`cmathml.sty`: A TeX/LaTeX-based Syntax for Content MathML*

Michael Kohlhase
Jacobs University, Bremen
`http://kwarc.info/kohlhase`

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Abstract

The `cmathml` package is part of the sTeX collection, a version of TeX/LaTeX that allows to markup TeX/LaTeX documents semantically without leaving the document format, essentially turning TeX/LaTeX into a document format for mathematical knowledge management (MKM).

This package provides a collection of semantic macros for content MathML and their LaTeXML bindings. These macros form the basis of a naive translation from semantically preloaded LaTeX formulae into the content MathML formulae via the LaTeXML system.

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*Version ? (last revised ?)

Contents

1 Introduction

This document describes the collection of semantic macros for content MATHML and their LATEXML bindings. These macros can be used to mark up mathematical formulae, exposing their functional/logical structure. This structure can be used by MKM systems for added-value services, either directly from the STEX sources, or after translation. Even though it is part of the STEX collection, it can be used independently. Note that this documentation of the package presupposes the discussion of the STEX collection to be self-contained.

1.1 Encoding Content MathML in TEX/LATEX

The `cmathml` packge presented here addresses part of transformation problem: representing mathematical formulae in the LATEX workflow, so that content MATHML representations can be derived from them. The underlying problem is that run-of-the-mill TEX/LATEX only specifies the presentation (i.e. what formulae look like) and not their content (their functional structure). Unfortunately, there are no good methods (yet) to infer the latter from the former, but there are ways to get presentation from content.

The solution to this problem is to dump the extra work on the author (after all she knows what she is talking about) and give them the chance to specify the intended structure. The markup infrastructure supplied by the `cmathml` package lets the author do this without changing the visual appearance, so that the LATEX workflow is not disrupted.

To use these `cmathml` macros in a LATEX document, you will have to include the `cmathml` package using `\usepackage{cmathml}` somewhere in the document preamble. Then you can use the macros

```
$\Ceq{\Cexp{\Ctimes{\Cimaginaryi,\Cpi}},\Cuminus{\Ccn{1}}}$
```

which will result in $e^{i\pi} = -1$ when the document is formatted in LATEX. If the document is converted to XML using the LATEXML conversion tool, then the result will be content MATHML representation:

```
<math xmlns="http://www.w3.org/1998/Math/MathML">
  <apply>
    <eq/>
    <apply>
      <exp/>
      <apply><times><imaginaryi/><pi/></times></apply>
    </apply>
    <apply><minus/><cn>1</cn></apply>
  </apply>
</math>
```

Example 1: Content MATHML Form of $e^{i\pi} = -1$

1.2 Changing the TEX/LATEX Presentation

It is possible to change the default presentation (i.e. the result under LATEX formatting): The semantic macros only function as interface control sequences, which call an internal macro that does the actual presentation. Thus we simply have to redefine the internal macro to change the presentation. This is possible locally or globally in the following way:

```
\makeatletter
\gdef\CMathML@exp#1{exp(#1)}
\def\CMathML@pi{\varpi}
\makeatother
```

The first line is needed to lift the LATEX redefinition protection for internal macros (those that contain the character), and the last line restores it for the rest of the document. The second line has a *global* (i.e. the presentation will be changed from this point on to the end of the document.) redefinition of the presentation of the exponential function in the LATEX output. The third line has a *local* redefinition of the presentation (i.e. in the local group induced by LATEX's `begin`/`end` grouping or by TEX's grouping induced by curly braces). Note that the argument structure has to be respected by the presentation redefinitions. Given the redefinitions above, our equation above would come out as $exp(i\varpi) = -1$.

1.3 The Future: Heuristic Parsing

The current implementation of content MATHML transformation from LATEX to MATHML lays a heavy burden on the content author: the LATEX source must be semantically preloaded — the structure of the formulae must be fully annotated. In our example above, we had to write

`\Ceq{A,B}` instead of the more conventional (and more legible) `A=B`.[1]

The reason for this is that this keeps the transformation to content MATHML very simple, predictable and robust at the expense of authoring convenience. The implementation described in this module should be considered as a first step and fallback solution only. Future versions of the LATEXML tool will feature more intelligent solutions for determining the implicit structure of more conventional mathematical notations (and LATEX representations), so that writing content MATHML via LATEX will become less tedious.

However, such more advanced techniques usually rely on linguistic, structural, and semantic information about the mathematical objects and their preferred representations. They tend to be

less predictable to casual users and may lead to semantically unexpected results.[2]

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[1] EDNOTE: come up with a good mixed example
[2] EDNOTE: talk about sTeX and extensibility in MathML/OpenMath/OMDoc

2 The User Interface

We will now tabulate the semantic macros for the Content MATHML elements. We have divided them into modules based on the sectional structure of the MATHML2 recommendation (2^{nd} edition). Before we go into the specific elements one-by-one, we will discuss some general properties of the `cmatml` macros and their LaTeXML bindings.

2.1 Generalities of the Encoding

The semantic macros provided by the `cmatml` package differ mainly in the way they treat their arguments. The simplest case are those for constants 2.12 that do not take any. Others take one, two, three, or even four arguments, which have to be TeX tokens or have to be wrapped in curly braces. For operators that are associative like addition the argument sequence is provided as a single TeX argument (wrapped in curly braces) that contains a comma-separated sequence of arguments (wrapped in curly braces where necessary).

\Capply The current setup of the `cmathml` infrastructure minimizes the need of specifying the MATHML `apply` element, since the macros are all in applied form: As we have seen in the example in the Introduction 1, a macro call like `\Cexp{A}` corresponds to the application of the exponential function to some object, so the necessary `apply` elements in the MATHML representation are implicit in the LaTeX formulation and are thus added by the transformation. Of course this only works, if the function is a content MATHML element. Often, in mathematics we will have situations, where the function is a variable (or "arbitrary but fixed") function. Then the formula $f(x)$ represented as `$f(x)$` in TeX could (and sometimes will) be misunderstood by the Math parser as $f \cdot x$, i.e. a product of the number f with the number x, where x has brackets for some

EdNote(3) reason. In this case, we can disambiguate by using `\Capply{f}x`, which will also format as $f(x)$.[3]

By the same token, we do not need to represent the qualifier elements `condition` and `domainofapplication`[1], for binding operators. They are are folded into the special forms of the semantic macros for the binding operators below (the ones with the `Cond` and `DA` endings):

For operators that are associative, commutative, and idempotent (ACI i.e. bracketing, order, and multiplicity of arguments does not matter) MATHML supplies the a special form of application as a binding operator (often called the corresponding "big operator)", which ranges over a whole set of arguments. For instance for the ACI operator $\cup$ for set union has the "big" operator for unions over collections of sets e.g. used in the power set $\bigcup_{S \subseteq T} S$ of a set T. In some cases, the "big" operators are provided independently by MATHML, e.g. the ACI addition operator has the sum operator as a corresponding "big operator": $\sum_{x \in \mathbb{N}} x^i$ is the sum of the powers of x for all natural numbers. Where they are not, we will supply extra macros in the `cmathml` package, e.g. the `\CUnion` macro as the big operator for `\Cunion`.

Finally, some of the binding operators have multiple content models flagged by the existence of various modifier elements. In these cases, we have provided different semantic macros for the different cases.

2.2 The Token Elements

The MATHML token elements are very simple containers that wrap some presentation MATHML text. The `csymbol` element is the extension element in MATHML. It's content is the presentation of symbol, and it has a `definitionURL` attribute that allows to specify a URI that specifies the semantics of the symbol. This URL can be specified in an optional argument to the `\Ccsymbol`

\Ccn macro, in accordance with usual mathematical practice, the `definitionURL` is not presented.

\Cci

\Ccsymbol

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[3]EDNOTE: what about n-ary functions?

[1]We do not support the `fn` element as it is deprecated in MATHML2 and the `declare` and `sep` elements, since their semantic status is unclear (to the author, if you feel it is needed, please gripe to me).

macro	args	Example	Result
\Ccn	token	\Ccn{t}	t
\Cci	token	\Cci{t}	t
\Ccsymbol	token, URI	\Ccsymbol[http://w3.org]{t}	t

Like the \Ccsymbol macro, all other macros in the camthml package take an optional argument[2] for the definitionURL attribute in the corresponding MATHML element.

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[2]This may change into a KeyVaL argument in future versions of the cmathml package.

2.3 The Basic Content Elements

The basic elements comprise various pieces of the MATHML infrastructure. Most of the semantic macros in this section are relatively uneventful.

