$ | $E_{\text{vib,initial}}$ | ΔE_{vib} |
| U_{g} | $U_{\text{g,final}}$ | $U_{\text{g,initial}}$ | ΔU_{g} |
| U_{e} | $U_{\text{e,final}}$ | $U_{\text{e,initial}}$ | ΔU_{e} |
| U_{s} | $U_{\text{s,final}}$ | $U_{\text{s,initial}}$ | ΔU_{s} |

These commands are intended to be semantically helpful.