THE REC-THY PACKAGE

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ABSTRACT. The rec-thy package is designed to help mathematicians publishing papers in the area of recursion theory (aka Computability Theory) easily use standard notation. This includes easy commands to denote Turing reductions, Turing functionals, c.e. sets, stagewise computations, forcing and syntactic classes.

1. INTRODUCTION

This package aims to provide a useful set of LaTeX macros covering basic computability theory notation. Given the variation in usage in several areas this package had to pick particular notational conventions. The package author would like to encourage uniformity in these conventions but has included a multitude of package options to allow individual authors to choose alternative conventions or exclude that part of the package. Some effort has been made to align the semantic content of documents created with this package with the LaTeX source. The author hopes that eventually this package may be incorporated into some larger package for typesetting papers in mathematical logic.

While computability theory is now the more popular name for the subject also known as recursion theory the author deliberately choose to title this package rec-thy to avoid confusion with the proliferation of packages for typesetting computer science related disciplines. While the subject matter of computability theory and theoretical computer science overlap significantly the notational conventions often differ.

Comments, patches, suggestions etc.. are all welcome. This project is hosted on github at https://github.com/TruePath/Recursion-Theory-Latex-Package.

2. USAGE

Include the package in your document by placing `\usepackage{rec-thy}` into your preamble after placing rec-thy.sty somewhere TeX can find it. The commands in this package have been divided into related groups. The commands in a given section can be disabled by passing the appropriate package option. For instance to disable the commands in the general mathematics section and the delimiters section you would include the following in your preamble `\usepackage[nomath,nodelim]{rec-thy}`. The commands in each subsection along with their results are listed below and the

options to disable the commands in each grouping or modify their behavior are listed in that subsection. Aliases and variants of a command are listed below the initial version of a command and aliases are indented.

Significant use is made in this package of optional arguments delimited either by square brackets or parenthesis. Users of the package should take care to wrap arguments that may themselves include brackets or parenthesis in braces. For example `\REset(\REset(X){e}){i}` should be fixed to `\REset({\REset(X){e}}){i}`.

3. Alternate Symbols

While the symbols used by default in the package are suggested for adoption to achieve greater consistency users may wish to specify their own symbols and options have been provided to enable this. The following parameters may be specified.

modulescr	Sets the script used to typeset the `\module` command. Default is mathcal.
reqscr	Sets the script used to typeset requirements. Default is mathscr.
pfcasefont	Sets the script used to typeset Case in the cases helper.
emptystr	Sets the empty string symbol. Default is $\langle\rangle$
concatsym	Sets the concat symbol. Default is $\widehat{\ }$
cdeltasym	Sets the symbol used to denote computably Δ formulas. Default is ${}^{C}\Delta$.
cpisym	Same for Π formulas. Default is ${}^{C}\Pi$.
csigmasym	Same for Σ formulas. Default is ${}^{C}\Sigma$.
recfnlsym	Sets the symbol used for recursive functionals. Default is Φ.
recfsym	Sets the symbol used for recursive functions. Default is ϕ.
usesym	Sets the symbol used for the use operator. Default is $\mathfrak{u}$ where this is printed using `\symbfrak` if unicode-math is loaded and with `\mathfrak` otherwise.
ballsymb	Sets the symbol used for the ball command. Default is $\mathscr{B}$.
lstrdelim,rstrdelim	Left and right delimiters for `\str`
lcodedelim,rcodedelim	Left and right delimiters for `\code`
lpairdelim,rpairlim,pairsup	Left and right delimiters for `\pair` and superscript.

As an example of how to use these commands consider the following code changing the ball symbol to **B**.

```
\def\myballsymb{\mathbf{B}}

\usepackage[suppPriorityTrees, ballsymb=myballsymb]{rec-thy}
```

4. Commands

A few general conventions are usually followed in the commands. Whenever an operator can be used as a binary operator (as in $X \cup Y$) and as an operation on some collection $\bigcup_{i\in\omega} X_i$ the binary operator will begin with a lowercase letter `\union` and the operation on the collection will begin with a capital letter `\Union`. If the first letter is already capitalized then the second letter is used instead.

Objects that have a natural stagewise approximation generally admit an optional argument in brackets to specify a stage. For instance `\REset[s]{e}` yields $W_{e,s}$. An optional argument in parenthesis is used for relativization. For instance `\REset(X){e}` produces W_e^X. A notable exception to this rule are the formula classes where square brackets are used to indicate an oracle to be placed in the superscript, e.g., `\pizn[X]{2}` yields $\Pi_2^{0,X}$, so as not to generate confusion with the alternative notion $\Pi_2^0(X)$. Also a lowercase first letter in a formula class indicates the lightface version while a capital first letter indicates the boldface version.

Unless indicated otherwise all macros are to be used inside math mode. Indented commands indicate an alias for the command on the line above.

4.1. **Priority Trees.**

Note the commands in this section double as suggestions for standardized notation.

`\PriorityTree`	$\mathbb{T}$	Priority Tree
`\tpath`	$\mathbb{f}$	Truepath.
`\tpath[s]`	$\mathbb{f}_s$	Approximate Truepath.
`\xi \leftof \eta`	$\xi <_L \eta$	The left of relation for priority tree arguments
`\module{R}[X]{i,j}`	$\mathcal{R}_{i,j}$	Module in tree construction (superscript optional arg)
`\ball[X]{y}{s}`	$\mathscr{B}^X(y,s)$	Location of ball y (headed to X) at s
`\ball{y}{s}`	$\mathscr{B}(y,s)$	Location of ball y at s

4.2. **Computations.**

To disable these commands pass the option `nocomputations`. To specify an alternative symbol for either recursive functionals or recursive functions pass `recfnlsym=macroname` or `recfsym=macroname`. For instance, to use ψ for recursive functions and Ψ for recursive functionals pass the options `recfsym=psi, recfnlsym=Psi`.