`\Cinverse`
`\Ccompose`
`\Cident`
`\Cdomain`
`\Ccodomain`
`\Cimage`

macro	args	Example	Result
`\Cinverse`	1	`\Cinverse{f}`	f^{-1}
`\Ccompose`	1	`\Ccompose{f,g,h}`	$f \circ g \circ h$
`\Cident`	0	`\Cident`	id
`\Cdomain`	1	`\Cdomain{f}`	$\mathrm{dom}(f)$
`\Ccodomain`	1	`\Ccodomain{f}`	$\mathrm{codom}(f)$
`\Cimage`	1	`\Cimage{f}`	$\mathbf{Im}(f)$

`\Clambda`
`\ClambdaDA`
`\Crestrict`

EdNote(4)

For the `lambda` element, we only have the `domainofapplication` element, so that we have three forms a λ-construct can have. The first one is the simple one where the first element is a bound variable. The second one restricts the applicability of the bound variable via a `domainofapplication` element, while the third one does not have a bound variable, so it is just a function restriction operator.[4]

macro	args	Example	Result
`\Clambda`	2	`\Clambda{x,y}{A}`	$\lambda(x, y, A)$
`\ClambdaDA`	3	`\ClambdaDA{x}{C}{A}`	$\lambda(x, y : C, A)$
`\Crestrict`	2	`\Crestrict{f}{S}`	$f|_S$

`ccinterval`
`cointerval`
`ocinterval`
`oointerval`

The `interval` constructor actually represents four types of intervals in MATHML. Therefore we have four semantic macros, one for each combination of open and closed endings:

macro	args	Example	Result
`\Cccinterval`	2	`\Cccinterval{1}{2}`	$[1, 2]$
`\Ccointerval`	2	`\Ccointerval{1}{2}`	$[1, 2)$
`\Cocinterval`	2	`\Cocinterval{1}{2}`	$(1, 2]$
`\Coointerval`	2	`\Coointerval{1}{2}`	$(1, 2)$

`\Cpiecewise`
`\Cpiece`
`\Cotherwise`

The final set of semantic macros are concerned with piecewise definition of functions.

macro	args	Example	Result
`\Cpiecewise`	1	see below	see below
`\Cpiece`	2	`\Cpiece{A}{B}`	A if B
`\Cotherwise`	1	`\Cotherwise{B}`	1 $else$

For instance, we could define the abstract value function on the reals with the following markup

Semantic Markup	Formatted

`\Ceq{\Cabs{x},`
`    \Cpiecewise{\Cpiece{\Cuminus{x}}{\Clt{x,0}}`
`              \Cpiece{0}{\Ceq{x,0}}`
`                  \Cotherwise{x}}}`
	$|x| = \begin{cases} -(x) & \text{if } (x < 0) \\ 0 & \text{if } (x = 0) \\ x & else \end{cases}$

---

[4]EDNOTE: need ClambdaCond

2.4 Elements for Arithmetic, Algebra, and Logic

This section introduces the infrastructure for the basic arithmetic operators. The first set is very simple

`\Cquotient`
`\Cfactorial`
`\Cdivide`
`\Cminus`
`\Cplus`
`\Cpower`
`\Crem`
`\Ctimes`
`\Croot`

macro	args	Example	Result
`\Cquotient`	2	`\Cquotient{1}{2}`	$\frac{1}{2}$
`\Cfactorial`	1	`\Cfactorial{7}`	$7!$
`\Cdivide`	2	`\Cdivide{1}{2}`	$1 \div 2$
`\Cminus`	2	`\Cminus{1}{2}`	$1 - 2$
`\Cplus`	1	`\Cplus{1}`	1
`\Cpower`	2	`\Cpower{x}{2}`	x^2
`\Crem`	2	`\Crem{7}{2}`	$7 \bmod 2$
`\Ctimes`	1	`\Ctimes{1,2,3,4}`	$1 \cdot 2 \cdot 3 \cdot 4$
`\Croot`	2	`\Croot{3}{2}`	$\sqrt[3]{2}$

The second batch below is slightly more complicated, since they take a set of arguments. In the `cmathml` package, we treat them like associative operators, i.e. they act on a single argument that contains a sequence of comma-separated arguments[5]

EdNote(5)

`\Cmax`
`\Cmin`
`\Cgcd`
`\Clcm`

macro	args	Example	Result
`\Cmax`	1	`\Cmax{1,3,6}`	$\max(1,3,6)$
`\Cmin`	1	`\Cmin{1,4,5}`	$\min(1,4,7)$
`\Cgcd`	1	`\Cgcd{7,3,5}`	$\gcd(7,3,5)$
`\Clcm`	1	`\Clcm{3,5,4}`	$\operatorname{lcm}(3,5,4)$

EdNote(6)

The operators for the logical connectives are associative as well[6]. Here, conjunction, (exclusive) disjunction are n-ary associative operators, therefore their semantic macro only has one TeX argument which contains a comma-separated list of subformulae.

`\Cand`
`\Cor`
`\Cxor`
`\Cnot`
`\Cimplies`

macro	args	Example	Result
`\Cand`	1	`\Cand{A,B,C}`	$A \wedge B \wedge C$
`\Cor`	1	`\Cor{A,B,C}`	$A \vee B \vee C$
`\Cxor`	1	`\Cxor{A,B,C}`	$A \oplus B \oplus C$
`\Cnot`	1	`\Cnot{A}`	$\neg A$
`\Cimplies`	2	`\Cimplies{A}{B}`	$A \implies B$

The following are the corresponding big operators, where appropriate.

`\CAndDA`
`\CAndCond`
`\COrDA`
`\COrCond`
`\CXorDA`
`\CXorCond`

macro	args	Example	Result
`\CAndDA`	2	`\CAndDA\Cnaturalnumbers\phi`	$\bigwedge_{\mathbb{N}} \phi$
`\CAndCond`	3	`\CAndCond{x}{\Cgt{x}5}{\psi(x)}`	$\bigwedge_x x5$
`\COrDA`	2	`\COrDA\Cnaturalnumbers\phi`	$\bigvee_{\mathbb{N}} \phi$
`\COrCond`	3	`\COrCond{x}{\Cgt{x}5}{\psi(x)}`	$\bigvee_{x5} \psi(x)$
`\CXorDA`	2	`\CXorDA\Cnaturalnumbers\phi`	$\bigoplus_{\mathbb{N}} \phi$
`\CXorCond`	3	`\CXorCond{x}{\Cgt{x}5}{\psi(x)}`	$\bigoplus_{x5} \psi(x)$

The semantic macros for the quantifiers come in two forms: with- and without a condition qualifier. In a restricted quantification of the form $\forall x, C : A$, the bound variable x ranges over all values, such that C holds (x will usually occur in the condition C). In an unrestricted quantification of the form $\forall x : A$, the bound variable ranges over all possible values for x.

`\Cforall`
`\CforallCond`
`\Cexists`
`\CexistsCond`

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[5]EdNote: implement this in the latexml side
[6]EdNote: maybe add some precedences here.

macro	args	Example	Result
\Cforall	2	\Cforall{x,y}{A}	$\forall x, y\colon A$
\CforallCond	3	\CforallCond{x}{C}{A}	$\forall x, C\colon A$
\Cexists	2	\Cexists{x,y}{A}	$\exists x, y\colon A$
\CexistsCond	3	\CexistsCond{x}{C}{A}	$\exists x, C\colon A$

The rest of the operators are very simple in structure.

macro	args	Example	Result
\Cabs	1	\Cabs{x}	$\lvert x\rvert$
\Cconjugate	1	\Cconjugate{x}	$\overline{x}$
\Carg	1	\Carg{x}	$\angle x$
\Creal	1	\Creal{x}	$\Re x$
\Cimaginary	1	\Cimaginary{x}	$\Im x$
\Cfloor	1	\Cfloor{1.3}	$\lfloor 1.3 \rfloor$
\Cceiling	1	\Cceiling{x}	$\lceil x \rceil$

2.5 Relations

The relation symbols in MATHML are mostly *n*-ary associative operators (taking a comma-separated list as an argument).

macro	args	Example	Result
\Ceq	1	\CeqA,B,C	$A = B = C$
\Cneq	2	\Cneq{1}{2}	$1 \neq 2$
\Cgt	1	\Cgt{A,B,C}	$A > B > C$
\Clt	1	\Clt{A,B,C}	$A < B < C$
\Cgeq	1	\Cgeq{A,B,C}	$A \geq B \geq C$
\Cleq	1	\Cleq{A,B,C}	$A \leq B \leq C$
\Cequivalent	1	\Cequivalent{A,B,C}	$A \equiv B \equiv C$
\Capprox	2	\Capprox{1}{2}	$1 \approx 1.1$
\Cfactorof	2	\Cfactorof{7}{21}	$7 \mid 21$

2.6 Elements for Calculus and Vector Calculus

The elements for calculus and vector calculus have the most varied forms.

The integrals come in four forms: the first one is just an indefinite integral over a function, the second one specifies the bound variables, upper and lower limits. The third one specifies a set instead of an interval, and finally the last specifies a bound variable that ranges over a set specified by a condition.

macro	args	Example	Result
\Cint	1	\Cint{f}	$\int f$
\CintLimits	4	\CintLimits{x}{0}{\Cinfinit}{f(x)}	$\int_0^\infty f(x)dx$
\CintDA	2	\CintDA{\Creals}{f}	$\int_{\mathbb{R}} f$
\CintCond	3	\CintCond{x}{\Cin{x}{D}}{f(x)}	$\int_{x \in D} f(x)dx$

The differentiation operators are used in the usual way: simple differentiation is represented by the \Cdiff macro which takes the function to be differentiated as an argument, differentiation with the *d*-notation is possible by the \Cddiff, which takes the bound variable[7] as the first argument and the function expression (in the bound variable) as a second argument.

Partial Differentiation is specified by the \Cpartialdiff macro. It takes the overall degree as

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[7]EDNOTE: really only one?

the first argument (to leave it out, just pass the empty argument). The second argument is the list of bound variables (with their degrees; see below), and the last the function expression (in these bound variables). To specify the respective degrees of differentiation on the variables, we use the `\Cdegree` macro, which takes two arguments (but no optional argument), the first one is the degree (a natural number) and the second one takes the variable. Note that the overall degree has to be the sum of the degrees of the bound variables.

\Cdegree

macro	args	Example	Result
`\Cdiff`	1	`\Cdiff{f}`	f'
`\Cddiff`	2	`\Cddiff{x}{f}`	$\frac{df(x)}{dx}$
`\Cpartialdiff`	3	`\Cpartialdiff{3}{x,y,z}{f(x,y)}`	$\frac{\partial^3}{\partial x,y,z}f(x,y)$
`\Cpartialdiff`	3	`\Cpartialdiff{7}` `{\Cdegree{2}{x},\Cdegree{4}{y},z}` `{f(x,y)}`	$\frac{\partial^7}{\partial 2^x,4^y,z}f(x,y)$

\Climit
\ClimitCond

For content MathML, there are two kinds of limit expressions: The simple one is specified by the `\Climit` macro, which takes three arguments: the bound variable, the target, and the limit expression. If we want to place additional conditions on the limit construction, then we use the `\ClimitCond` macro, which takes three arguments as well, the first one is a sequence of bound variables, the second one is the condition, and the third one is again the limit expression.

