advanceddynamics
Advanced Dynamics Notation[1]
LaTeX Package

v1.0 2024-04-24

Nolan Canegallo

[1]Based on the notation from Dr. Mazzoleni's MAE 511/789 courses at North Carolina State University.

Contents

1 Introduction

This document serves as the documentation for the advanced dynamics notation LaTeX package `advanceddynamics` which provides a set of macros and commands to easily create text in the notation of the NCSU graduate courses *MAE 511 - Advanced Dynamics I* and *MAE 789 - Advanced Dynamics II* taught by Dr. Mazzoleni.

This document will outline all of the available commands and provide some examples of the typesetting.

1.1 Required Packages

There are 6 required packages to use `advanceddynamics`. They are:

1. `accents` for custom bar [1]
2. `amsmath` for math notation [4]
3. `amssymb` for math symbols [6]
4. `graphicx` for scaling subscripts and superscripts [2]
5. `mathtools` for additional math functionality [3]
6. `tensor` for prescripts [5]

These packages will be automatically imported when using `advanceddynamics`. However, importing these packages first is a good way to ensure that they load correctly, especially since this is my first LaTeX package. Note that `mathtools` already includes the `amsmath` package, so you can omit its import if desired.

This can be done with the following lines before your document's `\begin{document}`:

```
\usepackage{accents}
\usepackage{amsmath}
\usepackage{amsym}
\usepackage{graphicx}
\usepackage{mathtools}
\usepackage{tensor}
```

1.2 Obtaining the Package

The `advanceddynamics` package and documentation are available for download at:

```
https://github.com/nacanega/advanceddynamics
```

1.3 Using the Package

You can use `advanceddynamics` by including the following line before your document's `\begin{document}`:

```
\usepackage{advanceddynamics}
```

Note that you will need to ensure that the file `advanceddynamics.sty` is either located in the same location as your ".tex" files or placed with your other LaTeX distribution's local packages. More detailed information can be found in Section 10.1.

2 Frames of Reference

The commands in this section help the user to define reference frames and their corresponding sets of orthonormal unit vectors.[2] Note that all commands in this section should be used inside of a math environment.

Normal Reference Frames

2.1 \fr

`\fr{⟨point⟩}`

Frame. This command is used to add a bar above a character to allow it to be read as a frame attached to a specified point ⟨*point*⟩. Case-insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)

Example

Say we want to define an inertial reference frame about the point O.

This is accomplished with the LaTeX below:

```
\fr{O}
```

Display/Inline Mode Output

$$\bar{O}$$

2.2 \frsc

`\frsc{⟨frame⟩}`

Small-caps frame. This command is used to define frame ⟨*frame*⟩ in a subscript or superscript. Case-insensitive.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)

Example

Say we want to define x-component of the vector $\vec{r}$ expressed in the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\r_{x\frsc{O}}
```

Display/Inline Mode Output

$$r_{x\bar{O}}$$

[2]Note that my notation differs slightly from the original notation since unit vectors are always marked with a "hat" rather than a plain arrow.

2.3 \ihat

`\ihat{⟨frame⟩}`

I-hat. This command is used to display the $\hat{\imath}$ unit vector for a specified frame ⟨*frame*⟩. The bar is automatically added. Case-insensitive.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)

Example

Say we want to express $\hat{\imath}$ for the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\ihat{a}
```

Display/Inline Mode Output

$$\hat{\imath}_{\bar{A}}$$

2.4 \jhat

`\jhat{⟨frame⟩}`

J-hat. This command is used to display the $\hat{\jmath}$ unit vector for a specified frame ⟨*frame*⟩. The bar is automatically added. Case-insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)

Example

Say we want to express $\hat{\jmath}$ for the $\bar{B}$ frame.

This is accomplished with the LaTeX below:

```
\jhat{b}
```

Display/Inline Mode Output

$$\hat{\jmath}_{\bar{B}}$$

2.5 \khat

`\khat{⟨frame⟩}`

K-hat. This command is used to display the $\hat{k}$ unit vector for a specified frame ⟨*frame*⟩. The bar is automatically added. Case-insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)

Example

Say we want to express $\hat{k}$ for the $\bar{C}$ frame.

This is accomplished with the LaTeX below:

```
\khat{c}
```

Display/Inline Mode Output

$$\hat{k}_{\bar{C}}$$

2.6 \frDef

`\frDef{⟨point⟩}`

Define frame. This command is used define a frame as a point ⟨*point*⟩ and three orthonormal unit vectors. Case insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)

Example

Say we want to define the frame about the point P.

This is accomplished with the LaTeX below:

```
\frDef{P}
```

Display/Inline Mode Output

$$\bar{P} = \{P, \hat{\imath}_{\bar{P}}, \hat{\jmath}_{\bar{P}}, \hat{k}_{\bar{P}}\}$$

2.7 \frExp

`\frExp{⟨frame⟩}{⟨value⟩}`

Expressed in frame. This command is used to show that a matrix or vector quantity ⟨*value*⟩ is expressed in a given frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*value*⟩ = Vector or matrix quantity

Example

Say we want to show that $\vec{v}$ is expressed in the $\bar{B}$ frame.

This is accomplished with the LaTeX below:

```
\frExp{B}{\vec{v}}
```

Display/Inline Mode Output

$$[\vec{v}]_{\bar{B}}$$

2.8 \frVec

`\frVec{⟨frame⟩}{⟨icomp⟩}{⟨jcomp⟩}{⟨kcomp⟩}`

Vector frame components. This command is used to express a vector in terms of its components in each of the frame's unit vectors.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*icomp*⟩ = i-hat-component expression
⟨*jcomp*⟩ = j-hat-component expression
⟨*kcomp*⟩ = k-hat-component expression

Example

Say we want to express $[\vec{r}]_{\bar{O}} = \langle x, y, z\rangle$ in its $\bar{O}$ frame components.

This is accomplished with the LaTeX below:

```
\frVec{O}{x}{y}{z}
```

Display/Inline Mode Output

$$(x)\hat{\imath}_{\bar{O}} + (y)\hat{\jmath}_{\bar{O}} + (z)\hat{k}_{\bar{O}}$$

2.9 \frTen

`\frTen{⟨frame⟩}{⟨ii⟩}{⟨ij⟩}{⟨ik⟩}{⟨ji⟩}{⟨jj⟩}{⟨jk⟩}{⟨ki⟩}{⟨kj⟩}{⟨kk⟩}`

Tensor frame components. This command is used to express a tensor in terms of its components in each of the frame's unit vector combinations. Must be inside a `align` or `align*` environment.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*ii*⟩ = i-hat-i-hat-component expression
⟨*ij*⟩ = i-hat-j-hat-component expression
⟨*ik*⟩ = i-hat-k-hat-component expression
⟨*ji*⟩ = j-hat-i-hat-component expression
⟨*jj*⟩ = j-hat-j-hat-component expression
⟨*jk*⟩ = j-hat-k-hat-component expression
⟨*ki*⟩ = k-hat-i-hat-component expression
⟨*kj*⟩ = k-hat-j-hat-component expression
⟨*kk*⟩ = k-hat-k-hat-component expression

Example

Say we want to express $[\tilde{I}]_{\bar{O}}$ in its $\bar{O}$ frame components (say a-i).

This is accomplished with the LaTeX below:

```
\frTen{O}{a}{b}{c}{d}{e}{f}{g}{h}{i}
```

Display Mode Output

$$\begin{aligned}&(a)\hat{\imath}_{\bar{o}}\hat{\imath}_{\bar{o}}+(b)\hat{\imath}_{\bar{o}}\hat{\jmath}_{\bar{o}}+(c)\hat{\imath}_{\bar{o}}\hat{k}_{\bar{o}}\cdots\\&+(d)\hat{\jmath}_{\bar{o}}\hat{\imath}_{\bar{o}}+(e)\hat{\jmath}_{\bar{o}}\hat{\jmath}_{\bar{o}}+(f)\hat{\jmath}_{\bar{o}}\hat{k}_{\bar{o}}\cdots\\&+(g)\hat{k}_{\bar{o}}\hat{\imath}_{\bar{o}}+(h)\hat{k}_{\bar{o}}\hat{\jmath}_{\bar{o}}+(i)\hat{k}_{\bar{o}}\hat{k}_{\bar{o}}\end{aligned}$$

2.10 \frSub

`\frSub{⟨frame⟩}{⟨value⟩}{⟨subsc⟩}`

Subscript and frame. This command is used to add a pre-superscript frame ⟨*frame*⟩ and specified subscript ⟨*subsc*⟩ to a value ⟨*value*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*value*⟩ = Value to apply frame and subscript to
⟨*subsc*⟩ = Subscript value

Example

Say we want to define the velocity $\vec{v}$ of a satellite expressed in the $\bar{O}$ inertial reference frame.

This is accomplished with the LaTeX below:

```
\frSub{O}{\vec{v}}{satellite}
```

Display/Inline Mode Output

$${}^{\bar{O}}\vec{v}_{satellite}$$

2.11 \frx

`\frx{⟨frame⟩}{⟨value⟩}`

Frame x-component. This command defines the x-component of value ⟨*value*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*value*⟩ = The value that we want the x-component of

Example

Say we want to define the x-component of the vector $\vec{a}$ expressed in the $\bar{D}$ frame.

This is accomplished with the LaTeX below:

```
\frx{D}{\vec{a}}
```

Display/Inline Mode Output

$$\vec{a}_{x\bar{D}}$$

2.12 `\fry`

`\fry{⟨frame⟩}{⟨value⟩}`

Frame y-component. This command defines the y-component of value ⟨*value*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*value*⟩ = The value that we want the y-component of

Example

Say we want to define the y-component of the vector $\vec{a}$ expressed in the $\bar{D}$ frame.

This is accomplished with the LaTeX below:

```
\fry{D}{\vec{a}}
```

Display/Inline Mode Output

$$\vec{a}_{y\bar{D}}$$

2.13 `\frz`

`\frz{⟨frame⟩}{⟨value⟩}`

Frame z-component. This command defines the z-component of value ⟨*value*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*value*⟩ = The value that we want the z-component of

Example

Say we want to define the z-component of the vector $\vec{a}$ expressed in the $\bar{D}$ frame.

This is accomplished with the LaTeX below:

```
\frz{D}{\vec{a}}
```

Display/Inline Mode Output

$$\vec{a}_{z\bar{D}}$$

Numbered Normal Reference Frames

This type of frame is similar to a normal frame, except the unit vectors and point also have an associated number.

2.14 \frn

`\frn{⟨point⟩}{⟨num⟩}`

Numbered frame. This command is used to add a bar above a character and a numeric subscript ⟨*num*⟩ to allow it to be read as a frame attached to a specified point ⟨*point*⟩. Case-insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)
⟨*num*⟩ = Number of point

Example

Say we want to define an inertial reference frame about the point A_1.

This is accomplished with the LaTeX below:

```
\fr{A}{1}
```

Display/Inline Mode Output

$$\bar{A}_1$$

2.15 \frnsc

`\frnsc{⟨point⟩}{⟨num⟩}`

Small-caps numbered frame. This command is used to define a numbered frame in a subscript or superscript. Case-insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z) numNumber of point

Example

Say we want to define x-component of the vector $\vec{r}$ expressed in the $\bar{A}_1$ frame.

This is accomplished with the LaTeX below:

```
\r_{x\frnsc{A}{1}}
```

Display/Inline Mode Output

$$r_{x\bar{A}_1}$$

2.16 \ihatn

`\ihatn{⟨frame⟩}{⟨num⟩}`

I-hatn. This command is used to display the $\hat{\imath}$ unit vector for a specified frame ⟨*frame*⟩ with number ⟨*num*⟩. The bar is automatically added. Case-insensitive.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Number of point

Example

Say we want to express $\hat{\imath}$ for the $\bar{A}_1$ frame.

This is accomplished with the LaTeX below:

```
\ihatn{a}{1}
```

Display/Inline Mode Output

$$\hat{\imath}_{\bar{A}_1}$$

2.17 \jhatn

`\jhatn{⟨frame⟩}{⟨num⟩}`

J-hatn. This command is used to display the $\hat{\jmath}$ unit vector for a specified frame ⟨*frame*⟩ with number ⟨*num*⟩. The bar is automatically added. Case-insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)
⟨*num*⟩ = Number of point

Example

Say we want to express $\hat{\jmath}$ for the $\bar{B}_2$ frame.

This is accomplished with the LaTeX below:

```
\jhatn{b}{2}
```

Display/Inline Mode Output

$$\hat{\jmath}_{\bar{B}_2}$$

2.18 \khatn

`\khatn`{⟨*frame*⟩}{⟨*num*⟩}

K-hatn. This command is used to display the $\hat{k}$ unit vector for a specified frame ⟨*frame*⟩ with number ⟨*num*⟩. The bar is automatically added. Case-insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)
⟨*num*⟩ = Number of point

Example

Say we want to express $\hat{k}$ for the $\bar{C}_3$ frame.

This is accomplished with the LaTeX below:

```
\khatn{c}{3}
```

Display/Inline Mode Output

$$\hat{k}_{\bar{C}_3}$$

2.19 \frnDef

`\frnDef`{⟨*point*⟩}{⟨*num*⟩}

Define numbered frame. This command is used define a frame as a numbered point and three orthonormal unit vectors. Case insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)
⟨*num*⟩ = Number of point

Example

Say we want to define the frame about the point P_6.

This is accomplished with the LaTeX below:

```
\frnDef{P}{6}
```

Display/Inline Mode Output

$$\bar{P}_6 = \{P_6, \hat{\imath}_{\bar{P}_6}, \hat{\jmath}_{\bar{P}_6}, \hat{k}_{\bar{P}_6}\}$$

2.20 \frnExp

`\frnExp{⟨frame⟩}{⟨num⟩}{⟨value⟩}`

Expressed in numbered frame. This command is used to show that a matrix or vector quantity is expressed in a given numbered frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Number of point
⟨*value*⟩ = Vector or matrix quantity

Example

Say we want to show that $\vec{v}$ is expressed in the $\bar{B}_2$ frame.

This is accomplished with the LaTeX below:

```
\frnExp{B}{2}{\vec{v}}
```

Display/Inline Mode Output

$$[\vec{v}]_{\bar{B}_2}$$

2.21 \frnVec

`\frnVec{⟨frame⟩}{⟨num⟩}{⟨icomp⟩}{⟨jcomp⟩}{⟨kcomp⟩}`

Vector numbered frame components. This command is used to express a vector in terms of its components in each of the numbered frame's unit vectors.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Number of point
⟨*icomp*⟩ = i-hat-component expression
⟨*jcomp*⟩ = j-hat-component expression
⟨*kcomp*⟩ = k-hat-component expression

Example

Say we want to express $[\vec{r}]_{\bar{A}_1} = \langle x, y, z\rangle$ in its $\bar{A}1$ frame components.

This is accomplished with the LaTeX below:

```
\frnVec{A}{1}{x}{y}{z}
```

Display/Inline Mode Output

$$(x)\hat{\imath}_{\bar{A}_1} + (y)\hat{\jmath}_{\bar{A}_1} + (z)\hat{k}_{\bar{A}_1}$$

2.22 \frnTen

`\frnTen`{⟨*frame*⟩}{⟨*num*⟩}{⟨*ii*⟩}{⟨*ij*⟩}{⟨*ik*⟩}{⟨*ji*⟩}{⟨*jj*⟩}{⟨*jk*⟩}{⟨*ki*⟩}{⟨*kj*⟩}{⟨*kk*⟩}

Tensor numbered frame components. This command is used to express a tensor in terms of its components in each of the numbered frame's unit vector combinations. Must be inside a `align` or `align*` environment.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Number of point
⟨*ii*⟩ = i-hat-i-hat-component expression
⟨*ij*⟩ = i-hat-j-hat-component expression
⟨*ik*⟩ = i-hat-k-hat-component expression
⟨*ji*⟩ = j-hat-i-hat-component expression
⟨*jj*⟩ = j-hat-j-hat-component expression
⟨*jk*⟩ = j-hat-k-hat-component expression
⟨*ki*⟩ = k-hat-i-hat-component expression
⟨*kj*⟩ = k-hat-j-hat-component expression
⟨*kk*⟩ = k-hat-k-hat-component expression

Example

Say we want to express $[\tilde{I}]_{\bar{A}_1}$ in its $\bar{A}_1$ frame components (say a-i).

This is accomplished with the LaTeX below:

```
\frnTen{A}{1}{a}{b}{c}{d}{e}{f}{g}{h}{i}
```

Display Mode Output

$$\begin{aligned} &(a)\hat{\imath}_{\bar{A}_1}\hat{\imath}_{\bar{A}_1} + (b)\hat{\imath}_{\bar{A}_1}\hat{\jmath}_{\bar{A}_1} + (c)\hat{\imath}_{\bar{A}_1}\hat{k}_{\bar{A}_1}\cdots \\ &+ (d)\hat{\jmath}_{\bar{A}_1}\hat{\imath}_{\bar{A}_1} + (e)\hat{\jmath}_{\bar{A}_1}\hat{\jmath}_{\bar{A}_1} + (f)\hat{\jmath}_{\bar{A}_1}\hat{k}_{\bar{A}_1}\cdots \\ &+ (g)\hat{k}_{\bar{A}_1}\hat{\imath}_{\bar{A}_1} + (h)\hat{k}_{\bar{A}_1}\hat{\jmath}_{\bar{A}_1} + (i)\hat{k}_{\bar{A}_1}\hat{k}_{\bar{A}_1} \end{aligned}$$

2.23 \frnSub

`\frnSub{⟨frame⟩}{⟨num⟩}{⟨value⟩}{⟨subsc⟩}`

Subscript and numbered frame. This command is used to add a pre-superscript frame and specified subscript to a value.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Number of point
⟨*value*⟩ = Value to apply frame and subscript to
⟨*subsc*⟩ = Subscript value

Example

Say we want to define the velocity of a satellite expressed in the $\bar{A}_1$ inertial reference frame.

This is accomplished with the LaTeX below:

```
\frnSub{A}{1}{\vec{v}}{satellite}
```

Display/Inline Mode Output

$${}^{\bar{A}_1}\vec{v}_{satellite}$$

2.24 \frnx

`\frnx{⟨frame⟩}{⟨num⟩}{⟨value⟩}`

Numbered frame x-component. This command defines the x-component of value ⟨*value*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Number of point
⟨*value*⟩ = The value that we want the x-component of

Example

Say we want to define the x-component of the vector $\vec{a}$ expressed in the $\bar{D}_4$ frame.

This is accomplished with the LaTeX below:

```
\frnx{D}{4}{\vec{a}}
```

Display/Inline Mode Output

$$\vec{a}_{x\bar{D}_4}$$

2.25 \frny

\frny{⟨*frame*⟩}{⟨*num*⟩}{⟨*value*⟩}

Numbered frame y-component. This command defines the y-component of value ⟨*value*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Number of point
⟨*value*⟩ = The value that we want the y-component of

Example

Say we want to define the y-component of the vector $\vec{a}$ expressed in the $\bar{D}_4$ frame.

This is accomplished with the LaTeX below:

```
\frny{D}{4}{\vec{a}}
```

Display/Inline Mode Output

$$\vec{a}_{y_{\bar{D}_4}}$$

2.26 \frnz

\frnz{⟨*frame*⟩}{⟨*num*⟩}{⟨*value*⟩}

Numbered frame z-component. This command defines the z-component of value ⟨*value*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Number of point
⟨*value*⟩ = The value that we want the z-component of

Example

Say we want to define the z-component of the vector $\vec{a}$ expressed in the $\bar{D}_4$ frame.

This is accomplished with the LaTeX below:

```
\frnz{D}{4}{\vec{a}}
```

Display/Inline Mode Output

$$\vec{a}_{z_{\bar{D}_4}}$$

Special Reference Frames

This type of frame is similar to a normal frame, except the unit vectors are numbered lowercase versions of the specified point.