`\murec{x}{f(x)>1}`	$\mu x\,(f(x) > 1)$	Least x satisfying condition.
`\recf{e}`	ϕ_e	Computable functions
`\recf[s]{e}`	$\phi_{e,s}$	
`\recf{e}(x)`	$\phi_e(x)$	

`\recf[s]{e}(x)`	$\phi_{e,s}(x)$	
`\recf(Y){e}`	ϕ_e^Y	
`\recf[s](Y){e}`	$\phi_{e,s}^Y$	
`\recf(Y){e}(x)`	$\phi_e^Y(x)$	
`\recf[s](Y){e}(x)`	$\phi_{e,s}^Y(x)$	
`\recfnl{e}{Y}{x}`	$\Phi_e(Y;x)$	
`\recfnl[s]{e}{Y}{x}`	$\Phi_{e,s}(Y;x)$	Computable functionals
`\recfnl{e}{Y}{}`	$\Phi_e(Y)$	
`\recfnl{e}{}{x}`	Φ_e	
`\recfnl{e}{}{}`	Φ_e	
`\recfnl{e}{}{} \cequiv \recfnl{i}{}{}`	$\Phi_e \simeq \Phi_i$	Equivalent computations
`\recfnl{e}{}{} \ncequiv \recfnl{i}{}{}`	$\Phi_e \not\simeq \Phi_i$	Inequivalent computations
`\recfnl{e}{}{x}\conv`	$\Phi_e{\downarrow}$	Convergence
`\recfnl{e}{}{x}\conv[s]`	$\Phi_e{\downarrow_s}$	
`\recfnl{e}{}{x}\nconv`	$\Phi_{e^\wedge}{\downarrow}$	Divergence
`\recfnl{e}{}{x}\nconv[s]`	$\Phi_{e^\wedge}{\downarrow_s}$	
`\use{\recfnl{e}{Y}{x}}`	$\mathfrak{u}\left[\Phi_e(Y;x)\right]$	Use of a computation.
`\REset{e}`	W_e	
`\REset[s]{e}`	$W_{e,s}$	c.e. sets
`\REset(X){e}`	W_e^X	
`\REset[s](X){e}`	$W_{e,s}^X$	
`\Hop{e}(X)`	$\mathcal{H}_e(X)$	
`\Hop[s](X){e}`	$\mathcal{H}_{e,s}(X)$	Hop sets
`\Hop[s]{e}`	$\mathcal{H}_{e,s}(\emptyset)$	
`\Hop{e}`	$\mathcal{H}_e(\emptyset)$	
`\REAop{e}{\alpha}`	$\mathcal{J}_e^\alpha$	
`\reaop[f]{\alpha}(\eset)`		

4.3. **Degrees.** To disable these commands pass the option `nodegrees`.

`\Tdeg{d}`	$\mathbf{d}$	Turing degree
`\Tjump{X}` `\jump{X}`	X'	Turing jump
`\jjump{X}`	X''	
`\jumpn{X}{n}`	$X^{(n)}$	
`\Tzero`	$\mathbf{0}$	Computable degree
`\zeroj`	$\mathbf{0}'$	
`\zerojj`	$\mathbf{0}''$	
`\zerojjj`	$\mathbf{0}'''$	
`\zeron{n}`	$\mathbf{0}^{(n)}$	
`X \Tequiv Y` `X \Teq Y`	$X \equiv_{\mathbf{T}} Y$	Turing equivalence
`X \nTequiv Y` `X \nTeq Y`	$X \not\equiv_{\mathbf{T}} Y$	Turing inequivalence
`X \Tlneq Y`	$X <_{\mathbf{T}} Y$	
`X \Tleq Y`	$X \leq_{\mathbf{T}} Y$	
`X \Tgneq Y`	$X >_{\mathbf{T}} Y$	
`X \Tgeq Y`	$X \geq_{\mathbf{T}} Y$	
`X \Tgtr Y`	$X >_{\mathbf{T}} Y$	
`X \Tless Y`	$X <_{\mathbf{T}} Y$	
`X \nTleq Y`	$X \not\leq_{\mathbf{T}} Y$	
`X \nTgeq Y`	$X \not\geq_{\mathbf{T}} Y$	
`X \Tincompat Y` `X \Tincomp Y`	$X \mid_{\mathbf{T}} Y$	Turing incompatibility

`X \Tcompat Y`
`X \nTincomp Y`
`X \nTincompat Y`
	$X \nmid_{\mathbf{T}} Y$	

`\Tdeg{d} \Tdegjoin \Tdeg{d'}`	$\mathbf{d} \vee_{\mathbf{T}} \mathbf{d}'$	Join of degrees
`\Tdeg{d} \Tdegmeet \Tdeg{d'}` `\Tdeg{d} \Tmeet \Tdeg{d'}`	$\mathbf{d} \wedge_{\mathbf{T}} \mathbf{d}'$	Meet of degrees (when defined)

`X \Tplus Y`
`X \Tjoin Y`
`\TPlus_{i \in \omega} X_i`
`\TJoin_{i \in \omega} X_i`
	$X \oplus Y$
	$\bigoplus_{i \in \omega} X_i$
		Effective join of sets