\Ctendsto
\CtendstoAbove
\CtendstoBelow

If we want to speak qualitatively about limit processes (e.g. in the condition of a `\ClimitCond` expression), then can use the MathML `tendsto` element, which is represented by the `\Ctendsto` macro, wich takes two expressions arguments. In MathML, the `tendsto` element can be further specialized by an attribute to indicate the direction from which a limit is approached. In the `cmathml` package, we supply two additional (specialized) macros for that: `\CtendstoAbove` and `\CtendstoBelow`.

macro	args	Example	Result
`\Climit`	3	`\Climit{x}{0}{\Csin{x}}`	$\lim_{x\to 0}\sin(x)$
`\ClimitCond`	3	`\ClimitCond{x}{\Ctendsto{x}{0}}{\Ccos{x}}`	$\lim_{x\to 0}\cos(x)$
`\Ctendsto`	2	`\Ctendsto{f(x)}{2}`	$f(x)\to 2$
`\CtendstoAbove`	2	`\CtendstoAbove{x}{1}`	$x\searrow 1$
`\CtendstoBelow`	2	`\CtendstoBelow{x}{2}`	$x\nearrow 2$

\Cdivergence
\Cgrad
\Ccurl
\Claplacian

macro	args	Example	Result
`\Cdivergence`	1	`\Cdivergence{A}`	$\nabla\cdot A$
`\Cgrad`	1	`\Cgrad{\Phi}`	$\nabla\Phi$
`\Ccurl`	1	`\Ccurl{\Xi}`	$\nabla\times\Xi$
`\Claplacian`	1	`\Claplacian{A}`	$\nabla^2 A$

2.7 Sets and their Operations

\Cset
\Clist
\CsetDA
\CsetRes
\CsetCond
EdNote(8)

The `\Cset` macros is used as the simple finite set constructor, it takes one argument that is a comma-separated sequence of members of the set. `\CsetRes` allows to specify a set by restricting a set of variables, and `\CsetCond` is the general form of the set construction.[8]

macro	args	Example	Result
`\Cset`	1	`\Cset{1,2,3}`	$\{1,2,3\}$
`\CsetRes`	2	`\CsetRes{x}{\Cgt{x}5}`	$\{x\|x5\}$
`\CsetCond`	3	`\CsetCond{x}{\Cgt{x}5}{\Cpower{x}3}`	$\{x5\|x^3\}$
`\CsetDA`	3	`\CsetDA{x}{\Cgt{x}5}{S_x}}`	$\{x\in x5\|S_x\}$
`\Clist`	1	`\Clist{3,2,1}`	$\mathrm{list}(3,2,1)$

`\Cunion`
`\Cintersect`
`\Ccartesianproduct`
`\Csetdiff`
`\Ccard`
`\Cin`
`\Cnotin`

macro	args	Example	Result
`\Cunion`	1	`\Cunion{S,T,L}`	$S \cup T \cup L$
`\Cintersect`	1	`\Cintersect{S,T,L}`	$S \cap T \cap L$
`\Ccartesianproduct`	1	`\Ccartesianproduct{A,B,C}`	$A \times B \times C$
`\Csetdiff`	2	`\Csetdiff{S}{L}`	$S \setminus L$
`\Ccard`	1	`\Ccard{\Cnaturalnumbers}`	$\#\mathbb{N}$
`\Cin`	2	`\Cin{a}{S}`	$a \in S$
`\Cnotin`	2	`\Cnotin{b}{S}`	$b \notin S$

`\CUnionDA`
`\CUnionCond`
`\CIntersectDA`
`\CIntersectCond`
`\CCartesianproductDA`
`\CCartesianproductCond`

The following are the corresponding big operators for the first three binary ACI functions.

macro	args	Example	Result
`\CUnionDA`	2	`\CUnionDA\Cnaturalnumbers{S_i}`	$\bigwedge_\mathbb{N} S_i$
`\CUnionCond`	3	`\CUnionCond{x}{\Cgt{x}5}{S_x}}`	$\bigwedge_x x5$
`\CIntersectDA`	2	`\CIntersectDA\Cnaturalnumbers{S_i}`	$\bigvee_\mathbb{N} S_i$
`\CIntersectCond`	3	`\CIntersectCond{x}{\Cgt{x}5}{S_x}`	$\bigvee_{x5} S_x$
`\CCartesianproductDA`	2	`\CCartesianproductDA\Cnaturalnumbers{S_i}`	$\bigoplus_\mathbb{N} S_i$
`\CCartesianproductCond`	3	`\CCartesianproductCond{x}{\Cgt{x}5}{S_x}`	$\bigoplus_{x5} S_x$

`\Csubset`
`\Cprsubset`
`\Cnotsubset`
`\Cnotprsubset`

For the set containment relations, we are in a somewhat peculiar situation: content MATHML only supplies the subset side of the reations and leaves out the superset relations. Of course they are not strictly needed, since they can be expressed in terms of the subset relation with reversed argument order. But for the cmathml package, the macros have a presentational side (for the LaTeX workflow) and a content side (for the LaTeXML converter) therefore we will need macros for both relations.

macro	args	Example	Result
`\Csubset`	1	`\Csubset{S,T,K}`	$S \subseteq T \subseteq K$
`\Cprsubset`	1	`\Cprsubset{S,T,K}`	$S \subset T \subset K$
`\Cnotsubset`	2	`\Cnotsubset{S}{K}`	$S \nsubseteq K$
`\Cnotprsubset`	2	`\Cnotprsubset{S}{L}`	$S \not\subset L$

`\Csupset`
`\Cprsupset`
`\Cnotsupset`
`\Cnotprsupset`

The following set of macros are presented in LaTeX as their name suggests, but upon transformation will generate content markup with the MATHML elements (i.e. in terms of the subset relation).

macro	args	Example	Result
`\Csupset`	1	`\Csupset{S,T,K}`	$S \supseteq T \supseteq K$
`\Cprsupset`	1	`\Cprsupset{S,T,K}`	$S \supset T \supset K$
`\Cnotsupset`	2	`\Cnotsupset{S}{K}`	$S \nsupseteq K$
`\Cnotprsupset`	2	`\Cnotprsupset{S}{L}`	$S \not\supset L$

2.8 Sequences and Series

`\CsumLimits`
`\CsumCond`
`\CsumDA`
`\CprodLimist`
`\CprodCond`
`\CprodDA`

macro	args	Example	Result
`\CsumLimits`	4	`\CsumLimits{i}{0}{50}{x^i}`	$\sum_{i=0}^{50} x^i$
`\CsumCond`	3	`\CsumCond{i}{\Cintegers}{i}`	$\sum_{i\in\mathbb{Z}} i$
`\CsumDA`	2	`\CsumDA{\Cintegers}{f}`	$\sum_\mathbb{Z} f$
`\CprodLimits`	4	`\CprodLimits{i}{0}{20}{x^i}`	$\prod_{i=202^{20}} x^i$
`\CprodCond`	3	`\CprodCond{i}{\Cintegers}{i}`	$\prod_{i\in\mathbb{Z}} i$
`\CprodDA`	2	`\CprodDA{\Cintegers}{f}`	$\prod_f$

---

[8]EDNOTE: need to do this for lists as well? Probably

2.9 Elementary Classical Functions

`\Csin`
`\Ccos`
`\Ctan`
`\Csec`
`\Ccsc`
`\Ccot`

macro	args	Example	Result
`\Csin`	1	`\Csin{x}`	$\sin(x)$
`\Ccos`	1	`\Ccos{x}`	$\cos(x)$
`\Ctan`	1	`\Ctan{x}`	$\tan(x)$
`\Csec`	1	`\Csec{x}`	$\sec(x)$
`\Ccsc`	1	`\Ccsc{x}`	$\csc(x)$
`\Ccot`	1	`\Ccot{x}`	$\cot(x)$

`\Csinh`
`\Ccosh`
`\Ctanh`
`\Csech`
`\Ccsch`
`\Ccoth`

macro	args	Example	Result
`\Csinh`	1	`\Csinh{x}`	$\sinh(x)$
`\Ccosh`	1	`\Ccosh{x}`	$\cosh(x)$
`\Ctanh`	1	`\Ctanh{x}`	$\tanh(x)$
`\Csech`	1	`\Csech{x}`	$\mathrm{sech}(x)$
`\Ccsch`	1	`\Ccsch{x}`	$\mathrm{csch}(x)$
`\Ccoth`	1	`\Ccoth{x}`	$\coth(x)$

`\Carcsin`
`\Carccos`
`\Carctan`
`\Carcsec`
`\Carccsc`
`\Carccot`

macro	args	Example	Result
`\Carcsin`	1	`\Carcsin{x}`	$\arcsin(x)$
`\Carccos`	1	`\Carccos{x}`	$\arccos(x)$
`\Carctan`	1	`\Carctan{x}`	$\arctan(x)$
`\Carccosh`	1	`\Carccosh{x}`	$\mathrm{arccosh}(x)$
`\Carccot`	1	`\Carccot{x}`	$\mathrm{arccot}(x)$

`\Carcsinh`
`\Carccosh`
`\Carctanh`
`\Carcsech`
`\Carccsch`
`\Carccoth`

macro	args	Example	Result
`\Carccoth`	1	`\Carccoth{x}`	$\mathrm{arccoth}(x)$
`\Carccsc`	1	`\Carccsc{x}`	$\mathrm{arccsc}(x)$
`\Carcsinh`	1	`\Carcsinh{x}`	$\mathrm{arcsinh}(x)$
`\Carctanh`	1	`\Carctanh{x}`	$\mathrm{arctanh}(x)$
`\Cexp`	1	`\Cexp{x}`	$\exp(x)$
`\Cln`	1	`\Cln{x}`	$\ln(x)$
`\Clog`	2	`\Clog{5}{x}`	$\log_5(x)$

2.10 Statistics

The only semantic macro that is non-standard in this module is the one for the `moment` and `momentabout` elements in MATHML. They are combined into the semantic macro `CmomentA`; its first argument is the degree, its second one the point in the distribution, the moment is taken about, and the third is the distribution.