2.27 \uveca

`\uveca{⟨frame⟩}`

Unit vector 1. This command is used to display the first unit vector for a specified frame ⟨*frame*⟩. The bar is automatically added. Case-insensitive.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)

Example

Say we want to express the first unit vector for the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\uveca{a}
```

Display/Inline Mode Output

$$\hat{a}_1$$

2.28 \uvecb

`\uvecb{⟨frame⟩}`

Unit vector 2. This command is used to display the second unit vector for a specified frame ⟨*frame*⟩. The bar is automatically added. Case-insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)

Example

Say we want to express the second unit vector for the $\bar{B}$ frame.

This is accomplished with the LaTeX below:

```
\uvecb{b}
```

Display/Inline Mode Output

$$\hat{b}_2$$

2.29 \uvecc

`\uvecc{⟨frame⟩}`

Unit vector 3. This command is used to display the third unit vector for a specified frame ⟨*frame*⟩. The bar is automatically added. Case-insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)

Example

Say we want to express the third unit vector for the $\bar{C}$ frame.

This is accomplished with the LaTeX below:

```
\uvecc{c}
```

Display/Inline Mode Output

$$\hat{c}_3$$

2.30 \fruDef

`\fruDef{⟨point⟩}`

Define special frame. This command is used define a special frame as a point and three orthonormal unit vectors. Case insensitive.

⟨*point*⟩ = Point; letter (a-z, A-Z)

Example

Say we want to define the special frame about the point P.

This is accomplished with the LaTeX below:

```
\fruDef{P}
```

Display/Inline Mode Output

$$\bar{P} = \{P, \hat{p}_1, \hat{p}_2, \hat{p}_3\}$$

2.31 \fruVec

`\fruVec{⟨frame⟩}{⟨comp1⟩}{⟨comp2⟩}{⟨comp3⟩}`

Vector special frame components. This command is used to express a vector in terms of its components in each of the special frame's unit vectors.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*comp1*⟩ = 1-component expression
⟨*comp2*⟩ = 2-component expression
⟨*comp3*⟩ = 3-component expression

Example

Say we want to express $[\vec{r}]_{\bar{F}} = \langle x, y, z\rangle$ in its $\bar{F}$ frame components.

This is accomplished with the LaTeX below:

```
\fruVec{F}{x}{y}{z}
```

Display/Inline Mode Output

$$(x)\hat{f}_1 + (y)\hat{f}_2 + (z)\hat{f}_3$$

2.32 \fruTen

`\fruTen{⟨frame⟩}{⟨c11⟩}{⟨c12⟩}{⟨c13⟩}{⟨c21⟩}{⟨c22⟩}{⟨c23⟩}{⟨c31⟩}{⟨c32⟩}{⟨c33⟩}`

Tensor special frame components. This command is used to express a tensor in terms of its components in each of the special frame's unit vector combinations. Must be inside a `align` or `align*` environment.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*c11*⟩ = 1-1-component expression
⟨*c12*⟩ = 1-2-component expression
⟨*c13*⟩ = 1-3-component expression
⟨*c21*⟩ = 2-1-component expression
⟨*c22*⟩ = 2-2-component expression
⟨*c23*⟩ = 2-3-component expression
⟨*c31*⟩ = 3-1-component expression
⟨*c32*⟩ = 3-2-component expression
⟨*c33*⟩ = 3-3-component expression

Example

Say we want to express $[\tilde{I}]_{\bar{F}}$ in its $\bar{F}$ frame components (say a-i).

This is accomplished with the LaTeX below:

```
\fruTen{F}{a}{b}{c}{d}{e}{f}{g}{h}{i}
```

Display Mode Output

$$\begin{aligned}&(a)\hat{f}_1\hat{f}_1+(b)\hat{f}_1\hat{f}_2+(c)\hat{f}_1\hat{f}_3\cdots\\+&(d)\hat{f}_2\hat{f}_1+(e)\hat{f}_2\hat{f}_2+(f)\hat{f}_2\hat{f}_3\cdots\\+&(g)\hat{f}_3\hat{f}_1+(h)\hat{f}_3\hat{f}_2+(i)\hat{f}_3\hat{f}_3\end{aligned}$$

3 General Terms

This section includes the commands needed to typeset most of the terms from *MAE 511*. Note that all commands in this section should be used inside of a math environment. Note that when inputting strings, you will have to enclose in `\mathit` if longer than one character and in `\smca` when dealing with capital letters.

Translational Terms

3.1 \traV

`\traV{⟨frame⟩}{⟨point⟩}`

Translational velocity. This command is used to express the translational velocity of a point ⟨*point*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Letter (a-z, A-Z)
⟨*point*⟩ = Name of point; expression

Example

Say we want to define the velocity of particle B in its body frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\traV{b}{\smca{b}}
```

Display/Inline Mode Output

$${}^{\bar{B}}\vec{v}_{B}$$

3.2 \traA

`\traA{⟨frame⟩}{⟨point⟩}`

Translational acceleration. This command is used to express the translational acceleration of a point ⟨*point*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Letter (a-z, A-Z)
⟨*point*⟩ = Name of point; expression

Example

Say we want to define the acceleration of particle B in an inertial reference frame $\bar{O}$.

This is accomplished with the LaTeX below:

```
\traA{o}{\smca{b}}
```

Display/Inline Mode Output

$${}^{\bar{O}}\vec{a}_{B}$$

3.3 \relR

`\relR{⟨point⟩}{⟨refpt⟩}`

Relative displacement. This command is used to express the position of ⟨*point*⟩ relative to ⟨*refpt*⟩.

⟨*point*⟩ = Name of point; expression
⟨*refpt*⟩ = Name of reference point; expression

Example

Say we want to define the displacement of a particle A relative to the point O.

This is accomplished with the LaTeX below:

```
\relR{\smca{A}}{\smca{O}}
```

Display/Inline Mode Output

$$\vec{r}_{A/O}$$

3.4 \relV

\relV{⟨*frame*⟩}{⟨*point*⟩}{⟨*refpt*⟩}

Relative velocity. This command is used to express the velocity of ⟨*point*⟩ relative to ⟨*refpt*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame that velocity is expressed in
⟨*point*⟩ = Name of point; expression
⟨*refpt*⟩ = Name of reference point; expression

Example

Say we want to define the velocity of a particle B relative to the particle A in the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\relV{o}{\smca{B}}{\smca{A}}
```

Display/Inline Mode Output

$${}^{\bar{O}}\vec{v}_{B/A}$$

3.5 \relA

\relA{⟨*frame*⟩}{⟨*point*⟩}{⟨*refpt*⟩}

Relative acceleration. This command is used to express the acceleration of ⟨*point*⟩ relative to ⟨*refpt*⟩ in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame that velocity is expressed in
⟨*point*⟩ = Name of point; expression
⟨*refpt*⟩ = Name of reference point; expression

Example

Say we want to define the acceleration of a particle B relative to the particle A in the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\relA{o}{\smca{B}}{\smca{A}}
```

Display/Inline Mode Output

$${}^{\bar{O}}\vec{a}_{B/A}$$

3.6 \Forc

`\Forc{`$\langle sub \rangle$`}`

Force. This command is used to express a force with a specified subscript $\langle sub \rangle$.

$\langle sub \rangle$ = Subscript; expression

Example

Say we want to define a gravitational force with g-shorthand and a frictional force with friction written out.

This is accomplished with the LaTeX below:

```
\Forc{g} \text{ and } \Forc{\mathit{friction}}
```

Display/Inline Mode Output

$$\vec{F}_g \text{ and } \vec{F}_{\mathit{friction}}$$

Rotational Terms

3.7 \angV

`\angV{`$\langle frame1 \rangle$`}{`$\langle frame2 \rangle$`}`

Angular velocity. This command is used to express the angular velocity of $\langle frame2 \rangle$ relative to $\langle frame1 \rangle$.

$\langle frame1 \rangle$ = First frame; letter (a-z, A-Z)
$\langle frame2 \rangle$ = Second frame; letter (a-z, A-Z)

Example

Say we want to define the angular velocity of the $\bar{A}$ frame relative to the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\angV{O}{A}
```

Display/Inline Mode Output

$${}^{\bar{O}}\vec{\omega}^{\bar{A}}$$

3.8 \angA

`\angA{⟨frame1⟩}{⟨frame2⟩}`

Angular acceleration. This command is used to express the angular acceleration of ⟨*frame2*⟩ relative to ⟨*frame1*⟩.

⟨*frame1*⟩ = First frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Second frame; letter (a-z, A-Z)

Example

Say we want to define the angular acceleration of the $\bar{A}$ frame relative to the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\angA{O}{A}
```

Display/Inline Mode Output

$$ {}^{\bar{O}}\vec{\alpha}^{\bar{A}} $$

3.9 \angMp

`\angMp{⟨frame⟩}{⟨point1⟩}{⟨point2⟩}{⟨mass⟩}`

Particle angular momentum. This command is used to express the angular momentum of a particle with mass ⟨*mass*⟩ with respect to ⟨*point2*⟩ with respect to ⟨*point1*⟩, relative to the frame ⟨*frame*⟩.

⟨*frame*⟩ = Letter (a-z, A-Z)
⟨*point1*⟩ = Name of point1; expression
⟨*point2*⟩ = Name of point2; expression
⟨*mass*⟩ = Name of mass; expression

Example

Say we want to define the angular momentum of a particle of mass m with respect to B with respect to A expressed in the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\angMp{o}{\smca{A}}{\smca{B}}{m}
```

Display/Inline Mode Output

$$ {}^{\bar{o}}_{\scriptscriptstyle A}\vec{h}_{m/\scriptscriptstyle B} $$

3.10 \angMs

`\angMs{⟨frame⟩}{⟨point1⟩}{⟨point2⟩}`

System angular momentum. This command is used to express the angular momentum of a system with respect to ⟨*point2*⟩ with respect to ⟨*point1*⟩, relative to the frame ⟨*frame*⟩.

⟨*frame*⟩ = Letter (a-z, A-Z)
⟨*point1*⟩ = Name of point1; expression
⟨*point2*⟩ = Name of point2; expression

Example

Say we want to define the angular momentum of a system with respect to P with respect to Q expressed in the $\bar{F}$ frame.

This is accomplished with the LaTeX below:

```
\angMs{f}{\smca{Q}}{\smca{P}}
```

Display/Inline Mode Output

$${}^{\bar{F}}_{Q}\vec{h}_{P,\mathrm{sys}}$$

3.11 \angM

`\angM{⟨frame⟩}{⟨point1⟩}{⟨spec⟩}`

General angular momentum. This command is used to express the angular momentum of a specified particle, body, or system with respect to a specified point with respect to ⟨*point1*⟩, relative to the frame ⟨*frame*⟩.

⟨*frame*⟩ = Letter (a-z, A-Z)
⟨*point1*⟩ = Name of point1; expression
⟨*spec*⟩ = Specified particle, body, or system and specified point; expression

Example

Say we want to define the angular momentum of a rigid body with respect to its center of mass with respect to Q expressed in the $\bar{F}$ frame.

This is accomplished with the LaTeX below:

```
\angM{f}{\smca{Q}}{\CM}
```

Display/Inline Mode Output

$${}^{\bar{F}}_{Q}\vec{h}_{\mathrm{CM}}$$

3.12 \torq

`\torq{⟨sub⟩}`

Torque. This command is used to express a torque with a specified subscript ⟨*sub*⟩. Note that `\mathit` may be needed if the subscript is a word.

⟨*sub*⟩ = Subscript; expression

Example

Say we want to define a torque due to gravity with the g-shorthand and a torque due to a *motor*.

This is accomplished with the LaTeX below:

```
\torq{g} \text{ and } \torq{\mathit{motor}}
```

Display/Inline Mode Output

$$\vec{\tau}_g \text{ and } \vec{\tau}_{motor}$$

Matrix Terms

3.13 \rotM

`\rotM{⟨frame1⟩}{⟨frame2⟩}`

Rotation matrix. This command is used to express the rotation matrix to convert from ⟨*frame2*⟩ to ⟨*frame1*⟩.

⟨*frame1*⟩ = First frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Second frame; letter (a-z, A-Z)

Example

Say we want to define the rotation matrix to convert from the $\bar{O}$ frame to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\rotM{A}{O}
```

Display/Inline Mode Output

$${}^{\bar{A}}[C]^{\bar{O}}$$

3.14 \rotMd

`\rotMd{⟨frame1⟩}{⟨frame2⟩}`

Rotation matrix derivative. This command is used to express the derivative of the rotation matrix that converts from ⟨*frame2*⟩ to ⟨*frame1*⟩.

⟨*frame1*⟩ = First frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Second frame; letter (a-z, A-Z)

Example

Say we want to define the derivative of the rotation matrix that converts from the $\bar{O}$ frame to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\rotMd{A}{O}
```

Display/Inline Mode Output

$${}^{\bar{A}}[\dot{C}]^{\bar{O}}$$

3.15 \Rx

`\Rx{⟨angle⟩}`

X rotation matrix. This command is used to express the rotation matrix about the x-axis (positive CCW).

⟨*angle*⟩ = Angle name; expression

Example

Say we want to define the x rotation matrix using the angle ϕ.

This is accomplished with the LaTeX below:

```
\Rx{\phi}
```

Display/Inline Mode Output

$$[\mathrm{R}_x(\phi)]$$

3.16 \Ry

`\Ry{⟨angle⟩}`

Y rotation matrix. This command is used to express the rotation matrix about the y-axis (positive CCW).

⟨*angle*⟩ = Angle name; expression

Example

Say we want to define the y rotation matrix using the angle θ.

This is accomplished with the LaTeX below:

```
\Ry{\theta}
```

Display/Inline Mode Output

$$[\mathrm{R}_y(\theta)]$$

3.17 \Rz

`\Rz{⟨angle⟩}`

Z rotation matrix. This command is used to express the rotation matrix about the z-axis (positive CCW).

⟨*angle*⟩ = Angle name; expression

Example

Say we want to define the z rotation matrix using the angle ψ.

This is accomplished with the LaTeX below:

```
\Rz{\psi}
```

Display/Inline Mode Output

$$[\mathrm{R}_z(\psi)]$$

3.18 \omcrMat

`\omcrMat{⟨frame1⟩}{⟨frame2⟩}`

Omega cross matrix. This command is used to express the omega cross matrix, a matrix which when multiplied by a column vector is equivalent to taking the cross product of the angular velocity of ⟨*frame2*⟩ with respect to ⟨*frame1*⟩ and that vector.

⟨*frame1*⟩ = First frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Second frame; letter (a-z, A-Z)

Example

Say we want to define the omega cross matrix based on the relative angular velocity of the $\bar{B}$ frame with respect to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\omcrMat{A}{B}
```

Display/Inline Mode Output

$$\left[{}^{\bar{A}}\vec{\omega}^{\bar{B}}\times\right]_{\bar{B}}$$

3.19 \omcrx

`\omcrx{⟨frame1⟩}{⟨frame2⟩}`

Omega cross x-term. This command is the x-term of the omega cross matrix, a matrix which when multiplied by a column vector is equivalent to taking the cross product of the angular velocity of ⟨*frame2*⟩ with respect to ⟨*frame1*⟩ and that vector.

⟨*frame1*⟩ = First frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Second frame; letter (a-z, A-Z)

Example

Say we want to define the x-term of the omega cross matrix based on the relative angular velocity of the $\bar{B}$ frame with respect to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\omcrx{A}{B}
```

Display/Inline Mode Output

$${}^{\bar{A}}\omega^{\bar{B}}_{x\bar{B}}$$

3.20 \omcry

`\omcry{⟨frame1⟩}{⟨frame2⟩}`

Omega cross y-term. This command is the y-term of the omega cross matrix, a matrix which when multiplied by a column vector is equivalent to taking the cross product of the angular velocity of ⟨*frame2*⟩ with respect to ⟨*frame1*⟩ and that vector.

⟨*frame1*⟩ = First frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Second frame; letter (a-z, A-Z)

Example

Say we want to define the y-term of the omega cross matrix based on the relative angular velocity of the $\bar{B}$ frame with respect to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\omcry{A}{B}
```

Display/Inline Mode Output

$${}^{\bar{A}}\omega^{\bar{B}}_{y\bar{B}}$$

3.21 \omcrz

`\omcrz{⟨frame1⟩}{⟨frame2⟩}`

Omega cross z-term. This command is the z-term of the omega cross matrix, a matrix which when multiplied by a column vector is equivalent to taking the cross product of the angular velocity of ⟨*frame2*⟩ with respect to ⟨*frame1*⟩ and that vector.

⟨*frame1*⟩ = First frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Second frame; letter (a-z, A-Z)

Example

Say we want to define the z-term of the omega cross matrix based on the relative angular velocity of the $\bar{B}$ frame with respect to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\omcrz{A}{B}
```

Display/Inline Mode Output

$${}^{\bar{A}}\omega^{\bar{B}}_{z\bar{B}}$$

Inertia Terms

3.22 \inerTen

`\inerTen{⟨sub⟩}`

Inertia tensor. This command is used to express a generic inertia tensor with a specified subscript ⟨*sub*⟩.

⟨*sub*⟩ = Subscript; expression

Example

Say we want to define the inertia tensor about the center of mass.

This is accomplished with the LaTeX below:

```
\inerTen{\CM}
```

Display/Inline Mode Output

$$\tilde{I}_{\text{CM}}$$

3.23 \inerMat

`\inerMat{⟨frame⟩}{⟨sub⟩}`

Inertia tensor expressed as a matrix. This command is used to express a generic inertia tensor with a specified subscript ⟨*sub*⟩ as a matrix in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor about the center of mass and express it as a matrix in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\inerMat{a}{\CM}
```

Display/Inline Mode Output

$$[\tilde{I}_{\text{CM}}]_{\bar{A}}$$

3.24 \Ixx

`\Ixx{⟨frame⟩}{⟨sub⟩}`

Inertia tensor xx-component. This command is used to express the xx-component of the inertia tensor about a specified point in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor's xx-component about the center of mass in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\Ixx{a}{\CM}
```

Display/Inline Mode Output

$${}^{\bar{A}}I_{xx/\mathrm{CM}}$$

3.25 \Ixy

`\Ixy{⟨frame⟩}{⟨sub⟩}`

Inertia tensor xy-component. This command is used to express the xy-component of the inertia tensor about a specified point in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor's xy-component about the center of mass in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\Ixy{a}{\CM}
```

Display/Inline Mode Output

$${}^{\bar{A}}I_{xy/\mathrm{CM}}$$

3.26 \Ixz

`\Ixz{⟨frame⟩}{⟨sub⟩}`

Inertia tensor xz-component. This command is used to express the xz-component of the inertia tensor about a specified point in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor's xz-component about the center of mass in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\Ixz{a}{\CM}
```

Display/Inline Mode Output

$$^{\bar{A}}I_{xz/\mathrm{CM}}$$

3.27 \Iyx

`\Iyx{⟨frame⟩}{⟨sub⟩}`

Inertia tensor yx-component. This command is used to express the yx-component of the inertia tensor about a specified point in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor's yx-component about the center of mass in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\Iyx{a}{\CM}
```

Display/Inline Mode Output

$$^{\bar{A}}I_{yx/\mathrm{CM}}$$

3.28 \Iyy

`\Iyy{⟨frame⟩}{⟨sub⟩}`

Inertia tensor yy-component. This command is used to express the yy-component of the inertia tensor about a specified point in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor's yy-component about the center of mass in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\Iyy{a}{\CM}
```

Display/Inline Mode Output

$$^{\bar{A}}I_{yy/\mathrm{CM}}$$

3.29 \Iyz

`\Iyz{⟨frame⟩}{⟨sub⟩}`

Inertia tensor yz-component. This command is used to express the yz-component of the inertia tensor about a specified point in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor's yz-component about the center of mass in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\Iyz{a}{\CM}
```

Display/Inline Mode Output

$$^{\bar{A}}I_{yz/\mathrm{CM}}$$

3.30 \Izx

`\Izx{⟨frame⟩}{⟨sub⟩}`

Inertia tensor zx-component. This command is used to express the zx-component of the inertia tensor about a specified point in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor's zx-component about the center of mass in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\Izx{a}{\CM}
```

Display/Inline Mode Output

$${}^{\bar{A}}I_{zx/\mathrm{CM}}$$

3.31 \Izy

`\Izy{⟨frame⟩}{⟨sub⟩}`

Inertia tensor zy-component. This command is used to express the zy-component of the inertia tensor about a specified point in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor's zy-component about the center of mass in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\Izy{a}{\CM}
```

Display/Inline Mode Output

$${}^{\bar{A}}I_{zy/\mathrm{CM}}$$

3.32 \Izz

`\Izz{⟨frame⟩}{⟨sub⟩}`

Inertia tensor zz-component. This command is used to express the zz-component of the inertia tensor about a specified point in a specified frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) subSubscript; expression

Example

Say we want to define the inertia tensor's zz-component about the center of mass in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\Izz{a}{\CM}
```

Display/Inline Mode Output

$$^{\bar{A}}I_{zz/\mathrm{CM}}$$

3.33 \xrel

`\xrel{⟨frame⟩}{⟨point⟩}{⟨refpt⟩}`

Relative x-displacement. This command is used to express the displacement in x from ⟨*point*⟩ to ⟨*refpt*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) pointPoint; expressionrefptReference point; expression

Example

Say we want to define the displacement in x of a particle m_i relative to the center of mass in the $\bar{A}$ body frame.

This is accomplished with the LaTeX below:

```
\xrel{a}{m_{i}}{\CM}
```

Display/Inline Mode Output

$$^{\bar{A}}x_{m_i/\mathrm{CM}}$$

3.34 \yrel

`\yrel{⟨frame⟩}{⟨point⟩}{⟨refpt⟩}`

Relative y-displacement. This command is used to express the displacement in y from ⟨*point*⟩ to ⟨*refpt*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) pointPoint; expressionrefptReference point; expression

Example

Say we want to define the displacement in y of a particle m_i relative to the center of mass in the $\bar{A}$ body frame.

This is accomplished with the LaTeX below:

```
\yrel{a}{m_{i}}{\CM}
```

Display/Inline Mode Output

$${}^{\bar{A}}y_{m_i/\mathrm{CM}}$$

3.35 \zrel

`\zrel{⟨frame⟩}{⟨point⟩}{⟨refpt⟩}`

Relative z-displacement. This command is used to express the displacement in z from ⟨*point*⟩ to ⟨*refpt*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) pointPoint; expressionrefptReference point; expression

Example

Say we want to define the displacement in z of a particle m_i relative to the center of mass in the $\bar{A}$ body frame.

This is accomplished with the LaTeX below:

```
\zrel{a}{m_{i}}{\CM}
```

Display/Inline Mode Output

$${}^{\bar{A}}z_{m_i/\mathrm{CM}}$$

Other Terms

3.36 \vecF

`\vecF{⟨frame⟩}{⟨vector⟩}{⟨sub⟩}`

Vector in frame with subscript. This command is used to express a specified vector ⟨*vector*⟩ in a frame ⟨*frame*⟩ with a chosen subscript ⟨*sub*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z) vectorVector; expressionsubSubscript; expression

Example

Say we want to define a vector $\vec{s}$, which describes the position of a *bus* in the $\bar{E}$ frame.

This is accomplished with the LaTeX below:

```
\vecF{e}{s}{\mathit{bus}}
```

Display/Inline Mode Output

$$^{\bar{E}}\vec{s}_{bus}$$

3.37 \potEn

`\potEn`

Potential energy. This command is used to express the potential energy.

No input arguments.

Example

Define the potential energy of a particle of mass m due to gravity near the Earth's surface while treating $\bar{O}$ as an inertial reference frame attached to the Earth's surface.

This is accomplished with the LaTeX below:

```
\potEn \approx mgh
```

Display/Inline Mode Output

$$^{\bar{O}}V \approx mgh$$

3.38 \kinEn

`\kinEn`

Kinetic energy. This command is used to express the kinetic energy.

No input arguments.

Example

Define the kinetic energy of a particle of mass m translating at speed v while treating $\bar{O}$ as an inertial reference frame attached to the Earth's surface.

This is accomplished with the LaTeX below:

```
\kinEn = \frac{1}{2}mv^2
```

Display Mode Output

$${}^{\bar{O}}T_{o} = \frac{1}{2}mv^2$$

Inline Mode Output

${}^{\bar{O}}T_{o} = \frac{1}{2}mv^2$

4 Advanced Terms

This section includes the commands needed to typeset most of the terms from *MAE 789*. Note that all commands in this section should be used inside of a math environment.

Partial Terms

4.1 `\Pvec`

`\Pvec{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

P-vector. This command is used to express the P-vector of ⟨*frame2*⟩ relative to ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the P-vector of the $\bar{B}$ frame relative to the $\bar{A}$ with respect to θ.

This is accomplished with the LaTeX below:

```
\Pvec{a}{b}{\theta}
```

Display/Inline Mode Output

$$^{\bar{A}}\vec{P}_{\theta}^{\bar{B}}$$

4.2 \Pvecx

`\Pvecx`{⟨*frame1*⟩}{⟨*frame2*⟩}{⟨*var*⟩}

P-vector x-component. This command is used to express the x-component of the P-vector of ⟨*frame2*⟩ relative to ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the x-component of the P-vector of the $\bar{B}$ frame relative to the $\bar{A}$ with respect to θ.

This is accomplished with the LaTeX below:

```
\Pvecx{a}{b}{\theta}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{P}^{\bar{B}}_{\theta,x}$$

4.3 \Pvecy

`\Pvecy`{⟨*frame1*⟩}{⟨*frame2*⟩}{⟨*var*⟩}

P-vector y-component. This command is used to express the y-component of the P-vector of ⟨*frame2*⟩ relative to ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the y-component of the P-vector of the $\bar{B}$ frame relative to the $\bar{A}$ with respect to θ.

This is accomplished with the LaTeX below:

```
\Pvecy{a}{b}{\theta}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{P}^{\bar{B}}_{\theta,y}$$

4.4 \Pvecz

`\Pvecz{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

P-vector z-component. This command is used to express the z-component of the P-vector of ⟨*frame2*⟩ relative to ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the z-component of the P-vector of the $\bar{B}$ frame relative to the $\bar{A}$ with respect to θ.

This is accomplished with the LaTeX below:

```
\Pvecz{a}{b}{\theta}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{P}^{\bar{B}}_{\theta,z}$$

Total Terms

4.5 \Tvec

`\Tvec{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

T-vector. This command is used to express the T-vector of ⟨*frame2*⟩ relative to ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the T-vector of the $\bar{B}$ frame relative to the $\bar{A}$ with respect to θ.

This is accomplished with the LaTeX below:

```
\Tvec{a}{b}{\theta}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{T}^{\bar{B}}_{\theta}$$

4.6 \Tvecx

`\Tvecx{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

T-vector x-component. This command is used to express the x-component of the T-vector of ⟨*frame2*⟩ relative to ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the x-component of the T-vector of the $\bar{B}$ frame relative to the $\bar{A}$ with respect to θ.

This is accomplished with the LaTeX below:

```
\Tvecx{a}{b}{\theta}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{T}^{\bar{B}}_{\theta,x}$$

4.7 \Tvecy

`\Tvecy{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

T-vector y-component. This command is used to express the y-component of the T-vector of ⟨*frame2*⟩ relative to ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the y-component of the T-vector of the $\bar{B}$ frame relative to the $\bar{A}$ with respect to θ.

This is accomplished with the LaTeX below:

```
\Tvecy{a}{b}{\theta}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{T}^{\bar{B}}_{\theta,y}$$

4.8 \Tvecz

\Tvecz{⟨*frame1*⟩}{⟨*frame2*⟩}{⟨*var*⟩}

T-vector z-component. This command is used to express the z-component of the T-vector of ⟨*frame2*⟩ relative to ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the z-component of the T-vector of the $\bar{B}$ frame relative to the $\bar{A}$ with respect to θ.

This is accomplished with the LaTeX below:

```
\Tvecz{a}{b}{\theta}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{T}^{\bar{B}}_{\theta,z}$$

Equations of Motion Terms

The terms in this section are used most commonly when deriving equations of motion of systems using more advanced methods such as Lagrange's equations and Kane's equations.

4.9 \angVk

\angVk{⟨*frame1*⟩}{⟨*frame2*⟩}{⟨*k*⟩}

Angular velocity k. This command is used to express the angular velocity of ⟨*frame2*⟩-⟨*k*⟩ relative to ⟨*frame1*⟩.

⟨*frame1*⟩ = First frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Second frame; letter (a-z, A-Z)
⟨*k*⟩ = Number; positive integer

Example

Say we want to define the angular velocity of the $\bar{A}_5$ frame relative to the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\angVk{O}{A}{5}
```

Display/Inline Mode Output

$${}^{\bar{O}}\vec{\omega}^{\bar{A}_5}$$

4.10 \angAk

`\angAk{⟨frame1⟩}{⟨frame2⟩}{⟨k⟩}`

Angular acceleration k. This command is used to express the angular acceleration of ⟨*frame2*⟩-⟨*k*⟩ relative to ⟨*frame1*⟩.

⟨*frame1*⟩ = First frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Second frame; letter (a-z, A-Z)
⟨*k*⟩ = Number; positive integer

Example

Say we want to define the angular velocity of the $\bar{B}_6$ frame relative to the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\angAk{o}{b}{6}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{\alpha}^{\bar{B}_6}$$

4.11 \forc

`\forc{⟨sub⟩}`

Lowercase force. This command is used to express the forces (usually internal).

⟨*sub*⟩ = Subscript; expression

Example

Say we want to define the force acting on the ith body.

This is accomplished with the LaTeX below:

```
\forc{i}
```

Display/Inline Mode Output

$$\vec{f}_i$$

4.12 \ptraVr

\ptraVr{⟨*frame*⟩}{⟨*point*⟩}{⟨*r*⟩}

r-th partial velocity. This command is used to express rth partial velocity of ⟨*point*⟩ in ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression
⟨*r*⟩ = Number; positive integer

Example

Say we want to define the 4th partial velocity of m_i in $\bar{O}$.

This is accomplished with the LaTeX below:

```
\ptraVr{o}{m_i}{4}
```

Display/Inline Mode Output

$${}^{\bar{A}}_{O}\vec{v}_{m_i,4}$$

4.13 \ptraVt

\ptraVt{⟨*frame*⟩}{⟨*point*⟩}

time partial velocity. This command is used to express the time partial velocity of ⟨*point*⟩ in ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the time partial velocity of m_i in $\bar{O}$.

This is accomplished with the LaTeX below:

```
\ptraVt{o}{m_i}
```

Display/Inline Mode Output

$${}^{\bar{A}}_{O}\vec{v}_{m_i,t}$$

4.14 \pangVr

`\pangVr{⟨frame1⟩}{⟨frame2⟩}{⟨r⟩}`

r-th partial angular velocity. This command is used to express rth partial angular velocity of ⟨*frame2*⟩ in ⟨*frame1*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*r*⟩ = Number; positive integer

Example

Say we want to define the 4th partial angular velocity of $\bar{B}$ in $\bar{A}$.

This is accomplished with the LaTeX below:

```
\pangVr{a}{b}{4}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{\omega}^{\bar{B}}_{4}$$

4.15 \pangVrk

`\pangVrk{⟨frame1⟩}{⟨frame2⟩}{⟨k⟩}{⟨r⟩}`

r-th partial angular velocity k. This command is used to express rth partial angular velocity of ⟨*frame2*⟩-⟨*k*⟩ in ⟨*frame1*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*k*⟩ = Number; positive integer
⟨*r*⟩ = Number; positive integer

Example

Say we want to define the 4th partial angular velocity of $\bar{B}_2$ in $\bar{A}$.

This is accomplished with the LaTeX below:

```
\pangVr{a}{b}{2}{4}
```

Display/Inline Mode Output

$${}^{\bar{A}}\vec{\omega}^{\bar{B}_2}_{4}$$

4.16 \pangVt

`\pangVt{⟨frame1⟩}{⟨frame2⟩}`

time partial angular velocity. This command is used to express the time partial angular velocity of ⟨*frame2*⟩ in ⟨*frame1*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)

Example

Say we want to define the time partial angular velocity of $\bar{B}$ in $\bar{A}$.

This is accomplished with the LaTeX below:

```
\pangVt{o}{b}
```

Display/Inline Mode Output

$$^{\bar{A}}\vec{\omega}_t^{\bar{B}}$$

4.17 \Lagr

`\Lagr`

Lagrangian. Show the symbol for the Lagrangian.

No input arguments.

Example

Show the symbol for the Lagrangian.

This is accomplished with the LaTeX below:

```
\Lagr
```

Display/Inline Mode Output

$$^{\bar{O}}\mathcal{L}_O$$

4.18 \KFr

\KFr{⟨r⟩}

F_r. This command is used to express F_r from Kane's equations of motion.

⟨r⟩ = Number; positive integer

Example

Say we want to define F_1.

This is accomplished with the LaTeX below:

```
\KFr{1}
```

Display/Inline Mode Output

$$F_1$$

4.19 \KFrs

\KFrs{⟨r⟩}

F_r^*. This command is used to express F_r^* from Kane's equations of motion.

⟨r⟩ = r; positive integer

Example

Say we want to define F_1^*.

This is accomplished with the LaTeX below:

```
\KFrs{1}
```

Display/Inline Mode Output

$$F_1^*$$

5 Differentiation

This section includes the commands needed to typeset most derivatives and their calculation. Note that all commands in this section should be used inside of a math environment.

Time Derivatives

5.1 \derI

`\derI{⟨frame⟩}{⟨expr⟩}`

1st time derivative. This command is used to take the first time derivative of ⟨*expr*⟩ in the ⟨*frame*⟩ frame.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*expr*⟩ = Expression; expression

Example

Say we want to define the first time derivative of position, $\vec{r}$, in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\derI{a}{\vec{r}\,}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{A}}\mathrm{d}}{\mathrm{d}t}\left(\vec{r}\,\right)$$

5.2 \derII

`\derII{⟨frame⟩}{⟨expr⟩}`

2nd time derivative. This command is used to take the second time derivative of ⟨*expr*⟩ in the ⟨*frame*⟩ frame.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*expr*⟩ = Expression; expression

Example

Say we want to define the second time derivative of position, $\vec{r}$, in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\derII{a}{\vec{r}\,}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{A}}\mathrm{d}^2}{\mathrm{d}t^2}\left(\vec{r}\,\right)$$

5.3 \derN

`\derN{⟨frame⟩}{⟨expr⟩}{⟨n⟩}`

nth time derivative. This command is used to take the nth time derivative of ⟨*expr*⟩ in the ⟨*frame*⟩ frame.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*expr*⟩ = Expression; expression
⟨*n*⟩ = Number, positive integer

Example

Say we want to define the 100th time derivative of position, $\vec{r}$, in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\derN{a}{\vec{r}\,}{100}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{A}}\mathrm{d}^{100}}{\mathrm{d}t^{100}}\left(\vec{r}\,\right)$$

5.4 \tranI

`\tranI{⟨dframe⟩}{⟨eframe⟩}{⟨expr⟩}`

First-order transport theorem. This command is used to show how to take the first ⟨*dframe*⟩-frame time derivative of ⟨*expr*⟩ which is expressed in the ⟨*eframe*⟩-frame.

⟨*dframe*⟩ = Derivative frame; letter (a-z, A-Z)
⟨*eframe*⟩ = Expressed frame; letter (a-z, A-Z)
⟨*expr*⟩ = Expression; expression

Example

Say we want to find the first $\bar{B}$ frame time derivative of the vector $\vec{q}$, which is expressed in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\tranI{b}{a}{\vec{q}\,}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{B}}\mathrm{d}}{\mathrm{d}t}\left(\vec{q}\,\right) = \frac{{}^{\bar{A}}\mathrm{d}}{\mathrm{d}t}\left(\vec{q}\,\right) + {}^{\bar{B}}\vec{\omega}^{\bar{A}} \times \vec{q}$$

5.5 \tranII

`\tranII{⟨dframe⟩}{⟨eframe⟩}{⟨expr⟩}`

Second-order transport theorem. This command is used to show how to take the second ⟨*dframe*⟩-frame time derivative of ⟨*expr*⟩ which is expressed in the ⟨*eframe*⟩-frame.

⟨*dframe*⟩ = Derivative frame; letter (a-z, A-Z)
⟨*eframe*⟩ = Expressed frame; letter (a-z, A-Z)
⟨*expr*⟩ = Expression; expression

Example

Say we want to find the second $\bar{B}$ frame time derivative of the vector $\vec{q}$, which is expressed in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\tranII{b}{a}{\vec{q}\,}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{B}}\mathrm{d}^2}{\mathrm{d}t^2}(\vec{q}\,) = \frac{{}^{\bar{A}}\mathrm{d}^2}{\mathrm{d}t^2}(\vec{q}\,) + {}^{\bar{B}}\vec{\alpha}^{\bar{A}} \times \vec{q} + 2\,{}^{\bar{B}}\vec{\omega}^{\bar{A}} \times \frac{{}^{\bar{A}}\mathrm{d}}{\mathrm{d}t}(\vec{q}\,) + {}^{\bar{B}}\vec{\omega}^{\bar{A}} \times \left({}^{\bar{B}}\vec{\omega}^{\bar{A}} \times \vec{q}\right)$$

Partial Derivatives

5.6 \pderI

`\pderI{⟨frame⟩}{⟨var⟩}{⟨expr⟩}`

1st partial derivative. This command is used to take the first partial derivative with respect to ⟨*var*⟩ of ⟨*expr*⟩ in the ⟨*frame*⟩ frame.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol
⟨*expr*⟩ = Expression; expression

Example

Say we want to define the first partial derivative of velocity, $\vec{v}$, with respect to θ in the $\bar{B}$ frame.

This is accomplished with the LaTeX below:

```
\pderI{b}{\theta}{\vec{v}\,}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{B}}\partial}{\partial\theta}(\vec{v}\,)$$

5.7 \pderII

`\pderII{⟨frame⟩}{⟨var⟩}{⟨expr⟩}`

2nd partial derivative. This command is used to take the second partial derivative with respect to ⟨*var*⟩ of ⟨*expr*⟩ in the ⟨*frame*⟩ frame.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol
⟨*expr*⟩ = Expression; expression

Example

Say we want to define the second partial derivative of velocity, $\vec{v}$, with respect to θ in the $\bar{B}$ frame.

This is accomplished with the LaTeX below:

```
\pderII{b}{\theta}{\vec{v}\,}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{B}}\partial^2}{\partial\theta^2}(\vec{v}\,)$$

5.8 \pderN

`\pderN{⟨frame⟩}{⟨var⟩}{⟨expr⟩}{⟨n⟩}`

nth partial derivative. This command is used to take the nth partial derivative with respect to ⟨*var*⟩ of ⟨*expr*⟩ in the ⟨*frame*⟩ frame.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol
⟨*expr*⟩ = Expression; expression
⟨*n*⟩ = Number, positive integer

Example

Say we want to define the 30th partial derivative of velocity, $\vec{v}$, with respect to θ in the $\bar{B}$ frame.

This is accomplished with the LaTeX below:

```
\pderN{b}{\theta}{\vec{v}\,}{30}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{B}}\partial^{30}}{\partial\theta^{30}}(\vec{v}\,)$$

5.9 \ptranI

`\ptranI{⟨dframe⟩}{⟨eframe⟩}{⟨var⟩}{⟨expr⟩}`

First-order partial derivative transport theorem. This command is used to show how to take the first partial ⟨*dframe*⟩-frame derivative with respect to ⟨*var*⟩ of ⟨*expr*⟩ which is expressed in the ⟨*eframe*⟩-frame.

⟨*dframe*⟩ = Derivative frame; letter (a-z, A-Z)
⟨*eframe*⟩ = Expressed frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol
⟨*expr*⟩ = Expression; expression

Example

Say we want to find the first partial $\bar{B}$ frame derivative with respect to ϕ of the vector $\vec{q}$, which is expressed in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\ptranI{b}{a}{\phi}{\vec{q}\,}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{B}}\partial}{\partial\phi}(\vec{q}\,) = \frac{{}^{\bar{A}}\partial}{\partial\phi}(\vec{q}\,) + {}^{\bar{B}}\vec{P}^{\bar{A}}_{\phi}\times\vec{q}$$

Total Derivatives

5.10 `\tderI`

`\tderI{⟨frame⟩}{⟨var⟩}{⟨expr⟩}`

1st total derivative. This command is used to take the first total derivative with respect to ⟨*var*⟩ of ⟨*expr*⟩ in the ⟨*frame*⟩ frame.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol
⟨*expr*⟩ = Expression; expression

Example

Say we want to define the first total derivative of velocity, $\vec{v}$, with respect to ψ in the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\tderI{o}{\psi}{\vec{v}\,}
```

Display/Inline Mode Output

$${}^{\bar{O}}\frac{\mathrm{d}}{\mathrm{d}\psi}(\vec{v}\,)$$

5.11 `\tderII`

`\tderII{⟨frame⟩}{⟨var⟩}{⟨expr⟩}`

2nd total derivative. This command is used to take the second total derivative with respect to ⟨*var*⟩ of ⟨*expr*⟩ in the ⟨*frame*⟩ frame.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol
⟨*expr*⟩ = Expression; expression

Example

Say we want to define the second total derivative of velocity, $\vec{v}$, with respect to ψ in the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\tderII{o}{\psi}{\vec{v}\,}
```

Display/Inline Mode Output

$${}^{\bar{O}}\frac{\mathrm{d}^2}{\mathrm{d}\psi^2}(\vec{v}\,)$$

5.12 \tderN

`\tderN{⟨frame⟩}{⟨var⟩}{⟨expr⟩}{⟨n⟩}`

nth total derivative. This command is used to take the nth total derivative with respect to ⟨*var*⟩ of ⟨*expr*⟩ in the ⟨*frame*⟩ frame.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol
⟨*expr*⟩ = Expression; expression
⟨*n*⟩ = Number, positive integer

Example

Say we want to define the 30th total derivative of velocity, $\vec{v}$, with respect to ψ in the $\bar{O}$ frame.

This is accomplished with the LaTeX below:

```
\tderN{o}{\psi}{\vec{v}\,}{30}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{O}}\mathrm{d}^{30}}{\mathrm{d}\psi^{30}}(\vec{v}\,)$$

5.13 \ttranI

`\ttranI{⟨dframe⟩}{⟨eframe⟩}{⟨var⟩}{⟨expr⟩}`

First-order total derivative transport theorem. This command is used to show how to take the first total ⟨*dframe*⟩-frame derivative with respect to ⟨*var*⟩ of ⟨*expr*⟩ which is expressed in the ⟨*eframe*⟩-frame.