`X \ttlneq Y`	$X \lneq_{\mathrm{tt}} Y$	Truth table reducibilities
`X \ttleq Y`	$X \leq_{\mathrm{tt}} Y$	
`X \ttgneq Y`	$X \gneq_{\mathrm{tt}} Y$	
`X \ttgeq Y`	$X \geq_{\mathrm{tt}} Y$	
`X \ttgtr Y`	$X >_{\mathrm{tt}} Y$	
`X \ttless Y`	$X <_{\mathrm{tt}} Y$	
`X \ttnleq Y`	$X \not\leq_{\mathrm{tt}} Y$	
`X \ttngeq Y`	$X \not\geq_{\mathrm{tt}} Y$	

4.4. **Requirement Assistance.** To disable these commands pass the option `noreqhelper`. To disable the hyperlinked requirements pass `nohyperreqs`
Math mode is not required for `\req{R}{e}`

`\req{R}{e}`	$\mathscr{R}_e$	Requirement
`\req{R}[\nu]{e}`	$\mathscr{R}_e^\nu$	
`\req*{R}{e}`	$\mathscr{R}_e$	Requirement without hyperlinks
`\req*{R}[\nu]{e}`	$\mathscr{R}_e^\nu$	

We also introduce the following environments for introducing requirements. The requirement environment is used as follows

```
\begin{requirement}{\req{R^{*}}{r,j}}
        \recfnl{r}{B}{} = \REset{j} \implies
            \exists[k] \left( \Upsilon^{j}_k(
          C \Tplus \REset{j}) = B) \lor \
           REset{j} \Tleq \Tzero \right)
\end{requirement}
```

Giving output

$$\mathscr{R}^*_{r,j}: \qquad \Phi_r(B) = W_j \implies [\exists k]\Big(\Upsilon^j_k(C \oplus W_j) = B) \vee W_j \leq_{\mathbf{T}} \mathbf{0}\Big)$$

The require environment merges the `\req[\nu]{R}{e}` command directly into the environment arguments. It also creates an automatic label which makes use of the 1st and 2nd arguments but assumes the third argument contains only indexes whose names are subject to change. Unless `nohyperreqs` is passed the `\req[\nu]{R}{e}` automatically links to the defining require environment.

```
\begin{require}{R}{i}
        \recfnl{i}{B}{} = \REset{i} \implies    \exists
           [k] \left( \Upsilon^{i}_k(C \Tplus \REset{i
           }) = B) \lor \REset{j} \Tleq \Tzero \right)
\end{require}
```

Giving output

$$\mathscr{R}_i\colon \qquad \Phi_i(B) = W_i \implies [\exists k]\Big(\Upsilon^i_k(C \oplus W_i) = B) \vee W_j \leq_{\mathbf{T}} \mathbf{0}\Big)$$

To list multiple requirements at once without introducing unnecessary spaces we also introduce the requirements environment which can be used as follows. Note that one may *not* end the final line with a linebreak or an undesired tag will appear.

```
\begin{requirements}
\require{P}[A]{e} A \neq \recfnl{i}{}{} \\
\require{P}[B]{e} B \neq \recfnl{i}{}{} \\
\require{R}{i,\hat{i},j,\hat{j}} \recfnl{i}{A}{} = \
   hat{A} \land \recfnl{\hat{i}}{\hat{A}}{} = A \land
    \recfnl{j}{B}{} = \hat{B} \land \recfnl{\hat{j}}{\
   hat{B}}{} = B \implies \Gamma(\hat{A} \symdiff \hat
   {B}) = A \Tplus B
\end{requirements}
```

$$\mathscr{P}_e^A\colon \qquad A \neq \Phi_i$$

$$\mathscr{P}_e^B\colon \qquad B \neq \Phi_i$$

$$\mathscr{R}_{i,\hat{i},j,\hat{j}}\colon \quad \Phi_i(A) = \hat{A} \wedge \Phi_{\hat{i}}\big(\hat{A}\big) = A \wedge \Phi_j(B) = \hat{B} \wedge \Phi_{\hat{j}}\big(\hat{B}\big) = B \implies \Gamma(\hat{A} \,\Delta\, \hat{B}) = A \oplus B$$

4.5. **General Math Commands.** To disable these commands pass the option `nomath`.

`\eqdef`	$\stackrel{\text{def}}{=}$	Definitional equals
`\iffdef`	$\stackrel{\text{def}}{\iff}$	Definitional equivalence
`\aut`	Aut	Automorphisms of some structure
`\Ord`	Ord	Set of ordinals
`\abs{x}`	$\lvert x \rvert$	Absolute value
`\dom`	dom	Domain
`\rng`	rng	Range
`f\restr{X}`	$f\restriction_X$	Restriction
`\ordpair{x}{y}`	(x, y)	Ordered Pair
`f \compfunc g` `f \compose g`	$f \circ g$	Function composition
`f: X \pmapsto Y`	$f : X \nrightarrow Y$	partial function from X to Y.
`f: Y \pmapsfrom X`	$f : Y \nleftarrow X$	partial function from X to Y.
`f: X \fpmapsto Y`	$f : X \nrightarrow_{<\infty} Y$	finite partial function from X to Y.
`f: Y \fpmapsfrom X`	$f : Y \nleftarrow_{<\infty} X$	finite partial function from X to Y.
`\ParFuncs{X}{Y}`	$Y^{\subset X}$	set of partial functions from X to Y.
`\FinParFuncs{X}{Y}`	$Y^{\subset_{<\infty} X}$	set of finite partial functions from X to Y.
`\( \ensuretext{blah} \)` `\ensuretext{blah}`	blah	Types argument in text mode

4.6. **Operators.** Misc operators used in logic and computability. To disable these commands pass the option `nooperators`.