`\Cmean`
`\Csdev`
`\Cvar`
`\Cmedian`
`\Cmode`
`\Cmoment`
`\CmomentA`

macro	args	Example	Result
`\Cmean`	1	`\Cmean{X}`	$\mathrm{mean}(X)$
`\Csdev`	1	`\Csdev{X}`	$\mathrm{std}(X)$
`\Cvar`	1	`\Cvar{X}`	$\mathrm{var}(X)$
`\Cmedian`	1	`\Cmedian{X}`	$\mathrm{median}(X)$
`\Cmode`	1	`\Cmode{X}`	$\mathrm{mode}(X)$
`\Cmoment`	3	`\Cmoment{3}{X}`	$\langle X^3 \rangle$
`\CmomentA`	3	`\CmomentA{3}{p}{X}`	$\langle p^3 \rangle X$

2.11 Linear Algebra

In these semantic macros, only the matrix constructor is unusual; instead of constructing a matrix from `matrixrow` elements like MathML does, the macro follows the TeX/LaTeX tradition allows to give a matrix as an array. The first argument of the macro is the column specification (it will only be used for presentation purposes), and the second one the rows.

`\Cvector`
`\Cmatrix`
`\Cdeterminant`
`\Ctranspose`
`\Cselector`
`\Cvectorproduct`
`\Cscalarproduct`
`\Couterproduct`

macro	args	Example	Result
`\Cvector`	1	`\Cvector{1,2,3}`	$(1,2,3)$
`\Cmatrix`	2	`\Cmatrix{ll}{1 & 2\\ 3 & 4}`	$\begin{pmatrix} 1 & 2 \\ 3 & 4 \end{pmatrix}$
`\Cdeterminant`	1	`\Cdeterminant{A}`	$\|A\|$
`\Ctranspose`	1	`\Ctranspose{A}`	$A^\top$
`\Cselector`	2	`\Cselector{A}{2}`	A_2
`\Cvectproduct`	2	`\Cvectproduct{\phi}{\psi}`	$\phi \cdot \psi$
`\Cscalarproduct`	2	`\Cscalarproduct{\phi}{\psi}`	$\phi\psi$
`\Couterproduct`	2	`\Couterproduct{\phi}{\psi}`	$\phi \times \psi$

2.12 Constant and Symbol Elements

The semantic macros for the MathML constant and symbol elements are very simple, they do not take any arguments, and their name is just the MathML element name prefixed by a capital C.

`\Cintegers`
`\Creals`
`\Crationals`
`\Ccomplexes`
`\Cprimes`

macro	args	Example	Result
`\Cintegers`		`\Cintegers`	$\mathbb{Z}$
`\Creals`		`\Creals`	$\mathbb{R}$
`\Crationals`		`\Crationals`	$\mathbb{Q}$
`\Cnaturalnumbers`		`\Cnaturalnumbers`	$\mathbb{N}$
`\Ccomplexes`		`\Ccomplexes`	$\mathbb{C}$
`\Cprimes`		`\Cprimes`	$\mathbb{P}$

`\Cexponentiale`
`\Cimaginaryi`
`\Ctrue`
`\Cfalse`
`\Cemptyset`
`\Cpi`
`\Ceulergamma`
`\Cinfinit`

macro	args	Example	Result
`\Cexponemtiale`		`\Cexponemtiale`	e
`\Cimaginaryi`		`\Cimaginaryi`	i
`\Cnotanumber`		`\Cnotanumber`	NaN
`\Ctrue`		`\Ctrue`	true
`\Cfalse`		`\Cfalse`	false
`\Cemptyset`		`\Cemptyset`	$\emptyset$
`\Cpi`		`\Cpi`	π
`\Ceulergamma`		`\Ceulergamma`	γ
`\Cinfinit`		`\Cinfinit`	∞

2.13 Extensions

Content MathML does not (even though it claims to cover M-14 Math) symbols for all the common mathematical notions. The `cmathmlx` attempts to collect these and provide TeX/LaTeX and LaTeXML bindings.

`\Ccomplement`

macro	args	Example	Result
`\Ccomplement`	1	`\Ccomplement{\Cnaturalnumbers}`	$\mathbb{N}^c$

3 The Implementation

In this file we document both the implementation of the cmathml package, as well as the corresponding LaTeXML bindings. This keeps similar items close to each other, even though they eventually go into differing files and helps promote consistency. We specify which code fragment goes into which file by the XML-like grouping commands: The code between ⟨*sty⟩ and ⟨/sty⟩ goes into the package file cmathml.sty, and the code between ⟨*ltxml⟩ and ⟨/ltxml⟩ goes into cmathml.ltxml

3.1 Initialization and auxiliary functions

We first make sure that the STEX presentation package is loaded.

```
 1 ⟨∗sty | styx⟩
 2 \RequirePackage{presentation}
 3 ⟨/sty | styx⟩
```

Before we start im plementing the MathML macros, we will need to set up the packages for perl in the LaTeXML bindings file.

```
 4 ⟨∗ltxml | ltxmlx⟩
 5 # -*- CPERL -*-
 6 package LaTeXML::Package::Pool;
 7 use strict;
 8 use LaTeXML::Package;
 9 use LaTeXML::Document;
10 RequirePackage('LaTeX');
11 ⟨/ltxml | ltxmlx⟩
```

The next step is to itroduce two auxiliary functions, they are needed to work with n-ary function elements. The first one removes arbitrary tokens from a list, and the specializes that to commas. In particular remove_tokens_from_list($List, $pattern, $math) returns a new List (or MathList if $math is true) with all the tokens in $List except the ones which follow the pattern $pattern.

```
12 ⟨∗ltxml⟩
13 sub remove_tokens_from_list {
14   my ($list, $pattern, $math) = @_;
15   if (ref $list) {
16     my @toks = $list->unlist;
17     @toks = grep($_->toString !~ /$pattern/, @toks);
18     ($math ? (LaTeXML::MathList->new(@toks)) : (LaTeXML::List)->new(@toks)); }
19   else { undef; } }
20
21 sub remove_math_commas {
22   my ($whatsit, $argno) = @_;
23   my @args = $whatsit ? $whatsit->getArgs() : undef;
24   $argno--;
25   if ($args[$argno]) {
26     $args[$argno] = remove_tokens_from_list($args[$argno], ',', 1);
27     $whatsit->setArgs(@args);
28   }
29   return;
30 }
31 ⟨/ltxml⟩
```

The structural macros are rather simple:

```
32 ⟨∗sty⟩
33 \newcommand{\Capply}[3][]{#2(#3)}
34 ⟨/sty⟩
35 ⟨∗ltxml⟩
```

```
36 DefConstructor('\Capply [] {} {}',
37              "<ltx:XMApp ?#1(definitionURL='#1')()>#2 #3</ltx:XMApp>");
```
38 ⟨/ltxml⟩
39 %   after this, the implementation will always have the same form. We will first
40 %   implement a block of {\LaTeX} macros via a |\newcommand| and then specify the
41 %   corresponding {\latexml} bindings for them.
42 %
43 % \subsection{The Token Elements}\label{impl:tokens}
44 %
45 %   \begin{macrocode}
46 ⟨∗sty⟩
47 \def\CMathML@cn#1{#1}
48 \newcommand{\Ccn}[2][]{\CMathML@cn{#2}}
49 \def\CMathML@ci#1{#1}
50 \newcommand{\Cci}[2][]{\CMathML@ci{#2}}
51 \def\CMathML@csymbol#1{#1}
52 \newcommand{\Ccsymbol}[2][]{\CMathML@csymbol{#2}}
53 ⟨/sty⟩
54 ⟨∗ltxml⟩
55 DefConstructor('\Ccn [] {}',"#2");
56 DefConstructor('\Cci [] {}',"#2");
57 DefConstructor('\Ccsymbol [] {}',
58   "<ltx:XMTok role='CSYMBOL' meaning='#2' ?#1(definitionURL='#1')()/>");
59 ⟨/ltxml⟩
```

## 3.2   The Basic Elements