⟨*dframe*⟩ = Derivative frame; letter (a-z, A-Z)
⟨*eframe*⟩ = Expressed frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol
⟨*expr*⟩ = Expression; expression

Example

Say we want to find the first total $\bar{O}$ frame derivative with respect to ϕ of the vector $\vec{q}$, which is expressed in the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\ttranI{o}{a}{\phi}{\vec{q}\,}
```

Display/Inline Mode Output

$$\frac{{}^{\bar{O}}\mathrm{d}}{\mathrm{d}\phi}(\vec{q}\,) = \frac{{}^{\bar{A}}\mathrm{d}}{\mathrm{d}\phi}(\vec{q}\,) + {}^{\bar{O}}\vec{T}_{\phi}^{\bar{A}} \times \vec{q}$$

6 Vectors

This section includes the commands needed to typeset most vector quantities. Note that all commands in this section should be used inside of a math environment. Vectors should be in a display math environment.

Note that if you wish to attach a frame subscipt to any of the elementary vectors, you should also include `\!` or `\!\!` before the frame definition to remove the space between the closing bracket of the vector and the frame. This will be addressed in a future version.

Column Vectors

6.1 `\vecfrc`

`\vecfrc{⟨frame⟩}{⟨comp1⟩}{⟨comp2⟩}{⟨comp3⟩}`

Column vector in frame. This command produces a column vector in ⟨*frame*⟩ with x-component ⟨*comp1*⟩, y-component ⟨*comp2*⟩, and z-component ⟨*comp3*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*comp1*⟩ = x-component; expression
⟨*comp2*⟩ = y-component; expression
⟨*comp3*⟩ = z-component; expression

Example

Say we want to define a column vector in the $\bar{F}$ frame with components a, b, and c in the $\hat{\imath}_{\bar{F}}$, $\hat{\jmath}_{\bar{F}}$, and $\hat{k}_{\bar{F}}$ directions, respectively.

This is accomplished with the LaTeX below:

```
\vecfrc{f}{a}{b}{c}
```

Display Mode Output

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix}_{\bar{F}}$$

6.2 `\vecfrnc`

`\vecfrnc{⟨frame⟩}{⟨num⟩}{⟨comp1⟩}{⟨comp2⟩}{⟨comp3⟩}`

Column vector in numbered frame. This command produces a column vector in ⟨*frame*⟩ assigned number ⟨*num*⟩, with x-component ⟨*comp1*⟩, y-component ⟨*comp2*⟩, and z-component ⟨*comp3*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Frame; letter (a-z, A-Z)
⟨*comp1*⟩ = x-component; expression
⟨*comp2*⟩ = y-component; expression
⟨*comp3*⟩ = z-component; expression

Example

Say we want to define a column vector in the $\bar{F}_2$ frame with components a, b, and c in the $\hat{\imath}_{\bar{F}}$, $\hat{\jmath}_{\bar{F}}$, and $\hat{k}_{\bar{F}}$ directions, respectively.

This is accomplished with the LaTeX below:

```
\vecfrnc{f}{2}{a}{b}{c}
```

Display Mode Output

$$\begin{bmatrix} a \\ b \\ c \end{bmatrix}_{\bar{F}_2}$$

6.3 `\vecAc`

`\vecAc`

First elementary column vector. This command is used to express the elementary column vector along the x-direction of a frame.

No input arguments.

Example

Define the elementary column unit vector for the x-component.

This is accomplished with the LaTeX below:

```
\vecAc
```

Display Mode Output

$$\begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

6.4 `\vecBc`

`\vecBc`

Second elementary column vector. This command is used to express the elementary column vector along the y-direction of a frame.

No input arguments.

Example

Define the elementary column unit vector for the y-component.

This is accomplished with the LaTeX below:

```
\vecBc
```

Display Mode Output

$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

6.5 `\vecCc`

`\vecCc`

Third elementary column vector. This command is used to express the elementary column vector along the z-direction of a frame.

No input arguments.

Example

Define the elementary column unit vector for the z-component.

This is accomplished with the LaTeX below:

```
\vecCc
```

Display Mode Output

$$\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

Transposed Column Vectors

6.6 \vecfrcT

\vecfrcT{⟨*frame*⟩}{⟨*comp1*⟩}{⟨*comp2*⟩}{⟨*comp3*⟩}

Column vector in frame. This command produces a transposed column vector in ⟨*frame*⟩ with x-component ⟨*comp1*⟩, y-component ⟨*comp2*⟩, and z-component ⟨*comp3*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*comp1*⟩ = x-component; expression
⟨*comp2*⟩ = y-component; expression
⟨*comp3*⟩ = z-component; expression

Example

Say we want to define a transposed column vector in the $\bar{F}$ frame with components a, b, and c in the $\hat{\imath}_{\bar{F}}$, $\hat{\jmath}_{\bar{F}}$, and $\hat{k}_{\bar{F}}$ directions, respectively.

This is accomplished with the LaTeX below:

```
\vecfrcT{f}{a}{b}{c}
```

Display Mode Output

$$\begin{bmatrix} a & b & c \end{bmatrix}^{\mathrm{T}}_{\bar{F}}$$

6.7 \vecfrncT

`\vecfrncT{⟨frame⟩}{⟨num⟩}{⟨comp1⟩}{⟨comp2⟩}{⟨comp3⟩}`

Column vector in numbered frame. This command produces a transposed column vector in ⟨*frame*⟩ assigned number ⟨*num*⟩, with x-component ⟨*comp1*⟩, y-component ⟨*comp2*⟩, and z-component ⟨*comp3*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Frame; letter (a-z, A-Z)
⟨*comp1*⟩ = x-component; expression
⟨*comp2*⟩ = y-component; expression
⟨*comp3*⟩ = z-component; expression

Example

Say we want to define a transposed column vector in the $\bar{F}_2$ frame with components a, b, and c in the $\hat{\imath}_{\bar{F}}$, $\hat{\jmath}_{\bar{F}}$, and $\hat{k}_{\bar{F}}$ directions, respectively.

This is accomplished with the LaTeX below:

```
\vecfrncT{f}{2}{a}{b}{c}
```

Display Mode Output

$$\begin{bmatrix} a & b & c \end{bmatrix}^{\mathrm{T}}_{\bar{F}_2}$$

6.8 \vecAcT

`\vecAcT`

First transposed elementary column vector. This command is used to express the transposed elementary column vector along the x-direction of a frame.

No input arguments.

Example

Define the transposed elementary unit vector for the x-component.

This is accomplished with the LaTeX below:

```
\vecAcT
```

Display Mode Output

$$\begin{bmatrix} 1 & 0 & 0 \end{bmatrix}^{\mathrm{T}}$$

6.9 `\vecBcT`

`\vecBcT`

Second transposed elementary column vector. This command is used to express the transposed elementary column vector along the y-direction of a frame.

No input arguments.

Example

Define the transposed elementary unit vector for the y-component.

This is accomplished with the LaTeX below:

```
\vecBcT
```

Display Mode Output

$$\begin{bmatrix} 0 & 1 & 0 \end{bmatrix}^{\mathrm{T}}$$

6.10 `\vecCcT`

`\vecCcT`

Third transposed elementary column vector. This command is used to express the transposed elementary column vector along the z-direction of a frame.

No input arguments.

Example

Define the transposed elementary unit vector for the z-component.

This is accomplished with the LaTeX below:

```
\vecCcT
```

Display Mode Output

$$\begin{bmatrix} 0 & 0 & 1 \end{bmatrix}^{\mathrm{T}}$$

Row Vectors

6.11 \vecfrr

\vecfrr{⟨*frame*⟩}{⟨*comp1*⟩}{⟨*comp2*⟩}{⟨*comp3*⟩}

Row vector in frame. This command produces a row vector in ⟨*frame*⟩ with x-component ⟨*comp1*⟩, y-component ⟨*comp2*⟩, and z-component ⟨*comp3*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*comp1*⟩ = x-component; expression
⟨*comp2*⟩ = y-component; expression
⟨*comp3*⟩ = z-component; expression

Example

Say we want to define a row vector in the $\bar{F}$ frame with components a, b, and c in the $\hat{\imath}_{\bar{F}}$, $\hat{\jmath}_{\bar{F}}$, and $\hat{k}_{\bar{F}}$ directions, respectively.

This is accomplished with the LaTeX below:

```
\vecfrr{f}{a}{b}{c}
```

Display Mode Output

$$\begin{bmatrix} a & b & c \end{bmatrix}_{\bar{F}}$$

6.12 \vecfrnr

`\vecfrnr{⟨frame⟩}{⟨num⟩}{⟨comp1⟩}{⟨comp2⟩}{⟨comp3⟩}`

Row vector in numbered frame. This command produces a row vector in ⟨*frame*⟩ assigned number ⟨*num*⟩, with x-component ⟨*comp1*⟩, y-component ⟨*comp2*⟩, and z-component ⟨*comp3*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*num*⟩ = Frame; letter (a-z, A-Z)
⟨*comp1*⟩ = x-component; expression
⟨*comp2*⟩ = y-component; expression
⟨*comp3*⟩ = z-component; expression

Example

Say we want to define a row vector in the $\bar{F}_2$ frame with components a, b, and c in the $\hat{\imath}_{\bar{F}}$, $\hat{\jmath}_{\bar{F}}$, and $\hat{k}_{\bar{F}}$ directions, respectively.

This is accomplished with the LaTeX below:

```
\vecfrnr{f}{2}{a}{b}{c}
```

Display Mode Output

$$\begin{bmatrix} a & b & c \end{bmatrix}_{\bar{F}_2}$$

6.13 \vecAr

`\vecAr`

First elementary row vector. This command is used to express the elementary row vector along the x-direction of a frame.

No input arguments.

Example

Define the elementary row unit vector for the x-component.

This is accomplished with the LaTeX below:

```
\vecAr
```

Display Mode Output

$$\begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$$

6.14 \vecBr

`\vecBr`

Second elementary row vector. This command is used to express the elementary row vector along the y-direction of a frame.

No input arguments.

Example

Define the elementary row unit vector for the y-component.

This is accomplished with the LaTeX below:

```
\vecBr
```

Display Mode Output

$$\begin{bmatrix} 0 & 1 & 0 \end{bmatrix}$$

6.15 \vecCr

`\vecCr`

Third elementary row vector. This command is used to express the elementary row vector along the z-direction of a frame.

No input arguments.

Example

Define the elementary row unit vector for the z-component.

This is accomplished with the LaTeX below:

```
\vecCr
```

Display Mode Output

$$\begin{bmatrix} 0 & 0 & 1 \end{bmatrix}$$

7 Matrices

This section includes the commands needed to typeset most matrix quantities. Note that all commands in this section should be used inside of a math environent and a display math environment should be used for the best appearance.

Note that if you wish to attach a frame subscipt to any of the matrices without one, you should also include `\!` or `\!\!` before the frame definition to remove the space between the closing bracket of the vector and the frame. This will be addressed in a future version.

Standard Rotation Matrices

7.1 `\rotx`

`\rotx{⟨angle⟩}`

Rotation matrix about x. This command writes all the terms of a rotation matrix about the x-axis using a specified angle, ⟨*angle*⟩.

⟨*angle*⟩ = Rotation angle; symbol

Example

Say we want to define the rotation matrix about the x-axis using the angle ϕ.

This is accomplished with the LaTeX below:

```
\rotx{\phi}
```

Display Mode Output

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & c\phi & s\phi \\ 0 & -s\phi & c\phi \end{bmatrix}$$

7.2 \roty

`\roty{⟨angle⟩}`

Rotation matrix about y. This command writes all the terms of a rotation matrix about the y-axis using a specified angle, ⟨*angle*⟩.

⟨*angle*⟩ = Rotation angle; symbol

Example

Say we want to define the rotation matrix about the y-axis using the angle θ.

This is accomplished with the LaTeX below:

```
\roty{\theta}
```

Display Mode Output

$$\begin{bmatrix} c\theta & 0 & -s\theta \\ 0 & 1 & 0 \\ s\theta & 0 & c\theta \end{bmatrix}$$

7.3 \rotz

`\rotz{⟨angle⟩}`

Rotation matrix about z. This command writes all the terms of a rotation matrix about the z-axis using a specified angle, ⟨*angle*⟩.

⟨*angle*⟩ = Rotation angle; symbol

Example

Say we want to define the rotation matrix about the z-axis using the angle ψ.

This is accomplished with the LaTeX below:

```
\rotz{\psi}
```

Display Mode Output

$$\begin{bmatrix} c\psi & s\psi & 0 \\ -s\psi & c\psi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

7.4 \rotxq

`\rotxq{`⟨*num*⟩`}`

Rotation matrix about x using q shorthand. This command writes all the terms of a rotation matrix about the x-axis using a specified q_n, $n = \langle num \rangle$ and shorthand notation.

$\langle num \rangle$ = Variable number; positive integer

Example

Say we want to define the rotation matrix about the x-axis using the variable q_1.

This is accomplished with the LaTeX below:

```
\rotxq{\1}
```

Display Mode Output

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & c_1 & s_1 \\ 0 & -s_1 & c_1 \end{bmatrix}$$

7.5 \rotyq

`\rotyq{`⟨*num*⟩`}`

Rotation matrix about y using q shorthand. This command writes all the terms of a rotation matrix about the y-axis using a specified q_n, $n = \langle num \rangle$ and shorthand notation.

$\langle num \rangle$ = Variable number; positive integer

Example

Say we want to define the rotation matrix about the y-axis using the variable q_2.

This is accomplished with the LaTeX below:

```
\rotyq{\2}
```

Display Mode Output

$$\begin{bmatrix} c_2 & 0 & -s_2 \\ 0 & 1 & 0 \\ s_2 & 0 & c_2 \end{bmatrix}$$

7.6 \rotzq

`\rotzq{⟨num⟩}`

Rotation matrix about z using q shorthand. This command writes all the terms of a rotation matrix about the z-axis using a specified q_n, $n = \langle num \rangle$ and shorthand notation.

$\langle num \rangle$ = Variable number; positive integer

Example

Say we want to define the rotation matrix about the z-axis using the variable q_3.

This is accomplished with the LaTeX below:

```
\rotzq{\3}
```

Display Mode Output

$$\begin{bmatrix} c_3 & s_3 & 0 \\ -s_3 & c_3 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Transposed/Inverse Rotation Matrices

7.7 \rotxT

`\rotxT{⟨angle⟩}`

Transposed rotation matrix about x. This command writes all the terms of a transposed/inverse rotation matrix about the x-axis using a specified angle, $\langle angle \rangle$.

$\langle angle \rangle$ = Rotation angle; symbol

Example

Say we want to define the transposed/inverse rotation matrix about the x-axis using the angle ϕ.

This is accomplished with the LaTeX below:

```
\rotxT{\phi}
```

Display Mode Output

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & c\phi & -s\phi \\ 0 & s\phi & c\phi \end{bmatrix}$$

7.8 \rotyT

`\rotyT{⟨angle⟩}`

Transposed rotation matrix about y. This command writes all the terms of a transposed/inverse rotation matrix about the y-axis using a specified angle, ⟨*angle*⟩.

⟨*angle*⟩ = Rotation angle; symbol

Example

Say we want to define the transposed/inverse rotation matrix about the y-axis using the angle θ.

This is accomplished with the LaTeX below:

```
\rotyT{\theta}
```

Display Mode Output

$$\begin{bmatrix} c\theta & 0 & s\theta \\ 0 & 1 & 0 \\ -s\theta & 0 & c\theta \end{bmatrix}$$

7.9 \rotzT

`\rotzT{⟨angle⟩}`

Transposed rotation matrix about z. This command writes all the terms of a transposed/inverse rotation matrix about the z-axis using a specified angle, ⟨*angle*⟩.

⟨*angle*⟩ = Rotation angle; symbol

Example

Say we want to define the transposed/inverse rotation matrix about the z-axis using the angle ψ.

This is accomplished with the LaTeX below:

```
\rotzT{\psi}
```

Display Mode Output

$$\begin{bmatrix} c\psi & -s\psi & 0 \\ s\psi & c\psi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

7.10 \rotxqT

\rotxqT{⟨*num*⟩}

Transposed rotation matrix about x using q shorthand. This command writes all the terms of a transposed/inverse rotation matrix about the x-axis using a specified q_n, n = ⟨*num*⟩ and shorthand notation.

⟨*num*⟩ = Variable number; positive integer

Example

Say we want to define the transposed/inverse rotation matrix about the x-axis using the variable q_1.

This is accomplished with the LaTeX below:

```
\rotxqT{\1}
```

Display Mode Output

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & c_1 & -s_1 \\ 0 & s_1 & c_1 \end{bmatrix}$$

7.11 \rotyqT

\rotyqT{⟨*num*⟩}

Transposed rotation matrix about y using q shorthand. This command writes all the terms of a transposed/inverse rotation matrix about the y-axis using a specified q_n, n = ⟨*num*⟩ and shorthand notation.

⟨*num*⟩ = Variable number; positive integer

Example

Say we want to define the transposed/inverse rotation matrix about the y-axis using the variable q_2.

This is accomplished with the LaTeX below:

```
\rotyqT{\2}
```

Display Mode Output

$$\begin{bmatrix} c_2 & 0 & s_2 \\ 0 & 1 & 0 \\ -s_2 & 0 & c_2 \end{bmatrix}$$

7.12 \rotzqT

`\rotzqT{⟨num⟩}`

Transposed rotation matrix about z using q shorthand. This command writes all the terms of a transposed/inverse rotation matrix about the z-axis using a specified q_n, $n = \langle num \rangle$ and shorthand notation.

⟨*num*⟩ = Variable number; positive integer

Example

Say we want to define the transposed/inverse rotation matrix about the z-axis using the variable q_3.

This is accomplished with the LaTeX below:

```
\rotzqT{\3}
```

Display Mode Output

$$\begin{bmatrix} c_3 & -s_3 & 0 \\ s_3 & c_3 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Inertia Matrices

7.13 \inertiaMat

`\inertiaMat{⟨frame⟩}{⟨point⟩}`

Inertia matrix. This command is used to define the terms of an inertia tensor of a body about point ⟨*point*⟩ in matrix form with body frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the inertia matrix of body with body frame $\bar{B}$ about its center of mass.

This is accomplished with the LaTeX below:

```
\inertiaMat{b}{\CM}
```

Display Mode Output

$$\begin{bmatrix} {}^{\bar{B}}I_{xx/\mathrm{CM}} & -{}^{\bar{B}}I_{xy/\mathrm{CM}} & -{}^{\bar{B}}I_{xz/\mathrm{CM}} \\ -{}^{\bar{B}}I_{yx/\mathrm{CM}} & {}^{\bar{B}}I_{yy/\mathrm{CM}} & -{}^{\bar{B}}I_{yz/\mathrm{CM}} \\ -{}^{\bar{B}}I_{zx/\mathrm{CM}} & -{}^{\bar{B}}I_{zy/\mathrm{CM}} & {}^{\bar{B}}I_{zz/\mathrm{CM}} \end{bmatrix}$$

7.14 \inertiaMatsh

`\inertiaMatsh`

Shorthand inertia matrix. This command is used to define the terms of an inertia tensor in shorthand.

No input arguments.

Example

Define the shorthand inertia matrix.

This is accomplished with the LaTeX below:

```
\inertiaMatsh
```

Display Mode Output

$$\begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{yx} & I_{yy} & -I_{yz} \\ -I_{zx} & -I_{zy} & I_{zz} \end{bmatrix}$$

7.15 \inertiaDif

`\inertiaDif{⟨frame⟩}{⟨point⟩}`

Inertia difference matrix. This command is used to define the terms of an inertia difference tensor of a body about point ⟨*point*⟩ relative to its center of mass in matrix form with body frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the inertia difference matrix of body with body frame $\bar{B}$ about a point A.

This is accomplished with the LaTeX below:

```
\inertiaDif{b}{\smca{a}}
```

Display Mode Output

$$\begin{bmatrix} ({}^{\bar{B}}y_{\mathrm{CM}/A})^2 + ({}^{\bar{B}}z_{\mathrm{CM}/A})^2 & {}^{\bar{B}}x_{\mathrm{CM}/A}\,{}^{\bar{B}}y_{\mathrm{CM}/A} & {}^{\bar{B}}x_{\mathrm{CM}/A}\,{}^{\bar{B}}z_{\mathrm{CM}/A} \\ {}^{\bar{B}}y_{\mathrm{CM}/A}\,{}^{\bar{B}}x_{\mathrm{CM}/A} & ({}^{\bar{B}}x_{\mathrm{CM}/A})^2 + ({}^{\bar{B}}z_{\mathrm{CM}/A})^2 & {}^{\bar{B}}y_{\mathrm{CM}/A}\,{}^{\bar{B}}z_{\mathrm{CM}/A} \\ {}^{\bar{B}}z_{\mathrm{CM}/A}\,{}^{\bar{B}}x_{\mathrm{CM}/A} & {}^{\bar{B}}z_{\mathrm{CM}/A}\,{}^{\bar{B}}y_{\mathrm{CM}/A} & ({}^{\bar{B}}x_{\mathrm{CM}/A})^2 + ({}^{\bar{B}}y_{\mathrm{CM}/A})^2 \end{bmatrix}$$

7.16 `\inertiaDifsh`

`\inertiaDifsh`

Shorthand inertia difference matrix. This command is used to define the terms of an inertia difference tensor relative to its center of mass in shorthand.

No input arguments.

Example

Define the shorthand inertia difference matrix.

This is accomplished with the LaTeX below:

```
\inertiaDifsh
```

Display Mode Output

$$\begin{bmatrix} y^2+z^2 & xy & xz \\ yx & x^2+z^2 & yz \\ zx & zy & x^2+y^2 \end{bmatrix}$$

Other Matrices

7.17 `\tensorMat`

`\tensorMat{⟨frame⟩}{⟨tensor⟩}`

Tensor matrix. This command is used to define the terms of a matrix representation of the tensor ⟨*tensor*⟩ relative to the frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*tensor*⟩ = Tensor; expression

Example

Say we want to define a matrix representation of an inertia tensor about a body's center of mass expressed in its body frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\tensorMat{b}{\inerTen{\CM}}
```

Display Mode Output

$$\begin{bmatrix} \hat{\imath}_{\bar{B}}\cdot\tilde{I}_{\mathrm{CM}}\cdot\hat{\imath}_{\bar{B}} & \hat{\imath}_{\bar{B}}\cdot\tilde{I}_{\mathrm{CM}}\cdot\hat{\jmath}_{\bar{B}} & \hat{\imath}_{\bar{B}}\cdot\tilde{I}_{\mathrm{CM}}\cdot\hat{k}_{\bar{B}} \\ \hat{\jmath}_{\bar{B}}\cdot\tilde{I}_{\mathrm{CM}}\cdot\hat{\imath}_{\bar{B}} & \hat{\jmath}_{\bar{B}}\cdot\tilde{I}_{\mathrm{CM}}\cdot\hat{\jmath}_{\bar{B}} & \hat{\jmath}_{\bar{B}}\cdot\tilde{I}_{\mathrm{CM}}\cdot\hat{k}_{\bar{B}} \\ \hat{k}_{\bar{B}}\cdot\tilde{I}_{\mathrm{CM}}\cdot\hat{\imath}_{\bar{B}} & \hat{k}_{\bar{B}}\cdot\tilde{I}_{\mathrm{CM}}\cdot\hat{\jmath}_{\bar{B}} & \hat{k}_{\bar{B}}\cdot\tilde{I}_{\mathrm{CM}}\cdot\hat{k}_{\bar{B}} \end{bmatrix}$$

7.18 \sqMatiii

`\sqMatiii{⟨A11⟩}{⟨A12⟩}{⟨A13⟩}{⟨A21⟩}{⟨A22⟩}{⟨A23⟩}{⟨A31⟩}{⟨A32⟩}{⟨A33⟩}`

3x3 Matrix. This command is used to define a 3x3 square matrix with specified terms.