`x \meet y`	$x \wedge y$	Meet operation
`\Meet_{i\in \omega} x_i`	$\bigwedge_{i\in\omega} x_i$	
`x \join y`	$x \vee y$	Join operation
`\Join_{i\in \omega} x_i`	$\bigvee_{i\in\omega} x_i$	
`x \xor y`	$x \operatorname{xor} y$	

4.7. **Set Notation.** To disable these commands pass the option `nosets`.

Note that `\Cross` and `\cross` overwrite the existing commands saving them as `\CrossOrig` and `\crossOrig` respectively as these commands have varying meanings between different font packages. However, the other commands avoid overwriting existing commands with that name

`\set{(x,y)}{x > y}`	$\{(x,y) \mid x > y\}$	Set notation
`\set{(x,y)}`	$\{(x,y)\}$	
`\card{X}`	$\lvert X \rvert$	Cardinality
`X \union Y`	$X \cup Y$	Union
`\Union_{i \in \omega} X_i`	$\bigcup_{i\in\omega} X_i$	
`X \isect Y`	$X \cap Y$	Intersection
`\Isect_{i \in \omega} X_i`	$\bigcap_{i\in\omega} X_i$	
`X \cross Y`	$X \times Y$	Cartesian product (Cross Product)
`\Cross_{i \in \omega} X_i`	$\prod_{i\in\omega} X_i$	
`\powset{\omega}`	$\mathcal{P}(\omega)$	Powerset
`\powset[\alpha]{\omega}`	$\mathcal{P}_\alpha(A)$	Subsets of A of size $< \alpha$
`\eset`	$\varnothing$	Emptyset abbreviation
`x \nin A`	$x \notin A$	not an element
`\setcmp{X}`	$\overline{X}$	Set compliment
`X \setdiff Y`	$X - Y$	Set difference
`X \symdiff Y`	$X \Delta Y$	Symmetric difference

4.8. **Delimiters.** To disable these commands pass the option `nodelim`. To prevent only redefinition of `\llangle` and `\rrangle` (e.g. to use the XITS unusual

default) pass the option `nodoubleangles`.

`\gcode{\phi}`
`\godelnum{\phi}`
`\cornerquote{\phi}`
	$\ulcorner\phi\urcorner$	Godel Code/Corner Quotes

`\llangle x,y,z \rrangle`	$\langle\!\langle x, y, z \rangle\!\rangle$	Properly spaced double angle brackets

4.9. **Recursive vs. Computable.** To disable these commands pass the option `nonames`. To use recursive, r.e. and recursively enumerable everywhere pass the option `re`. To use computable, c.e. and computably enumerable everywhere pass the option `ce`. To force REA and CEA use the options `rea` and `cea`. If none of these options are passed the macros will expand as below. All macros in this section work in both text and math modes.

`\re`	r.e.
`\ce`	c.e.
`\REA`	REA
`\CEA`	CEA
`\recursive`	recursive
`\computable`	computable
`\recursivelyEnumerable`	recursively enumerable
`\computablyEnumerable`	computably enumerable
`\Recursive`	Recursive
`\Computable`	Computable
`\RecursivelyEnumerable`	Recursively enumerable
`\ComputablyEnumerable`	Computably enumerable

4.10. **Quantifiers & Connectives.** To disable these commands pass the option `noquants`. The commands `\exists` and `\forall` are standard but the package extends them.

`\exists[x < y]`	$[\exists x < y]$	
`\exists(x < y)`	$(\exists x < y)$	
`\exists*` `\existsinf`	$\exists^\infty$	
`\exists*[x < y]`	$\left[\exists^\infty x < y\right]$	
`\exists*(x < y)`	$(\exists^\infty x < y)$	
`\nexists[x < y]`	$\left[\nexists x < y\right]$	
`\nexists(x < y)`	$\left(\nexists x < y\right)$	
`\nexists*` `\nexistsinf`	$\nexists^\infty$	
`\nexists*[x < y]`	$\left[\nexists^\infty x < y\right]$	
`\nexists*(x < y)`	$\left(\nexists^\infty x < y\right)$	
`\forall[x < y]`	$[\forall x < y]$	
`\forall(x < y)`	$(\forall x < y)$	
`\forall*` `\forallae`	$\forall^*$	For almost all.
`\forall*[x < y]`	$\left[\forall^* x < y\right]$	
`\forall*(x < y)`	$\left(\forall^* x < y\right)$	
`\True`	$\top$	
`\False`	$\bot$	
`\Land \phi_i`	$\bigwedge \phi_i$	Operator form of and
`\Lor \phi_i`	$\bigvee \phi_i$	Operator form of or
`\LLand \phi_i`	$\bigwedge\!\!\bigwedge \phi_i$	Infinitary conjunction
`\LLor \phi_i`	$\bigvee\!\!\bigvee \phi_i$	Infinitary disjunction

4.11. **Spaces.** To disable these commands pass the option `nospaces`.

`\bstrs`	$2^{<\omega}$	Finite binary strings
`\wstrs`	$\omega^{<\omega}$	Finite sequences of integers
`\cantor`	2^ω	Cantor space
`\baire`	ω^ω	Baire space
`\Baire`	$\mathcal{N}$	Alternate baire space

4.12. **Strings.** To disable these commands pass the option `nostrings`.

To specify an alternative symbol for the empty string pass `emptystr=macroname`. For instance, to use λ as the empty string pass `emptystr=lambda`. Similarly, to specify an alternate value for the conatination symbol pass `concatsym=macroname`, e.g., if you specify `\def\plus{+}` and then pass `concatsym=plus` the concatenation symbol would be changed to $+$.