```
60 ⟨∗sty⟩
61 \def\CMathML@ccinterval#1#2{[#1,#2]}
62 \newcommand{\Cccinterval}[3][]{\CMathML@ccinterval{#2}{#3}}
63 \def\CMathML@cointerval#1#2{[#1,#2)}
64 \newcommand{\Ccointerval}[3][]{\CMathML@cointerval{#2}{#3}}
65 \def\CMathML@ocinterval#1#2{(#1,#2]}
66 \newcommand{\Cocinterval}[3][]{\CMathML@ocinterval{#2}{#3}}
67 \def\CMathML@oointerval#1#2{(#1,#2)}
68 \newcommand{\Coointerval}[3][]{\CMathML@oointerval{#2}{#3}}
69 ⟨/sty⟩
70 ⟨∗ltxml⟩
71 DefConstructor('\Cccinterval [] {}{}',
72              "<ltx:XMApp>"
73            . "<ltx:XMTok role='CONSTRUCTOR' meaning='ccinterval' ?#1(definitionURL='#1')()/>"
74            . "<ltx:XMArg>#2</ltx:XMArg>"
75            . "<ltx:XMArg>#3</ltx:XMArg></ltx:XMApp>");
76 DefConstructor('\Ccointerval [] {}{}',
77              "<ltx:XMApp>"
78            . "<ltx:XMTok role='CONSTRUCTOR' meaning='cointerval' ?#1(definitionURL='#1')()/>"
79            . "<ltx:XMArg>#2</ltx:XMArg>"
80            . "<ltx:XMArg>#3</ltx:XMArg></ltx:XMApp>");
81 DefConstructor('\Cocinterval [] {}{}',
82              "<ltx:XMApp>"
83            . "<ltx:XMTok role='CONSTRUCTOR' meaning='ocinterval' ?#1(definitionURL='#1')()/>"
84            . "<ltx:XMArg>#2</ltx:XMArg>"
85            . "<ltx:XMArg>#3</ltx:XMArg></ltx:XMApp>");
86 DefConstructor('\Coointerval [] {}{}',
87              "<ltx:XMApp>"
88            . "<ltx:XMTok role='CONSTRUCTOR' meaning='oointerval' ?#1(definitionURL='#1')()/>"
89            . "<ltx:XMArg>#2</ltx:XMArg>"
90            . "<ltx:XMArg>#3</ltx:XMArg></ltx:XMApp>");
```

```
 91 ⟨/ltxml⟩

 92 ⟨∗sty⟩
 93 \newcommand{\Cinverse}[2][]{#2^{-1}}
 94 % what about separator
 95 ⟨/sty⟩
 96 ⟨∗ltxml⟩
 97 DefConstructor('\Cinverse [] {}',
 98                "<ltx:XMApp>"
 99              . "<ltx:XMTok meaning='inverse' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
100              . "<ltx:XMArg>#2</ltx:XMArg>"
101              . "</ltx:XMApp>");
102 ⟨/ltxml⟩

103 ⟨∗sty⟩
104 \def\CMathML@lambda#1#2{\lambda({#1},{#2})}
105 \newcommand{\Clambda}[3][]{\CMathML@lambda{#2}{#3}}
106 \def\CMathML@lambdaDA#1#2#3{\lambda({#1}\colon{#2},#3)}
107 \newcommand{\ClambdaDA}[4][]{\CMathML@lambdaDA{#2}{#3}{#4}}
108 \def\CMathML@restrict#1#2{\left.#1\right|_{#2}}
109 \newcommand{\Crestrict}[3][]{\CMathML@restrict{#2}{#3}}
110 ⟨/sty⟩
111 %\ednote{need do deal with multiple variables!}
112 ⟨∗ltxml⟩
113 DefConstructor('\Clambda [] {}{}',
114                "<ltx:XMApp>"
115              . "<ltx:XMTok role='BINDER' meaning='lambda' ?#1(definitionURL='#1')()/>"
116              . "<ltx:XMArg>#2</ltx:XMArg>"
117              . "<ltx:XMArg>#2</ltx:XMArg>"
118              . "</ltx:XMApp>");
119 DefConstructor('\ClambdaDA [] {}{}',
120                "<ltx:XMApp>"
121              . "<ltx:XMTok role='BINDER' meaning='lambda' ?#1(definitionURL='#1')()/>"
122              . "<ltx:XMArg>#2</ltx:XMArg>"
123              . "<ltx:XMArg>#3</ltx:XMArg>"
124              . "<ltx:XMArg>#4</ltx:XMArg>"
125              . "</ltx:XMApp>");
126 DefConstructor('\Crestrict [] {}{}',
127                "<ltx:XMApp>"
128              . "<ltx:XMTok role='OPFUNCTION' meaning='restrict' ?#1(definitionURL='#1')()/>"
129              . "<ltx:XMArg>#2</ltx:XMArg>"
130              . "<ltx:XMArg>#3</ltx:XMArg>"
131              . "</ltx:XMApp>");
132 ⟨/ltxml⟩

133 ⟨∗sty⟩
134 \def\CMathML@composeOp{\circ}
135 \newcommand{\CcomposeOp}{\CMathML@composeOp}
136 \def\CMathML@compose#1{\assoc[p=500,pi=500]{\CMathML@composeOp}{#1}}
137 \newcommand{\Ccompose}[2][]{\CMathML@compose{#2}}
138 \def\CMathML@ident#1{\mathrm{id}}
139 \newcommand{\Cident}[1][]{\CMathML@ident{#1}}
140 \def\CMathML@domain#1{\mbox{dom}(#1)}
141 \newcommand{\Cdomain}[2][]{\CMathML@domain{#2}}
142 \def\CMathML@codomain#1{\mbox{codom}(#1)}
143 \newcommand{\Ccodomain}[2][]{\CMathML@codomain{#2}}
144 \def\CMathML@image#1{{\mathbf{Im}}(#1)}
145 \newcommand{\Cimage}[2][]{\CMathML@image{#2}}
146 \def\CMathML@piecewise#1{\left\{\begin{array}{ll}#1\end{array}\right.}
147 \newcommand{\Cpiecewise}[2][]{\CMathML@piecewise{#2}}
```

```
148 \def\CMathML@piece#1#2{#1&{\mathrm{if}}\;{#2}\\}
149 \newcommand{\Cpiece}[3][]{\CMathML@piece{#2}{#3}}
150 \def\CMathML@otherwise#1{#1&else\\}
151 \newcommand{\Cotherwise}[2][]{\CMathML@otherwise{#2}}
152 ⟨/sty⟩
153 ⟨∗ltxml⟩
154 DefConstructor('\CcomposeOp []',
155                "<ltx:XMTok meaning='compose' role='ID' ?#1(definitionURL='#1')()/>");
156 DefConstructor('\Ccompose [] {}',
157                "<ltx:XMApp>"
158              . "<ltx:XMTok role='MULOP' meaning='compose' ?#1(definitionURL='#1')()/>"
159              . "#2"
160              . "</ltx:XMApp>",
161        afterDigest=>sub { remove_math_commas($_[1], 2); });
162 DefConstructor('\Cident []',
163                "<ltx:XMTok meaning='ident' role='ID' ?#1(definitionURL='#1')()/>");
164 DefConstructor('\Cdomain [] {}',
165                "<ltx:XMApp>"
166              . "<ltx:XMTok role='OPFUNCTION' meaning='domain' ?#1(definitionURL='#1')()/>"
167              . "<ltx:XMArg>#2</ltx:XMArg>"
168              . "</ltx:XMApp>");
169 DefConstructor('\Ccodomain [] {}',
170                "<ltx:XMApp>"
171              . "<ltx:XMTok role='OPFUNCTION' meaning='codomain' ?#1(definitionURL='#1')()/>"
172              . "<ltx:XMArg>#2</ltx:XMArg>"
173              . "</ltx:XMApp>");
174 DefConstructor('\Cimage [] {}',
175                "<ltx:XMApp>"
176              . "<ltx:XMTok role='OPFUNCTION' meaning='image' ?#1(definitionURL='#1')()/>"
177              . "<ltx:XMArg>#2</ltx:XMArg>"
178              . "</ltx:XMApp>");
179 DefConstructor('\Cpiecewise [] {}',
180                "<ltx:XMApp>"
181              . "<ltx:XMTok role='OPFUNCTION' meaning='piecewise' ?#1(definitionURL='#1')()/>"
182              . "<ltx:XMArg>#2</ltx:XMArg>"
183              . "</ltx:XMApp>");
184 DefConstructor('\Cpiece [] {}{}',
185                "<ltx:XMApp>"
186              . "<ltx:XMTok role='OPFUNCTION' meaning='piece' ?#1(definitionURL='#1')()/>"
187              . "<ltx:XMArg>#2</ltx:XMArg>"
188              . "<ltx:XMArg>#3</ltx:XMArg>"
189              . "</ltx:XMApp>");
190 DefConstructor('\Cotherwise [] {}',
191                "<ltx:XMApp>"
192              . "<ltx:XMTok role='OPFUNCTION' meaning='otherwise' ?#1(definitionURL='#1')()/>"
193              . "<ltx:XMArg>#2</ltx:XMArg>"
194              . "</ltx:XMApp>");
195 ⟨/ltxml⟩
```

3.3   Elements for Arithmetic, Algebra, and Logic

```
196 ⟨∗sty⟩
197 \def\CMathML@quotient#1#2{\frac{#1}{#2}}
198 \newcommand{\Cquotient}[3][]{\CMathML@quotient{#2}{#3}}
199 \def\CMathML@factorialOp{!}
200 \newcommand{\CfactorialOp}{\CMathML@factorialOp}
201 \def\CMathML@factorial#1{#1{\CMathML@factorialOp}}
202 \newcommand{\Cfactorial}[2][]{\CMathML@factorial{#2}}
203 \def\CMathML@divideOp{\div}
```