$\langle Amn \rangle$ = (m,n) term; expression

Example

Say we want to define a 3x3 matrix with the values 1 to 9 ascending from left to right, top to bottom.

This is accomplished with the LaTeX below:

```
\sqMatiii{1}{2}{3}{4}{5}{6}{7}{8}{9}
```

Display Mode Output

$$\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$$

7.19 \eyeMatiii

`\eyeMatiii`

3x3 identity matrix.

No input arguments.

Example

Define the 3x3 identity matrix.

This is accomplished with the LaTeX below:

```
\eyeMatiii
```

Display Mode Output

$$\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

7.20 \dcm

`\dcm`

Direction cosine matrix. This command defines the terms of a direction cosine matrix.

No input arguments.

Example

Define the direction cosine matrix.

This is accomplished with the LaTeX below:

```
\dcm
```

Display Mode Output

$$\begin{bmatrix} C_{11'} & C_{12'} & C_{13'} \\ C_{21'} & C_{22'} & C_{23'} \\ C_{31'} & C_{32'} & C_{33'} \end{bmatrix}$$

7.21 \crossMat

`\crossMat{⟨arg⟩}{⟨xcomp⟩}{⟨ycomp⟩}zcomp`

Cross matrix. This command is used to define a cross matrix which when multiplied by a vector is equivalent to taking a cross product. Defined given the x, y, and z components of the first vector in the cross product.

⟨*xcomp*⟩ = x-component; expression
⟨*ycomp*⟩ = y-component; expression
⟨*zcomp*⟩ = z-component; expression

Example

Say we want to define a cross matrix for a vector $\vec{r} = [x\ y\ z]$.

This is accomplished with the LaTeX below:

```
\crossMat{x}{y}{z}
```

Display Mode Output

$$\begin{bmatrix} 0 & -z & y \\ z & 0 & -x \\ -y & x & 0 \end{bmatrix}$$

8 Equations

This section includes the commands needed to typeset most of the fundamental equations from advanced dynamics. Note that all commands in this section should be used inside of a math environment and a display math environment should be used for the best appearance.

Additionally, it should be mentioned that the descriptions of the functions may not be enough to understand all of these definitions. This is partly intentional since it is based on a notation from a course and fully comprehending the equations would require one taking the course themself. However, the descriptions may be updated to be more detailed in the future.

Newton's Second Law

8.1 \NewtonII

```
\NewtonII
```

Newton II. Shows Newton's Second Law for a system of k rigid bodies and n particles. Assumes Newton III.

No input arguments.

Example

Show the generic form of Newton's Second Law when Newton III applies.

This is accomplished with the LaTeX below:

```
\NewtonII
```

Display Mode Output

$$\sum \vec{F}_{\text{sys,ext}} = \sum_{i=1}^{k} m_{\text{T},i} \, {}^{\bar{O}}\vec{a}_{\text{CM},i/O} + \sum_{j=1}^{n} m_j \, {}^{\bar{O}}\vec{a}_{m_j/O}$$

8.2 `\NewtonIIpart`

`\NewtonIIpart`

Newton II for particles. Shows Newton's Second Law for a system of n particles. Assumes Newton III.

No input arguments.

Example

Show the particle form of Newton's Second Law.

This is accomplished with the LaTeX below:

```
\NewtonIIpart
```

Display Mode Output

$$\sum \vec{F}_{\text{sys,ext}} = \sum_{i=1}^{n} m_i \,{}^{\bar{O}}\vec{a}_{m_i/O}$$

8.3 `\NewtonIIrigp`

`\NewtonIIrigp`

Newton II for rigid body. Shows Newton's Second Law for a system of particles as a rigid body. Assumes Newton III.

No input arguments.

Example

Show the rigid body form of Newton's Second Law.

This is accomplished with the LaTeX below:

```
\NewtonIIrigp
```

Display Mode Output

$$\sum \vec{F}_{\text{sys,ext}} = m_{\text{T}} \,{}^{\bar{O}}\vec{a}_{\text{CM}/O}$$

8.4 \NewtonIIgen

`\NewtonIIgen`

Generalized Newton II. Shows Newton's Second Law for a generic system of n particles.

No input arguments.

Example

Show the generic form of Newton's Second Law.

This is accomplished with the LaTeX below:

```
\NewtonIIgen
```

Display Mode Output

$$\sum_{i=1}^{n} \vec{F}_i + \sum_{i=1}^{n} \sum_{j=1}^{n} \vec{f}_{ij} = m_{\mathrm{T}}\, {}^{\mathcal{O}}\vec{a}_{\mathrm{CM}/O}$$

Full Inertia Equations

8.5 \inerTenDef

`\inerTenDef{`$\langle point \rangle$`}`

Inertia tensor definition. Defines the inertia tensor about a specified point, $\langle point \rangle$.

$\langle point \rangle$ = Point; expression

Example

Say we want to define the inertia tensor about point A.

This is accomplished with the LaTeX below:

```
\inerTenDef{\smca{A}}
```

Display Mode Output

$$\tilde{I}_{A} \equiv \sum_{i=1}^{n} m_i \left[\left(\vec{r}_{m_i/A} \cdot \vec{r}_{m_i/A} \right) \tilde{1} - \vec{r}_{m_i/A} \vec{r}_{m_i/A} \right]$$

8.6 \parAxisTen

`\parAxisTen{⟨point⟩}`

Parallel axis theorem tensor definition. Expression of the parallel axis theorem in tensor form about a specified point A.

⟨*point*⟩ = Point; expression

Example

Say we want to define the inertia tensor about point A using the parallel axis theorem.

This is accomplished with the LaTeX below:

```
\parAxisTen{\smca{A}}
```

Display Mode Output

$$\tilde{I}_{A} = \tilde{I}_{\text{CM}} + m_{\text{T}} \left[\left(\vec{r}_{\text{CM}/A} \cdot \vec{r}_{\text{CM}/A} \right) \tilde{1} - \vec{r}_{\text{CM}/A} \vec{r}_{\text{CM}/A} \right]$$

8.7 \rRel

`\rRel{⟨frame⟩}{⟨sys⟩}{⟨point⟩}`

Relative displacement. This is the relative displacement vector for the inertia tensor of the system ⟨*sys*⟩ relative to the point ⟨*point*⟩ with respect to the frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*sys*⟩ = System name; expression
⟨*point*⟩ = Reference point; expression

Example

Say we want to define the relative displacement of a mass element m_i relative to the point B in the body frame $\bar{B}$

This is accomplished with the LaTeX below:

```
\rRel{b}{m_i}{\smca{B}}
```

Display Mode Output

$$\vec{r}_{m_i/B} \equiv \left({}^{\bar{B}}x_{m_i/B} \right) \hat{\imath}_{\bar{B}} + \left({}^{\bar{B}}y_{m_i/B} \right) \hat{\jmath}_{\bar{B}} + \left({}^{\bar{B}}z_{m_i/B} \right) \hat{k}_{\bar{B}}$$

8.8 \IxxSum

`\IxxSum{⟨frame⟩}{⟨point⟩}`

I_{xx} term sum definition. Defines the I_{xx} term of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the I_{xx} term of the inertia tensor about point A in frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\IxxSum{b}{\smca{a}}
```

Display Mode Output

$$^{\bar{B}}I_{xx/A} \equiv \sum_{i=1}^{n} m_i \left(\left(^{\bar{B}}y_{m_i/A} \right)^2 + \left(^{\bar{B}}z_{m_i/A} \right)^2 \right)$$

8.9 \IxySum

`\IxySum{⟨frame⟩}{⟨point⟩}`

I_{xy} term sum definition. Defines the I_{xy} term of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the I_{xy} term of the inertia tensor about point A in frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\IxySum{b}{\smca{a}}
```

Display Mode Output

$$^{\bar{B}}I_{xy/A} \equiv \sum_{i=1}^{n} m_i \, ^{\bar{B}}x_{m_i/A} \, ^{\bar{B}}y_{m_i/A}$$

8.10 \IxzSum

`\IxzSum{⟨frame⟩}{⟨point⟩}`

I_{xz} term sum definition. Defines the I_{xz} term of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the I_{xz} term of the inertia tensor about point A in frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\IxzSum{b}{\smca{a}}
```

Display Mode Output

$$^{\bar{B}}I_{xy/A} \equiv \sum_{i=1}^{n} m_i \, {}^{\bar{B}}x_{m_i/A} \, {}^{\bar{B}}z_{m_i/A}$$

8.11 \IyxSum

`\IyxSum{⟨frame⟩}{⟨point⟩}`

I_{yx} term sum definition. Defines the I_{yx} term of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the I_{yx} term of the inertia tensor about point A in frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\IyxSum{b}{\smca{a}}
```

Display Mode Output

$$^{\bar{B}}I_{yx/A} \equiv \sum_{i=1}^{n} m_i \, {}^{\bar{B}}y_{m_i/A} \, {}^{\bar{B}}x_{m_i/A}$$

8.12 \IyySum

`\IyySum{⟨frame⟩}{⟨point⟩}`

I_{yy} term sum definition. Defines the I_{yy} term of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the I_{yy} term of the inertia tensor about point A in frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\IyySum{b}{\smca{a}}
```

Display Mode Output

$$^{\bar{B}}I_{yy/A} \equiv \sum_{i=1}^{n} m_i \left(\left(^{\bar{B}}x_{m_i/A} \right)^2 + \left(^{\bar{B}}z_{m_i/A} \right)^2 \right)$$

8.13 \IyzSum

`\IyzSum{⟨frame⟩}{⟨point⟩}`

I_{yz} term sum definition. Defines the I_{yz} term of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the I_{yz} term of the inertia tensor about point A in frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\IyzSum{b}{\smca{a}}
```

Display Mode Output

$$^{\bar{B}}I_{yz/A} \equiv \sum_{i=1}^{n} m_i \, ^{\bar{B}}y_{m_i/A} \, ^{\bar{B}}z_{m_i/A}$$

8.14 \IzxSum

\IzxSum{⟨*frame*⟩}{⟨*point*⟩}

I_{zx} term sum definition. Defines the I_{zx} term of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the I_{zx} term of the inertia tensor about point A in frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\IzxSum{b}{\smca{a}}
```

Display Mode Output

$$^{\bar{B}}I_{zx/A} \equiv \sum_{i=1}^{n} m_i \, ^{\bar{B}}z_{m_i/A} \, ^{\bar{B}}x_{m_i/A}$$

8.15 \IzySum

\IzySum{⟨*frame*⟩}{⟨*point*⟩}

I_{zy} term sum definition. Defines the I_{zy} term of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the I_{zy} term of the inertia tensor about point A in frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\IzySum{b}{\smca{a}}
```

Display Mode Output

$$^{\bar{B}}I_{zy/A} \equiv \sum_{i=1}^{n} m_i \, ^{\bar{B}}z_{m_i/A} \, ^{\bar{B}}y_{m_i/A}$$

8.16 \IzzSum

\IzzSum{⟨*frame*⟩}{⟨*point*⟩}

I_{zz} term sum definition. Defines the I_{zz} term of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the I_{zz} term of the inertia tensor about point A in frame $\bar{B}$.

This is accomplished with the LaTeX below:

```
\IzzSum{b}{\smca{a}}
```

Display Mode Output

$$^{\bar{B}}I_{zz/A} \equiv \sum_{i=1}^{n} m_i \left(\left(^{\bar{B}}x_{m_i/A} \right)^2 + \left(^{\bar{B}}y_{m_i/A} \right)^2 \right)$$

8.17 \parAxis

\parAxis{⟨*frame*⟩}{⟨*point*⟩}

Parallel axis theorem in matrix form. Defines the terms of the inertia tensor about a point ⟨*point*⟩ in frame ⟨*frame*⟩ using the parallel axis theorem.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*point*⟩ = Point; expression

Example

Say we want to define the inertia tensor in matrix form about point A in frame $\bar{B}$ using the parallel axis theorem.

This is accomplished with the LaTeX below:

```
\parAxis{b}{\smca{a}}
```

Display Mode Output

$$\begin{aligned}[\tilde{I}_A]_{\bar{B}} = &\begin{bmatrix} ^{\bar{B}}I_{xx/A} & -^{\bar{B}}I_{xy/A} & -^{\bar{B}}I_{xz/A} \\ -^{\bar{B}}I_{yx/A} & ^{\bar{B}}I_{yy/A} & -^{\bar{B}}I_{yz/A} \\ -^{\bar{B}}I_{zx/A} & -^{\bar{B}}I_{zy/A} & ^{\bar{B}}I_{zz/A} \end{bmatrix} \\ &+ m_{\mathrm{T}} \begin{bmatrix} (^{\bar{B}}y_{\mathrm{CM}/A})^2 + (^{\bar{B}}z_{\mathrm{CM}/A})^2 & ^{\bar{B}}x_{\mathrm{CM}/A}\,^{\bar{B}}y_{\mathrm{CM}/A} & ^{\bar{B}}x_{\mathrm{CM}/A}\,^{\bar{B}}z_{\mathrm{CM}/A} \\ ^{\bar{B}}y_{\mathrm{CM}/A}\,^{\bar{B}}x_{\mathrm{CM}/A} & (^{\bar{B}}x_{\mathrm{CM}/A})^2 + (^{\bar{B}}z_{\mathrm{CM}/A})^2 & ^{\bar{B}}y_{\mathrm{CM}/A}\,^{\bar{B}}z_{\mathrm{CM}/A} \\ ^{\bar{B}}z_{\mathrm{CM}/A}\,^{\bar{B}}x_{\mathrm{CM}/A} & ^{\bar{B}}z_{\mathrm{CM}/A}\,^{\bar{B}}y_{\mathrm{CM}/A} & (^{\bar{B}}x_{\mathrm{CM}/A})^2 + (^{\bar{B}}y_{\mathrm{CM}/A})^2 \end{bmatrix}\end{aligned}$$

Short Inertia Equations

8.18 \rRelsh

`\rRelsh{⟨frame⟩}{⟨sys⟩}{⟨point⟩}`

Relative displacement shorthand. This is the shorthand relative displacement vector for the inertia tensor of the system ⟨*sys*⟩ relative to the point ⟨*point*⟩ with respect to the frame ⟨*frame*⟩.

⟨*frame*⟩ = Frame; letter (a-z, A-Z)
⟨*sys*⟩ = System name; expression
⟨*point*⟩ = Reference point; expression

Example

Say we want to define the relative displacement using shorthand summation of a mass element m_i relative to the point B in the body frame $\bar{B}$

This is accomplished with the LaTeX below:

```
\rRelsh{b}{m_i}{\smca{B}}
```

Display Mode Output

$$^{\bar{B}}\vec{r}_{m_i/B} = (x)\hat{\imath}_{\bar{B}} + (y)\hat{\jmath}_{\bar{B}} + (z)\hat{k}_{\bar{B}}$$

8.19 \IxxSumsh

`\IxxSumsh`

I_{xx} sum shorthand. Defines the I_{xx} term of the inertia tensor using summation and shorthand notation.

No input arguments.

Example

Define the I_{xx} term of the inertia tensor using shorthand summation notation.

This is accomplished with the LaTeX below:

```
\IxxSumsh
```

Display Mode Output

$$I_{xx} = \sum_{i=1}^{n} m_i \left(y_i^2 + z_i^2\right)$$

8.20 `\IxySumsh`

`\IxySumsh`

I_{xy} sum shorthand. Defines the I_{xy} term of the inertia tensor using summation and shorthand notation.

No input arguments.

Example

Define the I_{xy} term of the inertia tensor using shorthand summation notation.

This is accomplished with the LaTeX below:

```
\IxySumsh
```

Display Mode Output

$$I_{xy} = \sum_{i=1}^{n} m_i x_i y_i$$

8.21 `\IxzSumsh`

`\IxzSumsh`

I_{xz} sum shorthand. Defines the I_{xz} term of the inertia tensor using summation and shorthand notation.

No input arguments.

Example

Define the I_{xz} term of the inertia tensor using shorthand summation notation.

This is accomplished with the LaTeX below:

```
\IxzSumsh
```

Display Mode Output

$$I_{xz} = \sum_{i=1}^{n} m_i x_i z_i$$

8.22 \IyxSumsh

`\IyxSumsh`

I_{yx} sum shorthand. Defines the I_{yx} term of the inertia tensor using summation and shorthand notation.

No input arguments.

Example

Define the I_{yx} term of the inertia tensor using shorthand summation notation.

This is accomplished with the LaTeX below:

```
\IyxSumsh
```

Display Mode Output

$$I_{yx} = \sum_{i=1}^{n} m_i y_i x_i$$

8.23 \IyySumsh

`\IyySumsh`

I_{yy} sum shorthand. Defines the I_{yy} term of the inertia tensor using summation and shorthand notation.

No input arguments.

Example

Define the I_{yy} term of the inertia tensor using shorthand summation notation.

This is accomplished with the LaTeX below:

```
\IyySumsh
```

Display Mode Output

$$I_{yy} = \sum_{i=1}^{n} m_i \left(x_i^2 + z_i^2\right)$$

8.24 \IyzSumsh

`\IyzSumsh`

I_{yz} sum shorthand. Defines the I_{yz} term of the inertia tensor using summation and shorthand notation.

No input arguments.

Example

Define the I_{yz} term of the inertia tensor using shorthand summation notation.

This is accomplished with the LaTeX below:

```
\IyzSumsh
```

Display Mode Output

$$I_{yz} = \sum_{i=1}^{n} m_i y_i z_i$$

8.25 \IzxSumsh

`\IzxSumsh`

I_{zx} sum shorthand. Defines the I_{zx} term of the inertia tensor using summation and shorthand notation.

No input arguments.

Example

Define the I_{zx} term of the inertia tensor using shorthand summation notation.

This is accomplished with the LaTeX below:

```
\IzxSumsh
```

Display Mode Output

$$I_{zx} = \sum_{i=1}^{n} m_i z_i x_i$$

8.26 \IzySumsh

`\IzySumsh`

I_{zy} sum shorthand. Defines the I_{zy} term of the inertia tensor using summation and shorthand notation.

No input arguments.

Example

Define the I_{zy} term of the inertia tensor using shorthand summation notation.

This is accomplished with the LaTeX below:

```
\IzySumsh
```

Display Mode Output

$$I_{zy} = \sum_{i=1}^{n} m_i z_i y_i$$

8.27 \IzzSumsh

`\IzzSumsh`

I_{zz} sum shorthand. Defines the I_{zz} term of the inertia tensor using summation and shorthand notation.