`\str{1,0,1}` `\code{5,8,13}`	$\langle 1,0,1\rangle$ $\langle 5,8,13\rangle$	Strings/Codes for strings
`\EmptyStr` `\estr`	$\langle\rangle$ $\langle\rangle$	Empty string
`\decode{\sigma}{3}`	$(\sigma)_3$	Alternate notation for $\sigma(3)$
`\sigma\concat\tau` `\sigma\concat[0]`	$\sigma^\frown\tau$ $\sigma^\frown\langle 0\rangle$	Concatenation
`\strpred{\sigma}`	σ^-	The immediate predecessor of σ
`\lh{\sigma}`	$\lvert\sigma\rvert$	Length of σ
`\sigma \incompat \tau` `\sigma \incomp \tau`	$\sigma \mid \tau$ $\sigma \mid \tau$	Incompatible strings
`\sigma \compat \tau`	$\sigma \nmid \tau$	Compatible strings
`\pair{x}{y}`	$\langle x,y\rangle$	Code for the pair (x,y)
`\setcol{X}{n}`	$X^{[n]}$	$\{y \mid \langle n,y\rangle \in X\}$
`\setcol{X}{\leq n}`	$X^{[\leq n]}$	$\{\langle x,y\rangle \mid \langle x,y\rangle \in X \wedge x \leq n\}$

4.13. **Subfunctions.** To disable these commands pass the option `nosubfuns`.

`f \subfun g`	$f \prec g$	Varieties of the function extension relation
`f \supfun g`	$f \succ g$	
`f \nsubfun g`	$f \not\prec g$	
`f \nsupfun g`	$f \not\succ g$	
`f \subfuneq g`	$f \preceq g$	
`f \subfunneq g`	$f \precneq g$	
`f \supfuneq g`	$f \succeq g$	
`f \supfunneq g`	$f \precneq g$	
`f \nsubfuneq g`	$f \not\preceq g$	
`f \nsupfuneq g`	$f \not\succeq g$	

4.14. **Trees.** To disable these commands pass the option `notrees`.

`\CBderiv{T}` `\CBderiv[\alpha]{T}`	$T^{\langle 1\rangle}$ $T^{\langle \alpha\rangle}$	Cantor-Bendixson Derivative
`\pruneTree{T}`	$T^{\langle \infty\rangle}$	$\{\sigma \in T \mid (\exists g)(g \in [T] \wedge \sigma \subset g)\}$
`\hgt{T}`	$\|T\|$	

4.15. **Set Relations.** To disable these commands pass the option `nosetrels`. Note that many of these commands are extensions of existing commands.

`X \subset* Y` `X \subseteq* Y`	$X \subset^* Y$ $X \subseteq^* Y$	All but finitely much of X is in Y
`X \supset* Y` `X \supseteq* Y`	$X \supset^* Y$ $X \supseteq^* Y$	All but finitely much of Y is in X
`X \eq Y`	$X = Y$	Macro for =
`X \eq* Y` `X \eqae Y`	$X =^* Y$	Equal mod finite
`X \infsubset Y`	$X \subset_\infty Y$	$X \subset Y \wedge \|Y \setminus X\| = \omega$
`X \infsubset* Y`	$X \subset^*_\infty Y$	$X \subset^* Y \wedge \|Y \setminus X\| = \omega$
`X \infsupset Y`	$X \supset_\infty Y$	$Y \subset X \wedge \|X \setminus Y\| = \omega$
`X \infsupset* Y`	$X \supset^*_\infty Y$	$Y \subset^* X \wedge \|X \setminus Y\| = \omega$
`X \majsubset Y`	$X \subset_m Y$	X is a major subset of Y
`X \majsupset Y`	$X \supset_m Y$	Y is a major subset of X

4.16. **Ordinal Notations.** To disable these commands pass the option `noordinalnotations`.

`\wck`	ω_1^{CK}	First non-computable ordinal
`\ordzero`	0	Notation for ordinal 0
`\abs{\alpha}`	$\lvert\alpha\rvert$	Ordinal α denotes
`\kleeneO` `\ordNotations`	$\mathcal{O}_1$	Set of ordinal notations

`\kleeneO*`
`\uniqOrdNotations`
`\kleeneOuniq`
	$\mathcal{O}_1$	Unique set of ordinal notations

`\kleeneO(X)`	$\mathcal{O}_1^X$	Relativized ordinal notations
`\kleeneO[\alpha]`	$\mathcal{O}_{1,\lvert\alpha\rvert}$	Ordinal notations for ordinals $< \lvert\alpha\rvert$
`\kleeneO*(X)[\alpha]`	$\mathcal{O}^X_{1,\lvert\alpha\rvert}$	
`\alpha \kleeneless \beta`	$\alpha <_{\mathcal{O}_1} \beta$	Ordering on notations
`\alpha \kleenel \beta`	$\alpha <_{\mathcal{O}_1} \beta$	
`\alpha \kleeneleq \beta`	$\alpha \leq_{\mathcal{O}_1} \beta$	
`\alpha \kleenegtr \beta`	$\alpha >_{\mathcal{O}_1} \beta$	
`\alpha \kleenegeq \beta`	$\alpha \geq_{\mathcal{O}_1} \beta$	
`\alpha \kleenePlus \beta`	$\alpha +_{\mathcal{O}_1} \beta$	Effective addition of notations
`\alpha \kleeneMul \beta`	$\alpha \cdot_{\mathcal{O}_1} \beta$	Effective multiplication of notations
`\kleenelim{\lambda}{n}`	$\lambda_{[n]}$	The n-th element in effective limit defining notation λ
`\kleenepred{\alpha}`	α^-	Predecessor of α if defined
`\kleenehgt{R}`	$\lVert R\rVert_{\mathcal{O}_1}$	Height of computable relation R

4.17. **Forcing.** To disable these commands pass the option `noforcing`.