```
204 \newcommand{\CdivideOp}{\CMathML@divideOp}
205 \def\CMathML@divide#1#2{\infix[p=400]{\CMathML@divideOp}{#1}{#2}}
206 \newcommand{\Cdivide}[3][]{\CMathML@divide{#2}{#3}}
207 \def\CMathML@maxOp{\mathrm{max}}
208 \newcommand{\CmaxOp}{\CMathML@maxOp}
209 \def\CMathML@max#1{{\CMathML@maxOp}(#1)}
210 \newcommand{\Cmax}[2][]{\CMathML@max{#2}}
211 \def\CMathML@minOp{\mathrm{min}}
212 \newcommand{\CminOp}{\CMathML@minOp}
213 \def\CMathML@min#1{{\CMathML@minOp}(#1)}
214 \newcommand{\Cmin}[2][]{\CMathML@min{#2}}
215 \def\CMathML@minusOp{-}
216 \newcommand{\CminusOp}{\CMathML@minusOp}
217 \def\CMathML@minus#1#2{\infix[p=500]{\CMathML@minusOp}{#1}{#2}}
218 \newcommand{\Cminus}[3][]{\CMathML@minus{#2}{#3}}
219 \def\CMathML@uminus#1{\prefix[p=200]{\CMathML@minusOp}{#1}}
220 \newcommand{\Cuminus}[2][]{\CMathML@uminus{#2}}
221 \def\CMathML@plusOp{+}
222 \newcommand{\CplusOp}{\CMathML@plusOp}
223 \def\CMathML@plus#1{\assoc[p=500]{\CMathML@plusOp}{#1}}
224 \newcommand{\Cplus}[2][]{\CMathML@plus{#2}}
225 \def\CMathML@power#1#2{\infix[p=200]{^}{#1}{#2}}
226 \newcommand{\Cpower}[3][]{\CMathML@power{#2}{#3}}
227 \def\CMathML@remOp{\bmod}
228 \newcommand{\CremOp}{\CMathML@remOp}
229 \def\CMathML@rem#1#2{#1 \CMathML@remOp #2}
230 \newcommand{\Crem}[3][]{\CMathML@rem{#2}{#3}}
231 \def\CMathML@timesOp{\cdot}
232 \newcommand{\CtimesOp}{\CMathML@timesOp}
233 \def\CMathML@times#1{\assoc[p=400]{\CMathML@timesOp}{#1}}
234 \newcommand{\Ctimes}[2][]{\CMathML@times{#2}}
235 \def\CMathML@rootOp{\sqrt}
236 \newcommand{\CrootOp}{\CMathML@rootOp{}}
237 \def\CMathML@root#1#2{\CMathML@rootOp[#1]{#2}}
238 \newcommand{\Croot}[3][]{\CMathML@root{#2}{#3}}
239 \def\CMathML@gcd#1{\gcd(#1)}
240 \newcommand{\Cgcd}[2][]{\CMathML@gcd{#2}}
241 \def\CMathML@andOp{\wedge}
242 \newcommand{\CandOp}{\CMathML@andOp}
243 \def\CMathML@and#1{\assoc[p=400]{\CMathML@andOp}{#1}}
244 \newcommand{\Cand}[2][]{\CMathML@and{#2}}
245 \def\CMathML@orOp{\vee}
246 \newcommand{\CorOp}{\CMathML@orOp}
247 \def\CMathML@or#1{\assoc[p=500]{\CMathML@orOp}{#1}}
248 \newcommand{\Cor}[2][]{\CMathML@or{#2}}
249 \def\CMathML@xorOp{\oplus}
250 \newcommand{\CxorOp}{\CMathML@xorOp}
251 \def\CMathML@xor#1{\assoc[p=400]{\CMathML@xorOp}{#1}}
252 \newcommand{\Cxor}[2][]{\CMathML@xor{#2}}
253 \def\CMathML@notOp{\neg}
254 \newcommand{\CnotOp}{\CMathML@notOp}
255 \def\CMathML@not#1{\CMathML@notOp{#1}}
256 \newcommand{\Cnot}[2][]{\CMathML@not{#2}}
257 \def\CMathML@impliesOp{\Longrightarrow}
258 \newcommand{\CimpliesOp}{\CMathML@impliesOp}
259 \def\CMathML@implies#1#2{#1\CMathML@impliesOp{#2}}
260 \newcommand{\Cimplies}[3][]{\CMathML@implies{#2}{#3}}
261 ⟨/sty⟩
```

```
262 ⟨∗ltxml⟩
263 DefConstructor('\Cquotient [] {}{}',
264                "<ltx:XMApp>"
265              . "<ltx:XMTok role='OPFUNCTION' meaning='quotient' ?#1(definitionURL='#1')()/>"
266              . "<ltx:XMArg>#2</ltx:XMArg>"
267              . "<ltx:XMArg>#3</ltx:XMArg>"
268              . "</ltx:XMApp>");
269 DefConstructor('\CfactorialOp []',
270                "<ltx:XMTok meaning='factorial' role='ID' ?#1(definitionURL='#1')()/>");
271 DefConstructor('\Cfactorial [] {}',
272                "<ltx:XMApp>"
273              . "<ltx:XMTok role='OPFUNCTION' meaning='factorial' ?#1(definitionURL='#1')()/>"
274              . "<ltx:XMArg>#2</ltx:XMArg>"
275              . "</ltx:XMApp>");
276 DefConstructor('\CdivideOp []',
277                "<ltx:XMTok meaning='divide' role='ID' ?#1(definitionURL='#1')()/>");
278 DefConstructor('\Cdivide [] {}{}',
279                "<ltx:XMApp>"
280              . "<ltx:XMTok role='OPFUNCTION' meaning='divide' ?#1(definitionURL='#1')()/>"
281              . "<ltx:XMArg>#2</ltx:XMArg>"
282              . "<ltx:XMArg>#3</ltx:XMArg>"
283              . "</ltx:XMApp>");
284 DefConstructor('\CmaxOp []',
285                "<ltx:XMTok meaning='max' role='ID' ?#1(definitionURL='#1')()/>");
286 DefConstructor('\Cmax [] {}',
287                "<ltx:XMApp>"
288              . "<ltx:XMTok role='OPFUNCTION' meaning='max' ?#1(definitionURL='#1')()/>"
289              . "<ltx:XMArg>#2</ltx:XMArg>"
290              . "</ltx:XMApp>");
291 DefConstructor('\CminOp []',
292                "<ltx:XMTok meaning='min' role='ID' ?#1(definitionURL='#1')()/>");
293 DefConstructor('\Cmin [] {}',
294                "<ltx:XMApp>"
295              . "<ltx:XMTok role='OPFUNCTION' meaning='min' ?#1(definitionURL='#1')()/>"
296              . "<ltx:XMArg>#2</ltx:XMArg>"
297              . "</ltx:XMApp>");
298 DefConstructor('\CminusOp []',
299                "<ltx:XMTok meaning='minus' role='ID' ?#1(definitionURL='#1')()/>");
300 DefConstructor('\Cminus [] {}{}',
301                "<ltx:XMApp>"
302              . "<ltx:XMTok role='ADDOP' meaning='minus' ?#1(definitionURL='#1')()/>"
303              . "<ltx:XMArg>#2</ltx:XMArg>"
304              . "<ltx:XMArg>#3</ltx:XMArg>"
305              . "</ltx:XMApp>");
306 DefConstructor('\Cuminus [] {}',
307                "<ltx:XMApp>"
308              . "<ltx:XMTok role='OPFUNCTION' meaning='uminus' ?#1(definitionURL='#1')()/>"
309              . "<ltx:XMArg>#2</ltx:XMArg>"
310              . "</ltx:XMApp>");
311 DefConstructor('\CplusOp []',
312                "<ltx:XMTok meaning='plus' role='ID' ?#1(definitionURL='#1')()/>");
313 DefConstructor('\Cplus [] {}',
314                "<ltx:XMApp>"
315              . "<ltx:XMTok role='ADDOP' meaning='plus' ?#1(definitionURL='#1')()/>"
316              . "#2"
317              . "</ltx:XMApp>",
318        afterDigest=>sub { remove_math_commas($_[1], 2); });
319 DefConstructor('\Cpower [] {} {}',
```

```
320                    "<ltx:XMApp>"
321                  . "<ltx:XMTok role='OPFUNCTION' meaning='power' ?#1(definitionURL='#1')()/>"
322                  . "<ltx:XMArg>#2</ltx:XMArg>"
323                  . "<ltx:XMArg>#3</ltx:XMArg>"
324                  . "</ltx:XMApp>");
325 DefConstructor('\CremOp []',
326                    "<ltx:XMTok meaning='rem' role='ID' ?#1(definitionURL='#1')()/>");
327 DefConstructor('\Crem [] {}{}',
328                    "<ltx:XMApp>"
329                  . "<ltx:XMTok role='OPFUNCTION' meaning='rem' ?#1(definitionURL='#1')()/>"
330                  . "<ltx:XMArg>#2</ltx:XMArg>"
331                  . "<ltx:XMArg>#3</ltx:XMArg>"
332                  . "</ltx:XMApp>");
333 DefConstructor('\CtimesOp []',
334                    "<ltx:XMTok meaning='times' role='ID' ?#1(definitionURL='#1')()/>");
335 DefConstructor('\Ctimes [] {}',
336                    "<ltx:XMApp>"
337                  . "<ltx:XMTok role='MULOP' meaning='times' ?#1(definitionURL='#1')()/>"
338                  . "#2"
339                  . "</ltx:XMApp>",
340        afterDigest=>sub { remove_math_commas($_[1], 2); });
341 DefConstructor('\CrootOp []',
342                    "<ltx:XMTok meaning='root' role='ID' ?#1(definitionURL='#1')()/>");
343 DefConstructor('\Croot [] {}{}',
344                    "<ltx:XMApp>"
345                  . "<ltx:XMTok role='OPFUNCTION' meaning='root' ?#1(definitionURL='#1')()/>"
346                  . "<ltx:XMArg>#2</ltx:XMArg>"
347                  . "<ltx:XMArg>#3</ltx:XMArg>"
348                  . "</ltx:XMApp>");
349 DefConstructor('\Cgcd [] {}',
350                    "<ltx:XMApp>"
351                  . "<ltx:XMTok role='OPFUNCTION' meaning='gcd' ?#1(definitionURL='#1')()/>"
352                  . "<ltx:XMArg>#2</ltx:XMArg>"
353                  . "</ltx:XMApp>");
354 DefConstructor('\CandOp []',
355                    "<ltx:XMTok meaning='and' role='ID' ?#1(definitionURL='#1')()/>");
356 DefConstructor('\Cand [] {}',
357                    "<ltx:XMApp>"
358                  . "<ltx:XMTok role='CONNECTIVE' meaning='and' ?#1(definitionURL='#1')()/>"
359                  . "#2"
360                  . "</ltx:XMApp>",
361        afterDigest=>sub { remove_math_commas($_[1], 2); });
362 DefConstructor('\CorOp []',
363                    "<ltx:XMTok meaning='or' role='ID' ?#1(definitionURL='#1')()/>");
364 DefConstructor('\Cor [] {}',
365                    "<ltx:XMApp>"
366                  . "<ltx:XMTok role='CONNECTIVE' meaning='or' ?#1(definitionURL='#1')()/>"
367                  . "#2"
368                  . "</ltx:XMApp>",
369        afterDigest=>sub { remove_math_commas($_[1], 2); });
370 DefConstructor('\CxorOp []',
371                    "<ltx:XMTok meaning='xor' role='ID' ?#1(definitionURL='#1')()/>");
372 DefConstructor('\Cxor [] {}',
373                    "<ltx:XMApp>"
374                  . "<ltx:XMTok role='CONNECTIVE' meaning='xor' ?#1(definitionURL='#1')()/>"
375                  . "#2"
376                  . "</ltx:XMApp>",
377        afterDigest=>sub { remove_math_commas($_[1], 2); });
```