No input arguments.

Example

Define the I_{zz} term of the inertia tensor using shorthand summation notation.

This is accomplished with the LaTeX below:

```
\IzzSumsh
```

Display Mode Output

$$I_{zz} = \sum_{i=1}^{n} m_i \left(x_i^2 + y_i^2\right)$$

8.28 \IxxInt

`\IxxInt`

I_{xx} sum shorthand. Defines the I_{xx} term of the inertia tensor using integration and shorthand notation.

No input arguments.

Example

Define the I_{xx} term of the inertia tensor using shorthand integration notation.

This is accomplished with the LaTeX below:

```
\IxxInt
```

Display Mode Output

$$I_{xx} = \int_{\text{Body}} (y^2 + z^2)\mathrm{d}m = \iiint_V (y^2 + z^2)\, \rho(x, y, z)\, \mathrm{d}V$$

8.29 \IxyInt

`\IxyInt`

I_{xy} sum shorthand. Defines the I_{xy} term of the inertia tensor using integration and shorthand notation.

No input arguments.

Example

Define the I_{xy} term of the inertia tensor using shorthand integration notation.

This is accomplished with the LaTeX below:

```
\IxyInt
```

Display Mode Output

$$I_{xy} = \int_{\text{Body}} (xy)\, \mathrm{d}m = \iiint_V (xy)\, \rho(x, y, z)\, \mathrm{d}V$$

8.30 \IxzInt

`\IxzInt`

I_{xz} sum shorthand. Defines the I_{xz} term of the inertia tensor using integration and shorthand notation.

No input arguments.

Example

Define the I_{xz} term of the inertia tensor using shorthand integration notation.

This is accomplished with the LaTeX below:

```
\IxzInt
```

Display Mode Output

$$I_{xz} = \int_{\text{Body}} (xz)\,\mathrm{d}m = \iiint_V (xz)\,\rho(x,y,z)\,\mathrm{d}V$$

8.31 \IyxInt

`\IyxInt`

I_{yx} sum shorthand. Defines the I_{yx} term of the inertia tensor using integration and shorthand notation.

No input arguments.

Example

Define the I_{yx} term of the inertia tensor using shorthand integration notation.

This is accomplished with the LaTeX below:

```
\IyxInt
```

Display Mode Output

$$I_{yx} = \int_{\text{Body}} (yx)\,\mathrm{d}m = \iiint_V (yx)\,\rho(x,y,z)\,\mathrm{d}V$$

8.32 `\IyyInt`

`\IyyInt`

I_{yy} sum shorthand. Defines the I_{yy} term of the inertia tensor using integration and shorthand notation.

No input arguments.

Example

Define the I_{yy} term of the inertia tensor using shorthand integration notation.

This is accomplished with the LaTeX below:

```
\IyyInt
```

Display Mode Output

$$I_{yy} = \int_{\text{Body}} (x^2 + z^2)\, \mathrm{d}m = \iiint_V (x^2 + z^2)\, \rho(x, y, z)\, \mathrm{d}V$$

8.33 `\IyzInt`

`\IyzInt`

I_{yz} sum shorthand. Defines the I_{yz} term of the inertia tensor using integration and shorthand notation.

No input arguments.

Example

Define the I_{yz} term of the inertia tensor using shorthand integration notation.

This is accomplished with the LaTeX below:

```
\IyzInt
```

Display Mode Output

$$I_{yz} = \int_{\text{Body}} (yz)\, \mathrm{d}m = \iiint_V (yz)\, \rho(x, y, z)\, \mathrm{d}V$$

8.34 \IzxInt

`\IzxInt`

I_{zx} sum shorthand. Defines the I_{zx} term of the inertia tensor using integration and shorthand notation.

No input arguments.

Example

Define the I_{zx} term of the inertia tensor using shorthand integration notation.

This is accomplished with the LaTeX below:

```
\IzxInt
```

Display Mode Output

$$I_{zx} = \int_{\text{Body}} (zx)\, \mathrm{d}m = \iiint_V (zx)\, \rho(x, y, z)\, \mathrm{d}V$$

8.35 \IzyInt

`\IzyInt`

I_{zy} sum shorthand. Defines the I_{zy} term of the inertia tensor using integration and shorthand notation.

No input arguments.

Example

Define the I_{zy} term of the inertia tensor using shorthand integration notation.

This is accomplished with the LaTeX below:

```
\IzyInt
```

Display Mode Output

$$I_{zy} = \int_{\text{Body}} (zy)\, \mathrm{d}m = \iiint_V (zy)\, \rho(x, y, z)\, \mathrm{d}V$$

8.36 \IzzInt

`\IzzInt`

I_{zz} sum shorthand. Defines the I_{zz} term of the inertia tensor using integration and shorthand notation.

No input arguments.

Example

Define the I_{zz} term of the inertia tensor using shorthand integration notation.

This is accomplished with the LaTeX below:

```
\IzzInt
```

Display Mode Output

$$I_{zz} = \int_{\text{Body}} (x^2 + y^2)\,\mathrm{d}m = \iiint_V (x^2 + y^2)\,\rho(x, y, z)\,\mathrm{d}V$$

8.37 \parAxissh

`\parAxissh`

Parallel axis theorem in shorthand matrix form. Defines the terms of the inertia tensor about using the parallel axis theorem and shorthand.

No input arguments.

Example

Say we want to define the inertia tensor in matrix form using the parallel axis theorem in shorthand notation.

This is accomplished with the LaTeX below:

```
\parAxissh
```

Display Mode Output

$$\tilde{I}_{\text{CM}} = \begin{bmatrix} I_{xx} & -I_{xy} & -I_{xz} \\ -I_{yx} & I_{yy} & -I_{yz} \\ -I_{zx} & -I_{zy} & I_{zz} \end{bmatrix} + m_{\text{T}} \begin{bmatrix} y^2 + z^2 & xy & xz \\ yx & x^2 + z^2 & yz \\ zx & zy & x^2 + y^2 \end{bmatrix}$$

Angular Velocity Equations

8.38 \angVdef

`\angVdef{⟨frame1⟩}{⟨frame2⟩}`

Angular velocity definition. Defines the angular velocity of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)

Example

Say we want to define the angular velocity of the $\bar{B}$ frame relative to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\angVdef{a}{b}
```

Display Mode Output

$$^{\bar{A}}\vec{\omega}^{\bar{B}} \equiv \hat{\imath}_{\bar{B}}\left(\left(\frac{^{\bar{A}}\mathrm{d}}{\mathrm{d}t}\left(\hat{\jmath}_{\bar{B}}\right)\right)\cdot\hat{k}_{\bar{B}}\right)+\hat{\jmath}_{\bar{B}}\left(\left(\frac{^{\bar{A}}\mathrm{d}}{\mathrm{d}t}\left(\hat{k}_{\bar{B}}\right)\right)\cdot\hat{\imath}_{\bar{B}}\right)+\hat{k}_{\bar{B}}\left(\left(\frac{^{\bar{A}}\mathrm{d}}{\mathrm{d}t}\left(\hat{\imath}_{\bar{B}}\right)\right)\cdot\hat{\jmath}_{\bar{B}}\right)$$

8.39 \angVxdef

`\angVxdef{⟨frame1⟩}{⟨frame2⟩}`

Angular velocity x-component definition. Defines the x-component of the angular velocity of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)

Example

Say we want to define the x-component of the angular velocity of the $\bar{B}$ frame relative to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\angVxdef{a}{b}
```

Display Mode Output

$$^{\bar{A}}\omega^{\bar{B}}_{x\bar{B}} = \begin{bmatrix}0 & 0 & 1\end{bmatrix}\,^{\bar{B}}[C]^{\bar{A}}\,^{\bar{A}}[\dot{C}]^{\bar{B}}\begin{bmatrix}0 & 1 & 0\end{bmatrix}^{\mathrm{T}}$$

8.40 \angVydef

`\angVydef{⟨frame1⟩}{⟨frame2⟩}`

Angular velocity y-component definition. Defines the y-component of the angular velocity of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)

Example

Say we want to define the y-component of the angular velocity of the $\bar{B}$ frame relative to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\angVydef{a}{b}
```

Display Mode Output

$$^{\bar{A}}\omega^{\bar{B}}_{y\bar{B}} = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} {}^{\bar{B}}[C]^{\bar{A}}\, {}^{\bar{A}}[\dot{C}]^{\bar{B}} \begin{bmatrix} 0 & 0 & 1 \end{bmatrix}^{\mathrm{T}}$$

8.41 \angVzdef

`\angVzdef{⟨frame1⟩}{⟨frame2⟩}`

Angular velocity z-component definition. Defines the z-component of the angular velocity of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)

Example

Say we want to define the z-component of the angular velocity of the $\bar{B}$ frame relative to the $\bar{A}$ frame.

This is accomplished with the LaTeX below:

```
\angVzdef{a}{b}
```

Display Mode Output

$$^{\bar{A}}\omega^{\bar{B}}_{z\bar{B}} = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} {}^{\bar{B}}[C]^{\bar{A}}\, {}^{\bar{A}}[\dot{C}]^{\bar{B}} \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}^{\mathrm{T}}$$

8.42 \Pvecdef

`\Pvecdef{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

P-vector definition. Defines the P-vector of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the P-vector of the $\bar{B}$ frame relative to the $\bar{A}$ frame with respect to θ.

This is accomplished with the LaTeX below:

```
\Pvecdef{a}{b}{\theta}
```

Display Mode Output

$$^{\bar{A}}\vec{P}^{\bar{B}}_{\theta} \equiv \hat{\imath}_{\bar{B}} \left(\left(\frac{^{\bar{A}}\partial}{\partial\theta}\left(\hat{\jmath}_{\bar{B}}\right) \right) \cdot \hat{k}_{\bar{B}} \right) + \hat{\jmath}_{\bar{B}} \left(\left(\frac{^{\bar{A}}\partial}{\partial\theta}\left(\hat{k}_{\bar{B}}\right) \right) \cdot \hat{\imath}_{\bar{B}} \right) + \hat{k}_{\bar{B}} \left(\left(\frac{^{\bar{A}}\partial}{\partial\theta}\left(\hat{\imath}_{\bar{B}}\right) \right) \cdot \hat{\jmath}_{\bar{B}} \right)$$

8.43 \Pvecxdef

`\Pvecxdef{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

P-vector x-component definition. Defines the x-component of the P-vector of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the x-component of the P-vector of the $\bar{B}$ frame relative to the $\bar{A}$ frame with respect to θ.

This is accomplished with the LaTeX below:

```
\Pvecxdef{a}{b}{\theta}
```

Display Mode Output

$$^{\bar{A}}\vec{P}^{\bar{B}}_{\theta,x} = \begin{bmatrix} 0 & 0 & 1 \end{bmatrix} \, ^{\bar{B}}[C]^{\bar{A}} \frac{\partial}{\partial\theta} {}^{\bar{A}}[C]^{\bar{B}} \begin{bmatrix} 0 & 1 & 0 \end{bmatrix}^{\mathrm{T}}$$

8.44 \Pvecydef

`\Pvecydef{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

P-vector y-component definition. Defines the y-component of the P-vector of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the y-component of the P-vector of the $\bar{B}$ frame relative to the $\bar{A}$ frame with respect to θ.

This is accomplished with the LaTeX below:

```
\Pvecydef{a}{b}{\theta}
```

Display Mode Output

$$^{\bar{A}}\vec{P}^{\bar{B}}_{\theta,y} = \begin{bmatrix}1 & 0 & 0\end{bmatrix} \, ^{\bar{B}}[C]^{\bar{A}} \frac{\partial}{\partial\theta} {}^{\bar{A}}[C]^{\bar{B}} \begin{bmatrix}0 & 0 & 1\end{bmatrix}^{\mathrm{T}}$$

8.45 \Pveczdef

`\Pveczdef{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

P-vector z-component definition. Defines the z-component of the P-vector of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the z-component of the P-vector of the $\bar{B}$ frame relative to the $\bar{A}$ frame with respect to θ.

This is accomplished with the LaTeX below:

```
\Pveczdef{a}{b}{\theta}
```

Display Mode Output

$$^{\bar{A}}\vec{P}^{\bar{B}}_{\theta,z} = \begin{bmatrix}0 & 1 & 0\end{bmatrix} \, ^{\bar{B}}[C]^{\bar{A}} \frac{\partial}{\partial\theta} {}^{\bar{A}}[C]^{\bar{B}} \begin{bmatrix}1 & 0 & 0\end{bmatrix}^{\mathrm{T}}$$

8.46 \Tvecdef

`\Tvecdef{`⟨*frame1*⟩`}{`⟨*frame2*⟩`}{`⟨*var*⟩`}`

T-vector definition. Defines the T-vector of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the T-vector of the $\bar{B}$ frame relative to the $\bar{A}$ frame with respect to β.

This is accomplished with the LaTeX below:

```
\Tvecdef{a}{b}{\beta}
```

Display Mode Output

$${}^{\bar{A}}\vec{T}^{\bar{B}}_{\beta} \equiv \hat{\imath}_{\bar{B}}\left(\left(\frac{{}^{\bar{A}}\mathrm{d}}{\mathrm{d}\beta}(\hat{\jmath}_{\bar{B}})\right)\cdot\hat{k}_{\bar{B}}\right) + \hat{\jmath}_{\bar{B}}\left(\left(\frac{{}^{\bar{A}}\mathrm{d}}{\mathrm{d}\beta}\left(\hat{k}_{\bar{B}}\right)\right)\cdot\hat{\imath}_{\bar{B}}\right) + \hat{k}_{\bar{B}}\left(\left(\frac{{}^{\bar{A}}\mathrm{d}}{\mathrm{d}\beta}(\hat{\imath}_{\bar{B}})\right)\cdot\hat{\jmath}_{\bar{B}}\right)$$

8.47 \Tvecxdef

`\Tvecxdef{`⟨*frame1*⟩`}{`⟨*frame2*⟩`}{`⟨*var*⟩`}`

T-vector x-component definition. Defines the x-component of the T-vector of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the x-component of the T-vector of the $\bar{B}$ frame relative to the $\bar{A}$ frame with respect to β.

This is accomplished with the LaTeX below:

```
\Tvecxdef{a}{b}{\beta}
```

Display Mode Output

$${}^{\bar{A}}\vec{T}^{\bar{B}}_{\beta,x} = \begin{bmatrix}0 & 0 & 1\end{bmatrix}\,{}^{\bar{B}}[C]^{\bar{A}}\,\frac{\mathrm{d}}{\mathrm{d}\beta}\,{}^{\bar{A}}[C]^{\bar{B}}\begin{bmatrix}0 & 1 & 0\end{bmatrix}^{\mathrm{T}}$$

8.48 \Tvecydef

`\Tvecydef{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

T-vector y-component definition. Defines the y-component of the T-vector of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the y-component of the T-vector of the $\bar{B}$ frame relative to the $\bar{A}$ frame with respect to β.

This is accomplished with the LaTeX below:

```
\Tvecydef{a}{b}{\beta}
```

Display Mode Output

$$ {}^{\bar{A}}\vec{T}^{\bar{B}}_{\beta,y} = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} {}^{\bar{B}}[C]^{\bar{A}} \frac{\mathrm{d}}{\mathrm{d}\beta} {}^{\bar{A}}[C]^{\bar{B}} \begin{bmatrix} 0 & 0 & 1 \end{bmatrix}^{\mathrm{T}} $$

8.49 \Tveczdef

`\Tveczdef{⟨frame1⟩}{⟨frame2⟩}{⟨var⟩}`

T-vector z-component definition. Defines the z-component of the T-vector of frame ⟨*frame2*⟩ relative to frame ⟨*frame1*⟩ with respect to ⟨*var*⟩.

⟨*frame1*⟩ = Frame; letter (a-z, A-Z)
⟨*frame2*⟩ = Frame; letter (a-z, A-Z)
⟨*var*⟩ = Variable; symbol

Example

Say we want to define the z-component of the T-vector of the $\bar{B}$ frame relative to the $\bar{A}$ frame with respect to β.

This is accomplished with the LaTeX below:

```
\Tveczdef{a}{b}{\beta}
```

Display Mode Output

$$ {}^{\bar{A}}\vec{T}^{\bar{B}}_{\beta,z} = \begin{bmatrix} 0 & 1 & 0 \end{bmatrix} {}^{\bar{B}}[C]^{\bar{A}} \frac{\mathrm{d}}{\mathrm{d}\beta} {}^{\bar{A}}[C]^{\bar{B}} \begin{bmatrix} 1 & 0 & 0 \end{bmatrix}^{\mathrm{T}} $$

Angular Momentum Equations

8.50 \angMomPart

\angMomPart{⟨*frame*⟩}{⟨*point1*⟩}{⟨*point2*⟩}{⟨*mass*⟩}

Particle angular momentum definition. This command is used to define the angular momentum of a particle with mass ⟨*mass*⟩ with respect to ⟨*point2*⟩ with respect to ⟨*point1*⟩, relative to the frame ⟨*frame*⟩.

⟨*frame*⟩ = Letter (a-z, A-Z)
⟨*point1*⟩ = Name of point1; expression
⟨*point2*⟩ = Name of point2; expression
⟨*mass*⟩ = Name of mass; expression

Example

Say we want to define the angular momentum of a particle of mass m with respect to P with respect to Q expressed in the $\bar{F}$ frame.

This is accomplished with the LaTeX below:

```
\angMomPart{f}{\smca{q}}{\smca{p}}{m}
```

Display Mode Output

$$ {}^{\bar{F}}_{Q}\vec{h}_{m/P} \equiv \vec{r}_{m/P} \times m\,{}^{\bar{F}}\vec{v}_{m/Q} $$

8.51 \angMomSys

`\angMomSys{⟨frame⟩}{⟨point1⟩}{⟨point2⟩}`

System angular momentum. This command is used to express the angular momentum of a system with respect to ⟨*point2*⟩ with respect to ⟨*point1*⟩, relative to the frame ⟨*frame*⟩.

⟨*frame*⟩ = Letter (a-z, A-Z)
⟨*point1*⟩ = Name of point1; expression
⟨*point2*⟩ = Name of point2; expression

Example

Say we want to define the angular momentum of a system with respect to P with respect to Q expressed in the $\bar{F}$ frame.

This is accomplished with the LaTeX below:

```
\angMomSys{f}{\smca{Q}}{\smca{P}}
```

Display Mode Output

$$ {}^{\bar{F}}_{Q}\vec{h}_{P,\mathrm{sys}} \equiv \sum_{i=1}^{n} \vec{r}_{m_i/P} \times m_i\, {}^{\bar{F}}\vec{v}_{m_i/Q} $$

8.52 \angMomDefI

`\angMomDefI`

Angular momentum definition I. Generic angular momentum expression.

No input arguments.

Example

Show the generic expression for angular momentum.

This is accomplished with the LaTeX below:

```
\angMomDefI
```

Display Mode Output

$$ {}^{\bar{A}}_{Q}\vec{h}_{P,\mathrm{sys}} = {}^{\bar{F}}_{B}\vec{h}_{B,\mathrm{sys}} + \tilde{I}_{B} \cdot {}^{\bar{O}}\vec{\omega}^{\bar{F}} + \vec{r}_{\mathrm{CM}/B} \times m_{\mathrm{T}}\, {}^{\bar{A}}\vec{v}_{B/Q} + \vec{r}_{B/P} \times m_{\mathrm{T}}\, {}^{\bar{A}}\vec{v}_{\mathrm{CM}/Q} $$

8.53 \angMomDefII

`\angMomDefII`

Angular momentum definition II. Angular momentum of a rigid body.

No input arguments.

Example

Show the expression for the angular momentum of a rigid body.

This is accomplished with the LaTeX below:

```
\angMomDefII
```

Display Mode Output

$${}^{\bar{O}}_{Q}\vec{h}_{\text{CM}} = {}^{\bar{O}}_{\text{CM}}\vec{h}_{\text{CM}} = \tilde{I}_{\text{CM}} \cdot {}^{\bar{O}}\vec{\omega}^{\bar{F}}$$

8.54 \angMomDefIII

`\angMomDefIII`

Angular momentum definition III. Angular momentum about the origin with respect to a body frame.

No input arguments.

Example

Show the angular momentum definition III.

This is accomplished with the LaTeX below:

```
\angMomDefIII
```

Display Mode Output

$${}^{\bar{O}}_{O}\vec{h}_{O,\text{sys}} = {}^{\bar{O}}_{\text{CM}}\vec{h}_{\text{CM,sys}} + \vec{r}_{\text{CM}/O} \times m_{\text{T}}\, {}^{\bar{O}}\vec{v}_{\text{CM}/O}$$

8.55 \angMomDefIV

`\angMomDefIV`

Angular momentum definition IV. Angular momentum about an arbitrary point A.

No input arguments.

Example

Show the angular momentum definition IV.

This is accomplished with the LaTeX below:

```
\angMomDefIV
```

Display Mode Output

$$ {}^{\bar{O}}_{O}\vec{h}_{A,\text{sys}} = {}^{\bar{O}}_{O}\vec{h}_{\text{CM,sys}} + \vec{r}_{\text{CM}/A} \times m_{\text{T}}\, {}^{\bar{O}}\vec{v}_{\text{CM}/O} $$

Torque Equations

8.56 \torqueDef

`\torqueDef`

Torque definition. Torque definition for a system of n particles about point P.

No input arguments.

Example

Show the torque definition.

This is accomplished with the LaTeX below:

```
\torqueDef
```

Display Mode Output

$$ \vec{\tau}_{P,\text{net}} \equiv \sum_{i=1}^{n} \vec{r}_{m_i/P} \times \vec{F}_{i,\text{net}} $$

8.57 \torqueDefI

`\torqueDefI`

Torque definition I. Most general case, $\bar{O}$ is an IRF.

No input arguments.

Example

Show torque definition I.

This is accomplished with the LaTeX below:

```
\torqueDefI
```

Display Mode Output

$$\vec{\tau}_{P,\text{net}} = \frac{{}^{\bar{O}}\mathrm{d}}{\mathrm{dt}}\left({}^{\bar{O}}_{Q}\vec{h}_{P,\text{sys}}\right) + m_{\text{T}}\,{}^{\bar{O}}\vec{v}_{\text{CM}/P} \times {}^{\bar{O}}\vec{v}_{Q/P} + m_{\text{T}}\vec{r}_{\text{CM}/P} \times {}^{\bar{O}}\vec{a}_{Q/O}$$

8.58 \torqueDefII

`\torqueDefII`

Torque definition II. $Q = O$, $P = CM$, $\bar{O}$ is an IRF.

No input arguments.

Example

Show torque definition II.

This is accomplished with the LaTeX below:

```
\torqueDefII
```

Display Mode Output

$$\vec{\tau}_{\text{CM},\text{net}} = \frac{{}^{\bar{O}}\mathrm{d}}{\mathrm{dt}}\left({}^{\bar{O}}_{O}\vec{h}_{\text{CM},\text{sys}}\right)$$

8.59 \torqueDefIII

`\torqueDefIII`

Torque definition III. $Q = P = CM$, $\bar{O}$ is an IRF.

No input arguments.

Example

Show torque definition III.

This is accomplished with the LaTeX below:

```
\torqueDefIII
```

Display Mode Output

$$\vec{\tau}_{\text{CM,net}} = \frac{{}^{\bar{O}}\mathrm{d}}{\mathrm{d}t}\left({}^{\bar{O}}_{\text{CM}}\vec{h}_{\text{CM,sys}}\right)$$

8.60 \torqueDefIV

`\torqueDefIV`

Torque definition IV. $Q = P = O$, $\bar{O}$ is an IRF.

No input arguments.

Example

Show torque definition IV.

This is accomplished with the LaTeX below:

```
\torqueDefIV
```

Display Mode Output

$$\vec{\tau}_{O} = \frac{{}^{\bar{O}}\mathrm{d}}{\mathrm{d}t}\left({}^{\bar{O}}_{O}\vec{h}_{O,\text{sys}}\right)$$

8.61 \torqueDefV

```
\torqueDefV
```

Torque definition V. $Q = O$, P is a fixed point with respect to O, $\bar{O}$ is an IRF.

No input arguments.

Example

Show torque definition V.

This is accomplished with the LaTeX below:

```
\torqueDefV
```

Display Mode Output

$$\vec{\tau}_{P,\mathrm{net}} = \frac{{}^{\bar{O}}\mathrm{d}}{\mathrm{d}t}\left({}^{\bar{O}}_{O}\vec{h}_{P,\mathrm{sys}}\right)$$

Kinetic Energy Equations

8.62 \kinEnDef

```
\kinEnDef
```

Kinetic energy definition. Kinetic energy definition for a system of n particles.

No input arguments.

Example

Show the kinetic energy definition.

This is accomplished with the LaTeX below:

```
\kinEnDef
```

Display Mode Output

$${}^{\bar{O}}T_{O} \equiv \sum_{i=1}^{n} \frac{1}{2} m_i \, {}^{\bar{O}}\vec{v}_{m_i/O} \cdot {}^{\bar{O}}\vec{v}_{m_i/O}$$

8.63 \kinEnDefI

`\kinEnDefI`

Kinetic energy definition I. General expression for the kinetic energy for a system of n particles and any frames $\bar{O}$ and $\bar{A}$.

No input arguments.

Example

Show kinetic energy definition I.

This is accomplished with the LaTeX below:

```
\kinEnDefI
```

Display Mode Output

$$
{}^{\bar{O}}T_{O} = \tfrac{1}{2} m_{\mathrm{T}} {}^{\bar{O}}\vec{v}_{A/O} \cdot {}^{\bar{O}}\vec{v}_{A/O} + m_{\mathrm{T}} {}^{\bar{O}}\vec{v}_{A/O} \cdot {}^{\bar{O}}\vec{v}_{\mathrm{CM}/A} + \sum_{i=1}^{n} \tfrac{1}{2} m_i {}^{\bar{A}}\vec{v}_{m_i/A} \cdot {}^{\bar{A}}\vec{v}_{m_i/A}
$$

$$
+ \sum_{i=1}^{n} \tfrac{1}{2} m_i {}^{\bar{A}}\vec{v}_{m_i/A} \cdot \left({}^{\bar{O}}\vec{\omega}^{\bar{A}} \times \vec{r}_{m_i/A} \right) + \tfrac{1}{2} {}^{\bar{O}}\vec{\omega}^{\bar{A}} \cdot \tilde{I}_{A} \cdot {}^{\bar{O}}\vec{\omega}^{\bar{A}}
$$

8.64 \kinEnDefII

`\kinEnDefII`

Kinetic energy definition II. Expression for the kinetic energy for a rigid body with body frame $\bar{A}$. Valid for any frames $\bar{O}$ and $\bar{A}$.

No input arguments.

Example

Show kinetic energy definition II.

This is accomplished with the LaTeX below:

```
\kinEnDefII
```

Display Mode Output

$$
{}^{\bar{O}}T_{O} = \tfrac{1}{2} m_{\mathrm{T}} {}^{\bar{O}}\vec{v}_{A/O} \cdot {}^{\bar{O}}\vec{v}_{A/O} + m_{\mathrm{T}} {}^{\bar{O}}\vec{v}_{A/O} \cdot {}^{\bar{O}}\vec{v}_{\mathrm{CM}/A} + \tfrac{1}{2} {}^{\bar{O}}\vec{\omega}^{\bar{A}} \cdot \tilde{I}_{A} \cdot {}^{\bar{O}}\vec{\omega}^{\bar{A}}
$$

8.65 \kinEnDefIII

`\kinEnDefIII`

Kinetic energy definition III. Expression for the kinetic energy for a rigid body with body frame $\bar{A}$ and $A = CM$. Valid for any frames $\bar{O}$ and $\bar{A}$.

No input arguments.

Example

Show kinetic energy definition III.

This is accomplished with the LaTeX below:

```
\kinEnDefIII
```

Display Mode Output

$$ {}^{\bar{O}}T_{O} = \frac{1}{2} m_{\mathrm{T}} \, {}^{\bar{O}}\vec{v}_{\mathrm{CM}/O} \cdot {}^{\bar{O}}\vec{v}_{\mathrm{CM}/O} + \frac{1}{2} \, {}^{\bar{O}}\vec{\omega}^{\bar{A}} \cdot \tilde{I}_{\mathrm{CM}} \cdot {}^{\bar{O}}\vec{\omega}^{\bar{A}} $$

8.66 \kinEnDefIV

`\kinEnDefIV`

Kinetic energy definition IV. Expression for the kinetic energy for a rigid body with body frame $\bar{A}$ and A is a fixed point with respect to O (${}^{\bar{O}}\vec{v}_{A/O} = \vec{0}$). Valid for any frames $\bar{O}$ and $\bar{A}$.

No input arguments.

Example

Show kinetic energy definition IV.

This is accomplished with the LaTeX below:

```
\kinEnDefIV
```

Display Mode Output

$$ {}^{\bar{O}}T_{O} = \frac{1}{2} \, {}^{\bar{O}}\vec{\omega}^{\bar{A}} \cdot \tilde{I}_{A} \cdot {}^{\bar{O}}\vec{\omega}^{\bar{A}} $$

Alternate Kinetic Energy Equations

8.67 \TEq

`\TEq`

Alternative kinetic energy definition. Used to evaluate Ljapunov/Liapunov stability.

No input arguments.

Example

Show the alternative kinetic energy definition.

This is accomplished with the LaTeX below:

```
\TEq
```

Display Mode Output

$$^{\bar{O}}T_{o} = T_2 + T_1 + T_0$$

8.68 \TzeroEq

`\TzeroEq`

T_0 equation. This command defines the zeroth-order term of the kinetic energy.

No input arguments.

Example

Show the definition of T_0.

This is accomplished with the LaTeX below:

```
\TzeroEq
```

Display Mode Output

$$T_0 = \gamma(q_1, \ldots, q_n, t)$$

8.69 \ToneEq

`\ToneEq`

T_1 equation. This command defines the first-order term of the kinetic energy.

No input arguments.

Example

Show the definition of T_1.

This is accomplished with the LaTeX below:

```
\ToneEq
```

Display Mode Output

$$T_1 = \sum_{r=1}^{n} \beta_r \dot{q}_r, \quad \beta_r = \beta_r(q_1, \ldots, q_n, t)$$

8.70 \TtwoEq

`\TtwoEq`

T_2 equation. This command defines the second-order term of the kinetic energy.

No input arguments.

Example

Show the definition of T_2.

This is accomplished with the LaTeX below:

```
\TtwoEq
```

Display Mode Output

$$T_2 = \tfrac{1}{2} \sum_{r=1}^{n} \sum_{s=1}^{n} \alpha_{rs} \dot{q}_r \dot{q}_s, \quad \alpha_{rs} = \alpha_{rs}(q_1, \ldots, q_n, t)$$

Euler's Equations of Motion

8.71 \EulerEqx

`\EulerEqx`

Euler's equation about the x-axis. This command defines Euler's equation of motion about the x-axis for a rigid body about its principal axes.

No input arguments.

Example

Show the definition of Euler's equation of motion about the x-axis.

This is accomplished with the LaTeX below:

```
\EulerEqx
```

Display Mode Output

$$\tau_x = I_{xx}\dot{\omega}_x - (I_{yy} - I_{zz})\omega_y\omega_z$$

8.72 \EulerEqy

`\EulerEqy`

Euler's equation about the y-axis. This command defines Euler's equation of motion about the y-axis for a rigid body about its principal axes.

No input arguments.

Example

Show the definition of Euler's equation of motion about the y-axis.

This is accomplished with the LaTeX below:

```
\EulerEqy
```

Display Mode Output

$$\tau_y = I_{yy}\dot{\omega}_y - (I_{zz} - I_{xx})\omega_z\omega_x$$

8.73 \EulerEqz

`\EulerEqz`

Euler's equation about the z-axis. This command defines Euler's equation of motion about the z-axis for a rigid body about its principal axes.

No input arguments.

Example

Show the definition of Euler's equation of motion about the z-axis.

This is accomplished with the LaTeX below:

```
\EulerEqz
```

Display Mode Output

$$\tau_z = I_{zz}\dot{\omega}_z - (I_{xx} - I_{yy})\omega_x\omega_y$$

Lagrange's Equations

8.74 \Lagrangian

`\Lagrangian`

Lagrangian. This command defines the Lagrangian. You can use `$\mathcal{L}$` to get $\mathcal{L}$.

No input arguments.

Example

Show the definition of the Lagrangian.

This is accomplished with the LaTeX below:

```
\Lagrangian
```

Display Mode Output

$$^{\bar{o}}\mathcal{L}_o \equiv {}^{\bar{o}}T_o - {}^{\bar{o}}V$$

8.75 \Lagrange

`\Lagrange{⟨num⟩}`

Lagrange's equation. This command defines Lagrange's equation of a specified q_n where $n = \langle num \rangle$.

$\langle num \rangle$ = Number; positive integer

Example

Say we want to define Lagrange's equation for an arbitrary q_n.

This is accomplished with the LaTeX below:

```
\Lagrange{n}
```

Display Mode Output

$$\frac{\mathrm{d}}{\mathrm{dt}} \frac{\partial^{\bar{o}}\mathcal{L}_o}{\partial \dot{q}_n} - \frac{\partial^{\bar{o}}\mathcal{L}_o}{\partial q_n} = Q_{n,\mathrm{nc}}$$

8.76 \LagrangeTV

`\LagrangeTV{⟨num⟩}`

Lagrange's equation energy form. This command defines Lagrange's equation of a specified q_n where $n = \langle num \rangle$ in terms of the kinetic and potential energy.

$\langle num \rangle$ = Number; positive integer

Example

Say we want to define Lagrange's equation in energy form for an arbitrary q_n.

This is accomplished with the LaTeX below:

```
\LagrangeTV{n}
```

Display Mode Output

$$\frac{\mathrm{d}}{\mathrm{dt}} \frac{\partial}{\partial \dot{q}_n} {}^{\bar{o}}T_o - \frac{\partial}{\partial q_n} {}^{\bar{o}}T_o + \frac{\partial}{\partial q_n} {}^{\bar{o}}V = Q_{n,\mathrm{nc}}$$

Kane's Equations

8.77 \KaneEq

`\KaneEq`

Kane's equation. This command defines Kane's equation of motion.

No input arguments.

Example

Display Kane's equation of motion.

This is accomplished with the LaTeX below:

```
\KaneEq
```

Display Mode Output

$$F_r + F_r^* = 0$$

8.78 \Kaneqdot

`\Kaneqdot`

Kane's $\dot{q}_s$ definition. Defines the time derivative of the generalized coordinate.

No input arguments.

Example

Display Kane's $\dot{q}_s$ definition.

This is accomplished with the LaTeX below:

```
\Kaneqdot
```

Display Mode Output

$$\dot{q}_s = \sum_{i=1}^{n} w_{sr} u_r + x_s, \quad s = 1, \ldots, n$$

8.79 \Kaneomegar

`\Kaneomegar`

Kane's ${}^{\bar{O}}\vec{\omega}_r^{\bar{B}}$ definition. Defines the rth partial angular velocity.

No input arguments.

Example

Display Kane's ${}^{\bar{O}}\vec{\omega}_r^{\bar{B}}$ definition.

This is accomplished with the LaTeX below:

```
\Kaneomegar
```

Display Mode Output

$${}^{\bar{O}}\vec{\omega}_r^{\bar{B}} = \sum_{s=1}^{n} w_{sr}\, {}^{\bar{O}}\vec{P}_{q_s}^{\bar{B}}$$

8.80 \Kaneomegat

`\Kaneomegat`

Kane's ${}^{\bar{O}}\vec{\omega}_t^{\bar{B}}$ definition. Defines the time partial angular velocity.

No input arguments.

Example

Display Kane's ${}^{\bar{O}}\vec{\omega}_t^{\bar{B}}$ definition.

This is accomplished with the LaTeX below:

```
\Kaneomegat
```

Display Mode Output

$${}^{\bar{O}}\vec{\omega}_t^{\bar{B}} = {}^{\bar{O}}\vec{P}_t^{\bar{B}} + \sum_{s=1}^{n} x_s\, {}^{\bar{O}}\vec{P}_{q_s}^{\bar{B}}$$

8.81 \Kaneomega

\Kaneomega

Kane's ${}^{\bar{O}}\vec{\omega}^{\bar{B}}$ definition. Defines the angular velocity.

No input arguments.

Example

Display Kane's ${}^{\bar{O}}\vec{\omega}^{\bar{B}}$ definition.

This is accomplished with the LaTeX below:

```
\Kaneomega
```

Display Mode Output

$$ {}^{\bar{O}}\vec{\omega}^{\bar{B}} = {}^{\bar{O}}\vec{\omega}_t^{\bar{B}} + \sum_{r=1}^{n} {}^{\bar{O}}\vec{\omega}_r^{\bar{B}} $$

8.82 \Kanevcmr

\Kanevcmr

Kane's ${}^{\bar{O}}_{O}\vec{v}_{\mathrm{CM},r}$ definition. Defines the rth partial velocity.

No input arguments.

Example

Display Kane's ${}^{\bar{O}}_{O}\vec{v}_{\mathrm{CM},r}$ definition.

This is accomplished with the LaTeX below:

```
\Kanevcmr
```

Display Mode Output

$$ {}^{\bar{O}}_{O}\vec{v}_{\mathrm{CM},r} = \sum_{s=1}^{n} w_{sr} \, {}^{\bar{O}}\frac{\partial}{\partial q_s}\left(\vec{r}_{\mathrm{CM}/O}\right) $$

8.83 \Kanevcmt

`\Kanevcmt`

Kane's ${}^{\bar{O}}_{O}\vec{v}_{\text{CM},t}$ definition. Defines the time partial velocity.

No input arguments.

Example

Display Kane's ${}^{\bar{O}}_{O}\vec{v}_{\text{CM},t}$ definition.

This is accomplished with the LaTeX below:

```
\Kanevcmt
```

Display Mode Output

$$ {}^{\bar{O}}_{O}\vec{v}_{\text{CM},t} = \frac{{}^{\bar{O}}\partial}{\partial t}\left(\vec{r}_{\text{CM}/O}\right) + \sum_{s=1}^{n} x_s \, {}^{\bar{O}}\frac{\partial}{\partial q_s}\left(\vec{r}_{\text{CM}/O}\right) $$

8.84 \Kanevcm

`\Kanevcm`

Kane's ${}^{\bar{O}}\vec{v}_{\text{CM}/O}$ definition. Defines the velocity.

No input arguments.

Example

Display Kane's ${}^{\bar{O}}\vec{v}_{\text{CM}/O}$ definition.

This is accomplished with the LaTeX below:

```
\Kanevcm
```

Display Mode Output

$$ {}^{\bar{O}}\vec{v}_{\text{CM}/O} = {}^{\bar{O}}_{O}\vec{v}_{\text{CM},t} + \sum_{r=1}^{n} {}^{\bar{O}}_{O}\vec{v}_{\text{CM},r} u_r $$

8.85 \KaneFrPart

`\KaneFrPart`

Kane's F_r term for particles.

No input arguments.

Example

Show Kane's F_r term for particles.

This is accomplished with the LaTeX below:

```
\KaneFrPart
```

Display Mode Output

$$\sum_{l=1}^{N_{\mathrm{P}}} \vec{f}_l \cdot {}^{\bar{O}}_{O}\vec{v}_{m_l,r}$$

8.86 \KaneFrsPart

`\KaneFrsPart`

Kane's F_r^* term for particles.

No input arguments.

Example

Show Kane's F_r^* term for particles.

This is accomplished with the LaTeX below:

```
\KaneFrsPart
```

Display Mode Output

$$-\sum_{l=1}^{N_{\text{P}}} m_l \,{}^{\bar{O}}\vec{a}_{m_l/O} \cdot {}^{\bar{O}}_{O}\vec{v}_{m_l,r}$$

8.87 \KaneFrRig

`\KaneFrRig`

Kane's F_r term for rigid bodies.

No input arguments.

Example

Show Kane's F_r term for rigid bodies.

This is accomplished with the LaTeX below:

```
\KaneFrRig
```

Display Mode Output

$$\sum_{k=1}^{N_{\text{R}}} \left(\vec{F}_k \cdot {}^{\bar{O}}_{O}\vec{v}_{\text{CM}k,r} + \vec{\tau}_{k,\text{CM}k} \cdot {}^{\bar{O}}\vec{\omega}_r^{\bar{B}_k} \right)$$

8.88 \KaneFrsRig

`\KaneFrsRig`

Kane's F_r^* term for rigid bodies.

No input arguments.

Example

Show Kane's F_r^* equation for rigid bodies.

This is accomplished with the LaTeX below:

```
\KaneFrsRig
```

Display Mode Output

$$-\sum_{k=1}^{N_{\mathrm{R}}}\left(m_k\,{}^{\bar{O}}\vec{a}_{\mathrm{CM}k/O}\cdot{}^{\bar{O}}_{O}\vec{v}_{\mathrm{CM}k,r}+\left(\tilde{I}_{\mathrm{CM}k}\cdot{}^{\bar{O}}\vec{\alpha}^{\bar{B}_k}+{}^{\bar{O}}\vec{\omega}^{\bar{B}_k}\times\tilde{I}_{\mathrm{CM}k}\cdot{}^{\bar{O}}\vec{\omega}^{\bar{B}_k}\right)\cdot{}^{\bar{O}}\vec{\omega}_r^{\bar{B}_k}\right)$$

8.89 \KaneFr

`\KaneFr`

Kane's generalized F_r equation. The command defines Kane's F_r equation for a general system of N_{R} rigid bodies and N_{P} particles.

No input arguments.

Example

Show Kane's generalized F_r equation.

This is accomplished with the LaTeX below:

```
\KaneFr
```

Display Mode Output

$$F_r=\sum_{k=1}^{N_{\mathrm{R}}}\left(\vec{F}_k\cdot{}^{\bar{O}}_{O}\vec{v}_{\mathrm{CM}k,r}+\vec{\tau}_{k,\mathrm{CM}k}\cdot{}^{\bar{O}}\vec{\omega}_r^{\bar{B}_k}\right)+\sum_{l=1}^{N_{\mathrm{P}}}\vec{f}_l\cdot{}^{\bar{O}}_{O}\vec{v}_{m_l,r}$$

8.90 \KaneFrs

`\KaneFrs`

Kane's generalized F_r^* equation. The command defines Kane's F_r^* equation for a general system of N_{R} rigid bodies and N_{P} particles.

No input arguments.

Example

Show Kane's generalized F_r^* equation.

This is accomplished with the LaTeX below:

```
\KaneFrs
```

Display Mode Output

$$F_r^* = -\sum_{k=1}^{N_{\text{R}}} \left(m_k \, {}^{\bar{O}}\vec{a}_{\text{CM}k/O} \cdot {}^{\bar{O}}_{O}\vec{v}_{\text{CM}k,r} + \left(\tilde{I}_{\text{CM}k} \cdot {}^{\bar{O}}\vec{\alpha}^{\bar{B}_k} + {}^{\bar{O}}\vec{\omega}^{\bar{B}_k} \times \tilde{I}_{\text{CM}k} \cdot {}^{\bar{O}}\vec{\omega}^{\bar{B}_k} \right) \cdot {}^{\bar{O}}\vec{\omega}_r^{\bar{B}_k} \right) \cdots$$
$$+ \left(-\sum_{l=1}^{N_{\text{P}}} m_l \, {}^{\bar{O}}\vec{a}_{m_l/O} \cdot {}^{\bar{O}}_{O}\vec{v}_{m_l,r} \right)$$

9 Miscellaneous Commands

This section contains miscellaneous commands that do not fit into the other categories. Currently, there are only used to format characters as italicized small caps and arrange them as (pre-)super/subscripts. They are necessary to improve the appearance of capital letter superscripts and subscripts and their kerning.[3]

9.1 \CM

`\CM`

Center of mass. Creates small caps of CM for scripts.

No input arguments.

Example

Define the position vector $\vec{r}$ relative to the center of mass.

This is accomplished with the LaTeX below:

```
\vec{r}_{\CM}
```

Display/Inline Mode Output

$$\vec{r}_{\mathrm{CM}}$$

9.2 \comma

`\comma`

Comma. Creates a comma with adjusted kerning for scripts with small caps.

No input arguments.

Example

Show an example using the subscript $k, mathrmCM, i$.

This is accomplished with the LaTeX below:

```
v_{k,\CM,i} \text{ vs } v_{k\comma\CM\comma i}
```

Display/Inline Mode Output

$$v_{k,\mathrm{CM},i} \text{ vs } v_{k,\mathrm{CM},i}$$

[3]In future versions, other helper commands to aid in formatting may be added here. Ideally, however, commands will look at the input arguments and adjust the kerning automatically to reduce reliance on a lot of these helper commands. This requires advanced LaTeX scripting which is currently beyond my level. Eventually, the switch will be made though, making the package produce results that look better for users at the expense of some additional overhead and complexity.

9.3 \smca

`\smca{⟨string⟩}`

Small-caps. This command is used to convert text to small caps. This is necessary when subscripts or superscripts are capital letters. All previous commands that involve points or frames use this automatically but arbitrary subscripts and superscripts need this to specified explicitly. Note that for subscripts, you may need to adjust the spacing with `\!` or another command that adjusts kerning such as `\mkern`.

⟨*string*⟩ = String of characters

Example

Compare a superscript A and subscript B on v with and without small caps.

This is accomplished with the LaTeX below:

```
v^{A}_{\smca{b}} \text{ vs } v^{\smca{a}}_{\!\smca{b}}
```

Display/Inline Mode Output

$$v^{A}_{\textsc{b}} \text{ vs } v^{\textsc{a}}_{\!\textsc{b}}$$

9.4 \smn

`\smn{⟨expr⟩}`

Small number. This command is used to reduce math text to 50% of its original size after making it upright.

⟨*expr*⟩ = Expression; math expression or text

Example

Compare a subscript of Aircraft1 on v creating manually, using `\smca`, and using `\smn`.

This is accomplished with the LaTeX below:

```
v_{\mathit{Aircraft1}}
\text{ vs }
v_{\smca{Aircraft1}}
\text{ vs }
v_{\smn{Aircraft1}}
```

Display/Inline Mode Output

$$v_{\mathit{Aircraft1}} \text{ vs } v_{\textsc{Aircraft1}} \text{ vs } v_{\mathrm{Aircraft1}}$$

9.5 \sm

`\sm{⟨expr⟩}`

Small. This command is used to reduce any expression to 50% of its original size.

⟨*expr*⟩ = Expression; math expression or text

Example

Compare a subscript of Aircraft1 on v with, `\sm`, `\smn`, and `\smca`.

This is accomplished with the LaTeX below:

```
v_{\sm{Aircraft1}}
\text{ vs }
v_{\smn{Aircraft1}}
\text{ vs }
v_{\smca{Aircraft1}}
```

Display/Inline Mode Output

$$v_{Aircraft1} \text{ vs } v_{\mathrm{Aircraft1}} \text{ vs } v_{AIRCRAFT1}$$

9.6 \bart

`\bart{⟨sym⟩}`

Adds a slightly wider and thicker bar to the specified ⟨*sym*⟩.

⟨*sym*⟩ = Symbol; letter or symbol

Example

Compare `\bart` to `\bar` for the letter F

This is accomplished with the LaTeX below:

```
\bart{O} \text{ vs } \bar{O}
```

Display/Inline Mode Output

$$\bar{O} \text{ vs } \bar{O}$$

9.7 \Vs

`\Vs{⟨var⟩}{⟨sc1⟩}{⟨sc2⟩}{⟨sc3⟩}{⟨sc4⟩}`

Variable square scripts. Adds scripts to all corners of the input ⟨*var*⟩. Note that unlike the following `\V*` commands, this one does not adjust the kerning of any argument and is equivalent to `\tensor*[^{sc1}_{sc2}]{var}{_{sc3}^{sc4}}`.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Upper-left script; expression
⟨*sc2*⟩ = Lower-left script; expression
⟨*sc3*⟩ = Lower-right script; expression
⟨*sc4*⟩ = Upper-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Vs{a}{b}{c}{d}{e}
```

Display/Inline Mode Output

$${}^{b}_{c}a^{e}_{d}$$

9.8 \Vlt

`\Vlt{⟨var⟩}{⟨sc1⟩}{⟨sc2⟩}{⟨sc3⟩}`

Variable lower triangular scripts. Adds scripts to the lower triangular corners of the input ⟨*var*⟩.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Upper-left script; expression
⟨*sc2*⟩ = Lower-left script; expression
⟨*sc3*⟩ = Lower-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Vlt{a}{b}{c}{d}
```

Display/Inline Mode Output

$${}^{b}_{c}a_{d}$$

9.9 \Vut

`\Vut{⟨var⟩}{⟨sc1⟩}{⟨sc2⟩}{⟨sc3⟩}`

Variable upper triangular scripts. Adds scripts to the upper triangular corners of the input ⟨*var*⟩.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Upper-left script; expression
⟨*sc2*⟩ = Upper-right script; expression
⟨*sc3*⟩ = Lower-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Vut{a}{b}{c}{d}
```

Display/Inline Mode Output

$${}^{b}a^{c}_{d}$$

9.10 \Vup

`\Vup{⟨var⟩}{⟨sc1⟩}{⟨sc2⟩}`

Variable upper scripts. Adds scripts to all upper corners of the input ⟨*var*⟩.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Upper-left script; expression
⟨*sc2*⟩ = Upper-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Vup{a}{b}{c}
```

Display/Inline Mode Output

$${}^{b}a^{c}$$

9.11 \Vdg

`\Vdg{⟨var⟩}{⟨sc1⟩}{⟨sc2⟩}`

Variable diagonal scripts. Adds scripts to all main diagonal corners of the input ⟨*var*⟩.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Upper-left script; expression
⟨*sc2*⟩ = Lower-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Vdg{a}{b}{c}
```

Display/Inline Mode Output

$${}^{b}a_{c}$$

9.12 \Vsup

`\Vsup{⟨var⟩}{⟨sc1⟩}`

Variable superscript. Adds superscript to the input ⟨*var*⟩.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Upper-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Vsup{a}{b}
```

Display/Inline Mode Output

$$a^{b}$$

9.13 \Vsub

`\Vsub{⟨var⟩}{⟨sc1⟩}`

Variable subscript. Adds subscript to the input ⟨*var*⟩.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Lower-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Vsub{a}{b}
```

Display/Inline Mode Output

$$a_b$$

9.14 \Vpup

`\Vpup{⟨var⟩}{⟨sc1⟩}`

Variable presuperscript. Adds presuperscript to the input ⟨*var*⟩.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Upper-left script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Vpup{a}{b}
```

Display/Inline Mode Output

$${}^{b}a$$

9.15 \Ms

\Ms{⟨*mat*⟩}{⟨*sc1*⟩}{⟨*sc2*⟩}{⟨*sc3*⟩}{⟨*sc4*⟩}

Matrix square scripts. Adds scripts to all corners of the input matrix or other upright expression ⟨*mat*⟩.

⟨*mat*⟩ = Matrix (or upright expression), expression
⟨*sc1*⟩ = Upper-left script; expression
⟨*sc2*⟩ = Lower-left script; expression
⟨*sc3*⟩ = Lower-right script; expression
⟨*sc4*⟩ = Upper-right script; expression

Example

Show what ascending letters look like as arguments on the 3x3 identity matrix.

This is accomplished with the LaTeX below:

```
\Ms{\eyeMatiii}{a}{b}{c}{d}
```

Display Mode Output

$$ {}^{a}_{b}\!\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}^{d}_{c} $$

9.16 \Mup

\Mup{⟨*mat*⟩}{⟨*sc1*⟩}{⟨*sc2*⟩}

Matrix upper scripts. Adds scripts to upper corners of the input matrix or other upright expression ⟨*mat*⟩.

⟨*mat*⟩ = Matrix (or upright expression), expression
⟨*sc1*⟩ = Upper-left script; expression
⟨*sc2*⟩ = Upper-right script; expression

Example

Show what ascending letters look like as arguments on the 3x3 identity matrix.

This is accomplished with the LaTeX below:

```
\Mup{\eyeMatiii}{a}{b}
```

Display Mode Output

$$ {}^{a}\!\begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}^{b} $$

9.17 \Msub

\Msub{⟨*mat*⟩}{⟨*sc1*⟩}

Matrix subscript. Adds subscript to the input matrix or other upright expression ⟨*mat*⟩.

⟨*mat*⟩ = Matrix (or upright expression), expression
⟨*sc1*⟩ = Lower-right script; expression

Example

Show what ascending letters look like as arguments on the 3x3 identity matrix.

This is accomplished with the LaTeX below:

```
\Msub{\eyeMatiii}{a}
```

Display Mode Output

$$\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}_a$$

9.18 \Mpup

\Mpup{⟨*mat*⟩}{⟨*sc1*⟩}

Matrix presuperscript. Adds presuperscript to the input matrix or other upright expression ⟨*mat*⟩.

⟨*mat*⟩ = Matrix (or upright expression), expression
⟨*sc1*⟩ = Upper-left script; expression

Example

Show what ascending letters look like as arguments on the 3x3 identity matrix.

This is accomplished with the LaTeX below:

```
\Mpup{\eyeMatiii}{a}
```

Display Mode Output

$${}^{a}\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}$$

9.19 \But

`\But{⟨var⟩}{⟨sc1⟩}{⟨sc2⟩}{⟨sc3⟩}`

Bracket then upper triangular scripts. Adds scripts to the upper triangular corners of the added brackets around input ⟨*var*⟩ .

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Upper-left script; expression
⟨*sc2*⟩ = Upper-right script; expression
⟨*sc3*⟩ = Lower-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\But{a}{b}{c}{d}
```

Display/Inline Mode Output

$$^{b}[a]^{c}_{d}$$

9.20 \Bup

`\Bup{⟨var⟩}{⟨sc1⟩}{⟨sc2⟩}`

Bracket then upper scripts. Adds scripts to all upper corners of the added brackets around input ⟨*var*⟩.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Upper-left script; expression
⟨*sc2*⟩ = Upper-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Bup{a}{b}{c}
```

Display/Inline Mode Output

$$^{b}[a]^{c}$$

9.21 \Bsub

`\Bsub{⟨var⟩}{⟨sc1⟩}`

Bracket than subscript. Adds subscript to the added brackets around input ⟨*var*⟩.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Lower-right script; expression

Example

Show what ascending letters look like as arguments.

This is accomplished with the LaTeX below:

```
\Bsub{a}{b}
```

Display/Inline Mode Output

$$[a]_b$$

9.22 \Bsubv

`\Bsubv{⟨var⟩}{⟨sc1⟩}`

Bracket then subscript for vectors. Adds subscript to the added brackets around input ⟨*var*⟩. Note that this is needed to adjust the second bracket so that it is further from the vector arrow. Equivalent to `\Bsubt{var\mkern+2mu}`. Additionally, some symbols may appear fine without this additional kerning, which is why it was added in a separate command rather than by default in the previous command.

⟨*var*⟩ = Variable; expression
⟨*sc1*⟩ = Lower-right script; expression

Example

Show what ascending letters look like as arguments and compare to `\Bsub`

This is accomplished with the LaTeX below:

```
\Bsubv{\vec{a}}{b} \text{ vs } \Bsub{\vec{a}}{b}
```

Display/Inline Mode Output

$$[\vec{a}\mkern+2mu]_b \text{ vs } [\vec{a}]_b$$

10 Additional Information

This section contains additional information about the package including installation instructions, packages used for documentation and a brief description of what they are used for, and planned features for future versions.

10.1 Installation Instructions

There are currently two main ways to use this package:

1. The first is to download the `advanceddynamics.sty` file from GitHub and simply place it in the same folder as your document.
2. The second is to copy the package to your local distribution so that you can use it from any document. We will examine the first method here.

First download your preferred release from GitHub and then extract it.

Next, locate the install location for local packages. Default locations for the most common distributions are listed below:

- MacTeX (Mac Only)
  - `$HOME\Library\texmf`[4]
- MiKTeX (Windows/Linux/Mac)
  - User Specified: `https://miktex.org/kb/texmf-roots#:~:text=Your%20own%20TEXMF%20root%20directories`
- TeXLive (Windows/Linux/Mac)
  - Linux/Mac: `\usr\local\texlive\texmf-local`
  - Windows: `C:\Users\<user>\texlive\texmf-local`

Once you have located the folder, copy the `tex` and `doc` folders from the extracted package into this folder. The package should now be accessible to your preferred LaTeX distribution and IDE for all documents.

In the future, I hope that this package will be included with the distributions and then this setup will be unnecessary.

10.2 Additional Packages

In addition to the five packages used for typesetting equations in the main package, several additional packages were used to create this documentation. Note that for convenience, all of the packages used (including the ones mentioned in the Introduction, Section 1) and a brief description of what they are used for are listed on the following page:

[4] Note that the `Library` directory is hidden by default on Mac

1. `advanceddynamics.sty`: Provides package macros and commands

    `accents` for defining custom bar accent `\bart` [1]
    `amsmath` for math notation [4]
    `amssymb` for math symbols [6]
    `graphicx` for scaling subscripts and superscripts [2]
    `mathtools` for additional math functionality [3]
    `tensor` for prescripts [5]

2. `advdyndoc.sty`: Provides documentation macros and commands

    `amsmath` for math `align*` environment [4]
    `fontenc` for ASCII/monospace characters [Standard LaTeX 2_ε package]
    `tcolorbox` for titled example boxes and documentation commands [16]
    `xcolor` for custom text colors [13]
    `xparse` for `\NewDocumentCommand` command [15]

3. `advanceddynamicsmanual.tex`: Creates documentation PDF

    `advanceddynamics` for typesetting examples [See above]
    `advdyndoc` for documentation and formatting [See above]
    `biblatex` for generating the references section [9]
    `datetime2` for getting and formatting the current date [17]
    `enumitem` for formatting lists like these [8]
    `fancyhdr` for setting the document header [12]
    `geometry` for setting page layout [18]
    `hyperref` for linking to sections/labels and urls [14]
    `imakeidx` for generating the index section [7]
    `lastpage` for getting the last page number [11]
    `parskip` for removing paragraph indents [10]

10.3 Todos

This section details a list of planned future features to the package. Current plans include:

1. Use `xparse` to migrate commands from `\newcommand*` to `\DeclareDocumentCommand` and `\DeclareExpandableDocumentCommand`
    - Keep backwards compatibility, only modify/add commands
    - Unify frame and numbered frame notation by adding an optional input argument
    - Update commands that commonly have added subscripts/superscripts with an optional input argument
2. Update package to support importing macros/commmands by section
3. Format package to work with normal LaTeX installation methods
4. Allow for automatic splitting of long equations rather than predefined splits without breaking other math packages (difficult)

References for Package

[1] Javier Bezos. *The accents Package*. Version 1.4. May 12, 2006. URL: `https://mirrors.ctan.org/macros/latex/contrib/accents/accents.pdf`.

[2] David Carlisle and The LaTeX3 Project. *The graphicx Package*. Version 1.2d. Sept. 16, 2021. URL: `https://mirrors.ctan.org/macros/latex/required/graphics/grfguide.pdf`.

[3] Lars Madsen and The LaTeX3 Project. *The mathtools Package*. Version 1.29. June 29, 2022. URL: `https://mirrors.ctan.org/macros/latex/contrib/mathtools/mathtools.pdf`.

[4] The LaTeX3 Project and American Mathematical Society. *The amsmath Package*. Version 2.17o. May 13, 2023. URL: `https://mirrors.ctan.org/macros/latex/required/amsmath/amsldoc.pdf`.

[5] Philip G. Ratcliffe. *The tensor Package*. Version 2.2. July 18, 2023. URL: `https://mirrors.ctan.org/macros/latex/contrib/tensor/tensor-doc.pdf`.

[6] American Mathematical Society. *The amssymb Package*. Version 3.01. Jan. 14, 2013. URL: `https://mirror.las.iastate.edu/tex-archive/fonts/amsfonts/doc/amssymb.pdf`.

Additional References for Documentation

[7] Claudio Beccari and Enrico Gregorio. *The imakeidx Package*. Version 1.3e. Oct. 15, 2016. URL: `https://mirrors.ctan.org/macros/latex/contrib/imakeidx/imakeidx.pdf`.

[8] Javier Bezos. *The enumitem Package*. Version 3.9. June 20, 2019. URL: `https://mirrors.ctan.org/macros/latex/contrib/enumitem/enumitem.pdf`.

[9] Philip Kime and Moritz Wemheuer. *The biblatex Package*. Version 3.19. Mar. 5, 2023. URL: `https://mirrors.ctan.org/macros/latex/contrib/biblatex/doc/biblatex.pdf`.

[10] Frank Mittelbach. *The parskip Package*. Version 2.0h. Mar. 14, 2021. URL: `https://mirrors.ctan.org/macros/latex/contrib/parskip/parskip.pdf`.

[11] Hans-Martin Münch. *The lastpage Package*. Version 2.0b. (Latest 2.0c 2023-07-24). July 24, 2023. URL: `https://mirrors.ctan.org/macros/latex/contrib/lastpage/lastpage.pdf`.

[12] Pieter van Oostrum. *The fancyhdr Package*. Version 4.1. Nov. 9, 2022. URL: `https://mirrors.ctan.org/macros/latex/contrib/fancyhdr/fancyhdr.pdf`.

[13] The LaTeX Project. *The xcolor Package*. Version 2.14. June 12, 2022. URL: `https://mirrors.rit.edu/CTAN/macros/latex/contrib/xcolor/xcolor.pdf`.

[14] The LaTeX3 Project. *The hyperref Package*. Version 7.00x. (Latest 7.01b 2023-07-08). Apr. 22, 2023. URL: https://mirrors.ctan.org/macros/latex/contrib/hyperref/doc/hyperref-doc.pdf.

[15] The LaTeX3 Project. *The xparse Package*. Feb. 2, 2023. URL: https://mirrors.ctan.org/macros/latex/contrib/l3packages/xparse.pdf.

[16] Dr. Thomas F. Sturm. *The tcolorbox Package*. Version 6.0.3. (Latest 6.0.4 2023-06-19). Mar. 17, 2023. URL: https://mirrors.ctan.org/macros/latex/contrib/tcolorbox/tcolorbox.pdf.

[17] Nicola Talbot. *The datetime2 Package*. Version 1.5.7. Mar. 21, 2021. URL: https://mirrors.ctan.org/macros/latex/contrib/datetime2/datetime2.pdf.

[18] Hideo Umeki and David Carlisle. *The geometry Package*. Version 5.9. Jan. 2, 2020. URL: https://mirrors.ctan.org/macros/latex/contrib/geometry/geometry.pdf.

Note that packages that serve only as dependencies for imported packages are omitted.

Index