`\sigma \forces \phi` `\sigma \frc \phi`	$\sigma \Vdash \phi$	σ forces ϕ
`\sigma \forces(X) \phi`	$\sigma \Vdash^X_T \phi$	ϕ is formula relative to X
`\sigma \forces[T] \phi`	$\sigma \Vdash^X_T \phi$	Local forcing on T
`\sigma \forces* \phi`	$\sigma \Vdash^* \phi$	Strong forcing

4.18. **Syntax.** To disable these commands pass the option `nosyntax`.
All syntax classes can be relativized with an optional argument in square brackets even when not listed below. Only the Δ formula classes are listed below since the syntax is identical for Σ and Π. Capitalizing the first letter gives the boldface version in all cases (except the computable infinitary formulas as this doesn't make sense). Not all formulas/abbreviations are demonstrated below given the huge number but the enough are included to make it clear what command is required to generate the desired formula class, e.g., substituting pi for delta does what you think it does.

To change the syntax for the computable infinitary formulas you can pass the options `cdeltasym=macroname`, `csigmasym=macroname` and `cpisym=macroname` where macroname is the name (without the leading \) of the macro giving the desired symbol to use for the relevant class.

`\Cdeltan[X]{\alpha}`	${}^{c}\Delta_2^X$	The computable δ_α^X formulas
`\deltan{2}`	Δ_2	
`\deltan[X]{2}`	Δ_2^X	
`\deltaZeroN[X]{2}` `\deltazn[X]{2}`	$\Delta_2^{0,X}$	
`\deltaZeroOne[X]` `\deltazi[X]`	$\Delta_1^{0,X}$	
`\sigmaZeroTwo[X]` `\sigmazii[X]`	$\Delta_2^{0,X}$	
`\deltaZeroThree[X]` `\deltaziii[X]`	$\Delta_3^{0,X}$	
`\deltaOneN[X]{2}` `\deltaIn[X]{2}`	$\Delta_2^{1,X}$	
`\deltaOneOne[X]` `\deltaIi[X]`	$\Delta_1^{1,X}$	
`\deltaOneTwo[X]` `\deltaIii[X]`	$\Delta_2^{1,X}$	
`\deltaOneThree[X]` `\deltaIiii[X]`	$\Delta_3^{1,X}$	
`\pizi`	Π_1^0	
`\pizn[X]{n}`	$\Pi_n^{0,X}$	
`\Deltan{2}`	$\underset{\sim}{\mathbf{\Delta}}_2$	
`\DeltaOneN[X]{n}`	$\underset{\sim}{\mathbf{\Delta}}_n^{1,X}$	
`\logic{\omega_1}{\omega}`	$\mathcal{L}_{\omega_1,\omega}$	Indicates the kind of infinitary logic

4.19. **Proof Cases.** The pfcases enviornment provides a numbered, referenceable division of a proof segment into cases. Pass the option `nopfcases` to disable loading of this feature. Note these features are not available if you are using the package in a beamer document (not likely to be an issue).

To see how these commands work consider the following code.

```
\begin{proof}
\begin{pfcases}
\case[\( x = y \)]\label{case:first} %
Lorem ipsum dolor sit amet, consectetur adipiscing elit. In et enim eget nisl luctus

Vestibulum semper eget velit ut lobortis. In vel finibus est. Nullam tellus dolor, pe
```

```
\case[\( x = z \land z > q \land z < r \land x + z = r \)] \label{case:second} %
Quisque consectetur, felis non congue dictum, mauris mi suscipit sem, vel laoreet jus

\begin{pfcases}
\case[\( x=2 \)] \label{case:second:sub1} %
ipsum dolor sit amet, consectetur adipiscing elit. In et enim eget nisl luctus venena
\case[\( x = 3 \)] \label{case:second:sub2} %
consectetur adipiscing elit. In et enim eget nisl luctus venenatis. Pellentesque sed
\end{pfcases}

\end{pfcases}
\end{proof}
We can now reference the case number \ref{case:second} and cleveref \cref{case:second
```

This produces the following output.

Proof. Case 1 $x = y$**:** Lorem ipsum dolor sit amet, consectetur adipiscing elit. In et enim eget nisl luctus venenatis. Pellentesque sed erat sodales, tincidunt quam non, eleifend risus. Fusce aliquam dignissim pharetra. Integer id dui ac libero tincidunt consectetur. Sed laoreet nunc nec semper laoreet.

Vestibulum semper eget velit ut lobortis. In vel finibus est. Nullam tellus dolor, pellentesque sed orci sed, ornare pretium diam. Nam vel tincidunt tellus. Nulla at mi nisl.

Case 2 $x = z \land z > q \land z < r \land x + z = r$**:** Quisque consectetur, felis non congue dictum, mauris mi suscipit sem, vel laoreet justo ipsum in tellus. Suspendisse blandit malesuada velit faucibus pulvinar.

Case 2a $x = 2$**:** ipsum dolor sit amet, consectetur adipiscing elit. In et enim eget nisl luctus venenatis. Pellentesque sed erat sodales, tincidunt quam non, eleifend risus. Fusce aliquam dignissim pharetra. Integer id dui ac libero tincidunt consectetur. Sed laoreet nunc nec semper laoreet.

Case 2b $x = 3$**:** consectetur adipiscing elit. In et enim eget nisl luctus venenatis. Pellentesque sed erat sodales, tincidunt quam non, eleifend

□

We may reference the case number 2 and cleveref case 2 as well as case 2a and cleveref case 2b.