```
378 DefConstructor('\CnotOp []',
379                "<ltx:XMTok meaning='not' role='ID' ?#1(definitionURL='#1')()/>");
380 DefConstructor('\Cnot [] {}',
381                "<ltx:XMApp>"
382              . "<ltx:XMTok role='CONNECTIVE' meaning='not' ?#1(definitionURL='#1')()/>"
383              . "<ltx:XMArg>#2</ltx:XMArg>"
384              . "</ltx:XMApp>");
385 DefConstructor('\CimpliesOp []',
386                "<ltx:XMTok meaning='implies' role='ID' ?#1(definitionURL='#1')()/>");
387 DefConstructor('\Cimplies [] {}{}',
388                "<ltx:XMApp>"
389              . "<ltx:XMTok role='CONNECTIVE' meaning='implies' ?#1(definitionURL='#1')()/>"
390              . "<ltx:XMArg>#2</ltx:XMArg>"
391              . "<ltx:XMArg>#3</ltx:XMArg>"
392              . "</ltx:XMApp>");
393 ⟨/ltxml⟩
```

EdNote(9)   9

```
394 ⟨∗sty⟩
395 \def\CMathML@AndDA#1#2{\bigwedge_{#1}{#2}} % set, scope
396 \newcommand{\CAndDA}[3][]{\CMathML@AndDA{#2}{#3}}
397 \def\CMathML@AndCond#1#2#3{\bigwedge_{#2}{#3}} % bvars,condition, scope
398 \newcommand{\CAndCond}[4][]{\CMathML@AndCond{#2}{#2}{#3}}
399 \def\CMathML@OrDA#1#2{\bigvee_{#1}{#2}} % set, scope
400 \newcommand{\COrDa}[3][]{\CMathML@OrDA{#2}{#3}}
401 \def\CMathML@OrCond#1#2#3{\bigvee_{#2}{#3}}% bvars,condition, scope
402 \newcommand{\COrCond}[4][]{\CMathML@OrCond{#2}{#3}{#4}}
403 \def\CMathML@XorDA#1#2{\bigoplus_{#1}{#2}} % set, scope
404 \newcommand{\CXorDA}[3][]{\CMathML@XorDA{#2}{#3}}
405 \def\CMathML@XorCond#1#2#3{\bigoplus_{#2}{#3}}% bvars,condition, scope
406 \newcommand{\CXorCond}[4][]{\CMathML@XorCond{#2}{#3}{#4}}
407 %
408 \def\CMathML@forall#1#2{\forall{#1}\colon{#2}}
409 \newcommand{\Cforall}[3][]{\CMathML@forall{#2}{#3}}
410 \def\CMathML@forallCond#1#2#3{\forall{#1},{#2}\colon{#3}}  % list), condition, scope
411 \newcommand{\CforallCond}[4][]{\CMathML@forallCond{#2}{#3}{#4}}
412 ⟨/sty⟩
413 ⟨∗ltxml⟩
414 DefConstructor('\CAndDa [] {}{}',
415                "<ltx:XMApp>"
416              . "<ltx:XMTok role='BIGOP' meaning='and' ?#1(definitionURL='#1')()/>"
417              . "<ltx:XMArg>#2</ltx:XMArg>"
418              . "<ltx:XMArg>#3</ltx:XMArg>"
419              . "</ltx:XMApp>");
420 DefConstructor('\CAndCond [] {}{}{}',
421                "<ltx:XMApp>"
422              . "<ltx:XMTok role='BIGOP' meaning='and' ?#1(definitionURL='#1')()/>"
423              . "<ltx:XMArg>#2</ltx:XMArg>"
424              . "<ltx:XMArg>#3</ltx:XMArg>"
425              . "<ltx:XMArg>#4</ltx:XMArg>"
426              . "</ltx:XMApp>");
427 DefConstructor('\COrDa [] {}{}',
428                "<ltx:XMApp>"
429              . "<ltx:XMTok role='BIGOP' meaning='or' ?#1(definitionURL='#1')()/>"
430              . "<ltx:XMArg>#2</ltx:XMArg>"
431              . "<ltx:XMArg>#3</ltx:XMArg>"
432              . "</ltx:XMApp>");
```

---

[9]EDNOTE: need to do something about the associative things in ltxml

```
433 DefConstructor('\COrCond [] {}{}{}',
434                "<ltx:XMApp>"
435            . "<ltx:XMTok role='BIGOP' meaning='or' ?#1(definitionURL='#1')()/>"
436            . "<ltx:XMArg>#2</ltx:XMArg>"
437            . "<ltx:XMArg>#3</ltx:XMArg>"
438            . "<ltx:XMArg>#4</ltx:XMArg>"
439            . "</ltx:XMApp>");
440 DefConstructor('\CXorDa [] {}{}',
441                "<ltx:XMApp>"
442            . "<ltx:XMTok role='BIGOP' meaning='xor' ?#1(definitionURL='#1')()/>"
443            . "<ltx:XMArg>#2</ltx:XMArg>"
444            . "<ltx:XMArg>#3</ltx:XMArg>"
445            . "</ltx:XMApp>");
446 DefConstructor('\CXorCond [] {}{}{}',
447                "<ltx:XMApp>"
448            . "<ltx:XMTok role='BIGOP' meaning='xor' ?#1(definitionURL='#1')()/>"
449            . "<ltx:XMArg>#2</ltx:XMArg>"
450            . "<ltx:XMArg>#3</ltx:XMArg>"
451            . "<ltx:XMArg>#4</ltx:XMArg>"
452            . "</ltx:XMApp>");
453 DefConstructor('\Cforall [] {}{}',
454                "<ltx:XMApp>"
455            . "<ltx:XMTok role='BINDER' meaning='forall' ?#1(definitionURL='#1')()/>"
456            . "<ltx:XMArg>#2</ltx:XMArg>"
457            . "<ltx:XMArg>#3</ltx:XMArg>"
458            . "</ltx:XMApp>");
459 DefConstructor('\CforallCond [] {}{}{}',
460                "<ltx:XMApp>"
461            . "<ltx:XMTok role='BINDER' meaning='forall' ?#1(definitionURL='#1')()/>"
462            . "<ltx:XMArg>#2</ltx:XMArg>"
463            . "<ltx:XMArg>#3</ltx:XMArg>"
464            . "<ltx:XMArg>#4</ltx:XMArg>"
465            . "</ltx:XMApp>");
466 ⟨/ltxml⟩
467 ⟨∗sty⟩
468 \def\CMathML@exists#1#2{\exists{#1}\colon{#2}}
469 \newcommand{\Cexists}[3][]{\CMathML@exists{#2}{#3}}
470 \def\CMathML@esistsCont#1#2#3{\exists{#1},{#2}\colon{#3}}
471 \newcommand{\CexistsCond}[4][]{\CMathML@esistsCont{#2}{#3}{#4}}
472 ⟨/sty⟩
473 ⟨∗ltxml⟩
474 DefConstructor('\Cexists [] {}{}',
475                "<ltx:XMApp>"
476            . "<ltx:XMTok role='BINDER' meaning='exists' ?#1(definitionURL='#1')()/>"
477            . "<ltx:XMArg>#2</ltx:XMArg>"
478            . "<ltx:XMArg>#3</ltx:XMArg>"
479            . "</ltx:XMApp>");
480 DefConstructor('\CexistsCond [] {}{}{}',
481                "<ltx:XMApp>"
482            . "<ltx:XMTok role='BINDER' meaning='exists' ?#1(definitionURL='#1')()/>"
483            . "<ltx:XMArg>#2</ltx:XMArg>"
484            . "<ltx:XMArg>#3</ltx:XMArg>"
485            . "<ltx:XMArg>#4</ltx:XMArg>"
486            . "</ltx:XMApp>");
487 ⟨/ltxml⟩

488 ⟨∗sty⟩
489 \def\CMathML@abs#1{\left|#1\right|}
490 \newcommand{\Cabs}[2][]{\CMathML@abs{#2}}
```