To skip numbering and instead reference with the argument to `\case` use pfcases*. For instance, consider the following code.

```
\begin{proof}
\begin{pfcases*}
\case[\( x = y \)]\label{case*:first}  Lorem ipsum dolor sit amet, consectetur
\adipiscing elit. In et enim eget nisl luctus venenatis. Pellentesque sed erat
```

```
\sodales, tincidunt quam non, eleifend risus. Fusce aliquam dignissim pharetra.
\Integer id dui ac libero tincidunt consectetur. Sed laoreet nunc nec semper
\laoreet.

Vestibulum semper eget velit ut lobortis. In vel finibus est. Nullam tellus
dolor, pellentesque sed orci sed, ornare pretium diam. Nam vel tincidunt tellus.
Nulla at mi nisl.

\case[\( x = z \land z > q \land z < r \land x + z = r \)] \label{case*:second}
\Quisque consectetur, felis non congue dictum, mauris mi suscipit sem, vel
\laoreet justo ipsum in tellus. Suspendisse blandit malesuada velit faucibus
\pulvinar.

\begin{pfcases*}
\case[\( x=2 \)] \label{case*:second:sub1} Lorem ipsum dolor sit amet,
\consectetur adipiscing elit. In et enim eget nisl luctus venenatis.
\Pellentesque sed erat sodales, tincidunt quam non, eleifend risus. Fusce
\aliquam dignissim pharetra. Integer id dui ac libero tincidunt consectetur. Sed
\laoreet nunc nec semper laoreet.

\case[\( x = 3 \)] \label{case*:second:sub2}  consectetur adipiscing elit. In et
\enim eget nisl luctus venenatis. Pellentesque sed erat sodales, tincidunt quam
\non, eleifend
\end{pfcases*}
\end{pfcases*}
\end{proof}

Again we can ref case \ref{case*:second} and cleverref that \cref{case*:second}.  Als
```

Proof Case $x = y$**:** Lorem ipsum dolor sit amet, consectetur adipiscing elit. In et enim eget nisl luctus venenatis. Pellentesque sed erat sodales, tincidunt quam non, eleifend risus. Fusce aliquam dignissim pharetra. Integer id dui ac libero tincidunt consectetur. Sed laoreet nunc nec semper laoreet.

Vestibulum semper eget velit ut lobortis. In vel finibus est. Nullam tellus dolor, pellentesque sed orci sed, ornare pretium diam. Nam vel tincidunt tellus. Nulla at mi nisl.

Case $x = z \land z > q \land z < r \land x + z = r$**:** Quisque consectetur, felis non congue dictum, mauris mi suscipit sem, vel laoreet justo ipsum in tellus. Suspendisse blandit malesuada velit faucibus pulvinar.

Case $x = 2$**:** Lorem ipsum dolor sit amet, consectetur adipiscing elit. In et enim eget nisl luctus venenatis. Pellentesque sed erat sodales, tincidunt quam non, eleifend risus. Fusce aliquam dignissim pharetra. Integer id dui ac libero tincidunt consectetur. Sed laoreet nunc nec semper laoreet.

CASE $x = 3$**:** consectetur adipiscing elit. In et enim eget nisl luctus venenatis. Pellentesque sed erat sodales, tincidunt quam non, eleifend

□

Again we can ref case $x = z \wedge z > q \wedge z < r \wedge x + z = r$ and cleverref that case $x = z \wedge z > q \wedge z < r \wedge x + z = r$. Also case $x = 2$ and cleveref subcase $x = 3$.

If the choice of cleveref labels aren't to your taste please let me know and I will consider changing them. Also, note that by passing the options `pfcasefont=textit` one can change the font used to typeset Case to italics (or whatever other font command you choose).

4.20. **Steps.** To enable the steps environment you *must* pass the option `steps` when loading the package. This enables use of the steps environment to typeset presentation of procedures. The command `\begin{steps}` starts a list environment with an optional argument which is passed along unchanged as the optional argument to the underlying enumitem based list. Inside the steps environment the command `\step[steptitle]` prints a numbered step with steptitle displayed in bold. An example of the use of the steps environment is provided below.

```
\begin{steps}
    \step If \( x=5 \) fails to hold end the stage without acting.  Otherwise the mod

    \step If there is \( k < m  \) with \(  s_{k} - 1 \approx_i s - 1  \) perform the
        \begin{steps}
            \step Choose \( a \nin \setcol{A}{1} \) large.
            \step Set \( c = c_k, b = b_k, \hat{s}_0 = s_{k} - 1, \hat{s}_1 = s - 1 \
            \step Enumerate \( b \) into \( \setcol{A}{2} \) and set \( R_{j,e}(s) =
        \end{steps}
    \step If there is no such \( k \) we instead enumerate \( c_m \) into  \( \setcol

\end{steps}
```

This yields the following output:

Step 1 If $x = 5$ fails to hold end the stage without acting. Otherwise the module acts by executing the subsequent steps.

Step 2 If there is $k < m$ with $s_k - 1 \approx_i s - 1$ perform the following steps and end the stage.

- Step 2a Choose $a \notin A^{[1]}$ large.
- Step 2b Set $c = c_k, b = b_k, \hat{s}_0 = s_k - 1, \hat{s}_1 = s - 1$.
- Step 2c Enumerate b into $A^{[2]}$ and set $R_{j,e}(s) = 2$

Step 3 If there is no such k we instead enumerate c_m into $A^{[3]}$ and execute the procedure for expansionary stages.

4.21. **MRref.** Finally to enable the mrref helper macros pass the option `mrref`. These macros normalize the formating of mathscinet references for supported bibliography styles and ensure the MR numbers link to the mathscinet page of the article.

5. Release Notes

3.8.2 Removed option to put the set at the end of an `\REset` operation to avoid capturing later parenthesized arguments, e.g. `\REset{i}(A)` no longer works to avoid confusion with `\REset{i}(x)`. Fixed failed pdf doc update.

3.8.1 Fixed issues displaying the prime for jump operations.

3.8 Adjusted `\Tdeg` to be more beamer friendly and fixed it not to dumbly underline `0^n`. Fixed BeamerRequirements to work with differing values of `\abovedisplayskip`. Removed a few typos in docs for the requirements assistance. Added BeamerRequire and BeamerRequire* that put the requirements in a block and offer overlay specifications.

3.7 Fixed cases environment (both prettier and no problem with creating newline). Major re-factor to fix all options. Fixed bug with `\set` display. Added `\st` command inside the `\set` command to depreciate second argument. Added `\finSsets` (alt `\ssetsOfsize`), `\finsets` and optional argument to `\powset`. Changed `\REAop` so the hat is on the starred version as intended. Added the steps (experimental) environment which requires an option to enable and fixed some problems with existing options. Reimplemented `\REset` to use xparse to avoid some errors in unusual contexts. Fixed the display of `\tpath`. Depreciated `\iREAop` and `\oneREAop`. Fixed `\Join`.

3.6 Fixed `\REA[n]` so that dash is shorter. Added BeamerRequirements to add a block for requirements in beamer and fixed the requirements environment for beamer. Fixed `\req*` error. Improved syntax for `\recfnl` so it can accept a parenthesis delimited argument as the oracle. Improved `\setcol` to allow it to be used in a nested fashion without typesetting bugs. Changed the `\code` and `\pair` commands to use only a single angle bracket.

3.5 Added `\Hop` and misc code cleanup.

3.4 Eliminated dependence on undertilde which is missing from texlive

3.3.1 Fixed typo causing error under pdflatex.

3.3 - Fixed/added tweak to overline so it looks correct. Also added real symbols so that `\subfunneq` and `\supfunneq` can be defined appropriately. Added `\floor` and `\ceil`. Note these aren't yet shown off in package doc. Fixed incorrect use of tiny in math mode.

3.2 - Removed \reaop, \alphaREAop, \aREAop in favor of using the single form \REAop. Removed \functo, \map and funcomp, \hgtO as useless synonyms and removed \KleeneOBelow and KleeneOLess as beyond what the package should define. Added package option compat31 to ensure package compatibility with version 3.1. An optional parentheses delimited argument specifying the base has been added to \REAop. Both \REAop and the pair \REA/\CEA have been updated to ignore order of optional arguments. The square brackets used to delimit the argument to the use command are now auto-sized. Added \pmapsto, \pmapsfrom, \kleeneZero, \kleeneNum, \entersat. Also Misc typesetting fixes.

3.1 02/26/2019 - Fixed \wck to be ω_1^{CK}, i.e., have capitalized roman CK.

3.01 02/17/2019 - Fixed \RE \CE \Re and \Ce for the various capitalized versions. Fixed weird bug with \recfnl no longer working based on let. Removed \interior and
verb=⊂= as not really appropriate commands for the package and having bugs. Also fixed package to have correct version.

3.0 02/16/2019 - Added requirements environment for multiple requirements. Changed the \req and \require commands to take their optional argument after the first mandatory arguments as well as before. Added the commands \module and \modof and \xor. Improved the corner quotes. Added \leftofeq, \rightof, \rightofeq. Added \RE, \CE, \Ce, \Re and \Tincompat, \Tincomp, \Tcompat. Changed the way strings are symbolized and coded. Fixed suffix commands to work with unicode-math. Also added \require* inside \requirements. Added \nleftofeq, \nrightof, \nrightofeq, \nleftof. The commands \ancestor, \descendant etc... \reqof, \Astages and \Vstagesnow require the option suppPriorityTrees be passed to the class to use and should be viewed as depreciated. Fixed the options system so different symbols can be correctly passed to the class. Changed the way \recf works to comply with the usual syntax.

2.4.3 11/29/2018 - Rendered compatible with beamer by removing enumitem requirement if beamer is loaded.

2.4.2 11/29/2018 - Fixed horrible bugs introduced in last version and fixed many symbols to work even in pdflatex mode. Also have everything compiling again.

2.4.1 2/14/2018 - Moved to using xparse to define the case macros and several other macros to allow nested brackets for optional arguments. Added the recf command and cleaned up some option processing. Also worked around the mathtools/unicode-math font bug described here

2.4 1/17/2018 - Added priority tree helpers. Should be more robust with respect to existing definitions of common commands.

2.3 12/31/2017 - Added proof cases helper. Also fixed the issue with `\ncequiv` in XeLaTeX

2.2 11/14/2017 - Fixed `\Tdeg` so it works different on symbols and vars and added `\Tdegof` and `\Tvarof`. Added `\subfunneq` and `\supfunneq`.

2.1 10/05/2017 - Fixed way packages are required so rec-thy can be loaded in a flexible order. Also fixed one or two bugs.

2.0 09/26/2017 - Added support for introducing requirements, the subfunction relation and probably other undocumented features

1.3 06/20/2012 - Added abbreviations for computable infinitary formulas and made a few minor fixes.

1.2 01/01/2011 - Fixed awful option processing bug preventing most options from being recognized and added mrref option.

1.0 10/15/2010 - Initial public release