```
491 \def\CMathML@conjugate#1{\overline{#1}}
492 \newcommand{\Cconjugate}[2][]{\CMathML@conjugate{#2}}
493 \def\CMathML@arg#1{\angle #1}
494 \newcommand{\Carg}[2][]{\CMathML@arg{#2}}
495 \def\CMathML@real#1{\Re #1}
496 \newcommand{\Creal}[2][]{\CMathML@real{#2}}
497 \def\CMathML@imaginary#1{\Im #1}
498 \newcommand{\Cimaginary}[2][]{\CMathML@imaginary{#2}}
499 \def\CMathML@lcm#1{\mbox{lcm}(#1)}
500 \newcommand{\Clcm}[2][]{\CMathML@lcm{#2}}
501 \def\CMathML@floor#1{\left\lfloor{#1}\right\rfloor}
502 \newcommand{\Cfloor}[2][]{\CMathML@floor{#2}}
503 \def\CMathML@ceiling#1{\left\lceil{#1}\right\rceil}
504 \newcommand{\Cceiling}[2][]{\CMathML@ceiling{#2}}
505 ⟨/sty⟩
506 ⟨*ltxml⟩
507 DefConstructor('\Cabs [] {}',
508                "<ltx:XMApp>"
509                . "<ltx:XMTok role='OPFUNCTION' meaning='abs' ?#1(definitionURL='#1')()/>"
510                . "<ltx:XMArg>#2</ltx:XMArg>"
511                . "</ltx:XMApp>");
512 DefConstructor('\Cconjugate [] {}',
513                "<ltx:XMApp>"
514                . "<ltx:XMTok role='OPFUNCTION' meaning='conjugate' ?#1(definitionURL='#1')()/>"
515                . "<ltx:XMArg>#2</ltx:XMArg>"
516                . "</ltx:XMApp>");
517 DefConstructor('\Carg [] {}',
518                "<ltx:XMApp>"
519                . "<ltx:XMTok role='OPFUNCTION' meaning='arg' ?#1(definitionURL='#1')()/>"
520                . "<ltx:XMArg>#2</ltx:XMArg>"
521                . "</ltx:XMApp>");
522 DefConstructor('\Creal [] {}',
523                "<ltx:XMApp>"
524                . "<ltx:XMTok role='OPFUNCTION' meaning='real' ?#1(definitionURL='#1')()/>"
525                . "<ltx:XMArg>#2</ltx:XMArg>"
526                . "</ltx:XMApp>");
527 DefConstructor('\Cimaginary [] {}',
528                "<ltx:XMApp>"
529                . "<ltx:XMTok role='OPFUNCTION' meaning='imaginary' ?#1(definitionURL='#1')()/>"
530                . "<ltx:XMArg>#2</ltx:XMArg>"
531                . "</ltx:XMApp>");
532 DefConstructor('\Clcm [] {}',
533                "<ltx:XMApp>"
534                . "<ltx:XMTok role='OPFUNCTION' meaning='lcm' ?#1(definitionURL='#1')()/>"
535                . "<ltx:XMArg>#2</ltx:XMArg>"
536                . "</ltx:XMApp>");
537 DefConstructor('\Cfloor [] {}',
538                "<ltx:XMApp>"
539                . "<ltx:XMTok role='OPFUNCTION' meaning='floor' ?#1(definitionURL='#1')()/>"
540                . "<ltx:XMArg>#2</ltx:XMArg>"
541                . "</ltx:XMApp>");
542 DefConstructor('\Cceiling [] {}',
543                "<ltx:XMApp>"
544                . "<ltx:XMTok role='OPFUNCTION' meaning='ceiling' ?#1(definitionURL='#1')()/>"
545                . "<ltx:XMArg>#2</ltx:XMArg>"
546                . "</ltx:XMApp>");
547 ⟨/ltxml⟩
```

3.4 Relations

```
548 ⟨∗sty⟩
549 \def\CMathML@eqOp{=}
550 \newcommand{\CeqOp}{\CMathML@eqOp}
551 \def\CMathML@eq#1{\assoc[p=700]{\CMathML@eqOp}{#1}}
552 \newcommand{\Ceq}[2][]{\CMathML@eq{#2}}
553 \def\CMathML@neqOp{\neq}
554 \newcommand{\CneqOp}{\CMathML@neqOp}
555 \def\CMathML@neq#1#2{\infix[p=700]{\CMathML@neqOp}{#1}{#2}}
556 \newcommand{\Cneq}[3][]{\CMathML@neq{#2}{#3}}
557 \def\CMathML@gtOp{>}
558 \newcommand{\CgtOp}{\CMathML@gtOp}
559 \def\CMathML@gt#1{\assoc[p=700]{\CMathML@gtOp}{#1}}
560 \newcommand{\Cgt}[2][]{\CMathML@gt{#2}}
561 \def\CMathML@ltOp{<}
562 \newcommand{\CltOp}{\CMathML@ltOp}
563 \def\CMathML@lt#1{\assoc[p=700]{\CMathML@ltOp}{#1}}
564 \newcommand{\Clt}[2][]{\CMathML@lt{#2}}
565 \def\CMathML@geqOp{\geq}
566 \newcommand{\CgeqOp}{\CMathML@geqOp}
567 \def\CMathML@geq#1{\assoc[p=700]{\CMathML@geqOp}{#1}}
568 \newcommand{\Cgeq}[2][]{\CMathML@geq{#2}}
569 \def\CMathML@leqOp{\leq}
570 \newcommand{\CleqOp}{\CMathML@leqOp}
571 \def\CMathML@leq#1{\assoc[p=700]{\CMathML@leqOp}{#1}}
572 \newcommand{\Cleq}[2][]{\CMathML@leq{#2}}
573 \def\CMathML@equivalentOp{\equiv}
574 \newcommand{\CequivalentOp}{\CMathML@equivalentOp}
575 \def\CMathML@equivalent#1{\assoc[p=700]{\CMathML@equivalentOp}{#1}}
576 \newcommand{\Cequivalent}[2][]{\CMathML@equivalent{#2}}
577 \def\CMathML@approxOp{\approx}
578 \newcommand{\CapproxOp}{\CMathML@approxOp}
579 \def\CMathML@approx#1#2{#1\CMathML@approxOp{#2}}
580 \newcommand{\Capprox}[3][]{\CMathML@approx{#2}{#3}}
581 \def\CMathML@factorofOp{\mid}
582 \newcommand{\CfactorofOp}{\CMathML@factorofOp}
583 \def\CMathML@factorof#1#2{#1\CMathML@factorofOp{#2}}
584 \newcommand{\Cfactorof}[3][]{\CMathML@factorof{#2}{#3}}
585 ⟨/sty⟩
586 ⟨∗ltxml⟩
587 DefConstructor('\CeqOp []',
588                "<ltx:XMTok meaning='eq' role='ID' ?#1(definitionURL='#1')()/>");
589 DefConstructor('\Ceq [] {}',
590                "<ltx:XMApp>"
591              . "<ltx:XMTok meaning='eq' role='RELOP' ?#1(definitionURL='#1')()/>"
592              . "#2"
593              . "</ltx:XMApp>",
594        afterDigest=>sub { remove_math_commas($_[1], 2); });
595 DefConstructor('\CneqOp []',
596                "<ltx:XMTok meaning='neq' role='ID' ?#1(definitionURL='#1')()/>");
597 DefConstructor('\Cneq [] {}{}',
598                "<ltx:XMApp>"
599              . "<ltx:XMTok meaning='neq' role='RELOP' ?#1(definitionURL='#1')()/>"
600              . "<ltx:XMArg>#2</ltx:XMArg>"
601              . "<ltx:XMArg>#3</ltx:XMArg>"
602              . "</ltx:XMApp>");
603 DefConstructor('\CgtOp []',
604                "<ltx:XMTok meaning='gt' role='ID' ?#1(definitionURL='#1')()/>");
```

```
605 DefConstructor('\Cgt [] {}',
606              "<ltx:XMApp>"
607            . "<ltx:XMTok meaning='gt' role='RELOP' ?#1(definitionURL='#1')()/>"
608            . "#2"
609            . "</ltx:XMApp>",
610        afterDigest=>sub { remove_math_commas($_[1], 2); });
611 DefConstructor('\CltOp []',
612              "<ltx:XMTok meaning='lt' role='ID' ?#1(definitionURL='#1')()/>");
613 DefConstructor('\Clt [] {}',
614              "<ltx:XMApp>"
615            . "<ltx:XMTok meaning='lt' role='RELOP' ?#1(definitionURL='#1')()/>"
616            . "#2"
617            . "</ltx:XMApp>",
618        afterDigest=>sub { remove_math_commas($_[1], 2); });
619 DefConstructor('\CgeqOp []',
620              "<ltx:XMTok meaning='geq' role='ID' ?#1(definitionURL='#1')()/>");
621 DefConstructor('\Cgeq [] {}',
622              "<ltx:XMApp>"
623            . "<ltx:XMTok meaning='geq' role='RELOP' ?#1(definitionURL='#1')()/>"
624            . "#2"
625            . "</ltx:XMApp>",
626        afterDigest=>sub { remove_math_commas($_[1], 2); });
627 DefConstructor('\CleqOp []',
628              "<ltx:XMTok meaning='leq' role='ID' ?#1(definitionURL='#1')()/>");
629 DefConstructor('\Cleq [] {}',
630              "<ltx:XMApp>"
631            . "<ltx:XMTok meaning='leq' role='RELOP' ?#1(definitionURL='#1')()/>"
632            . "#2"
633            . "</ltx:XMApp>",
634        afterDigest=>sub { remove_math_commas($_[1], 2); });
635 DefConstructor('\CequivalentOp []',
636              "<ltx:XMTok meaning='equivalent' role='ID' ?#1(definitionURL='#1')()/>");
637 DefConstructor('\Cequivalent [] {}',
638              "<ltx:XMApp>"
639            . "<ltx:XMTok meaning='equivalent' role='RELOP' ?#1(definitionURL='#1')()/>"
640            . "#2"
641            . "</ltx:XMApp>");
642 DefConstructor('\CapproxOp []',
643              "<ltx:XMTok meaning='approx' role='ID' ?#1(definitionURL='#1')()/>");
644 DefConstructor('\Capprox [] {}{}',
645              "<ltx:XMApp>"
646            . "<ltx:XMTok meaning='approx' role='RELOP' ?#1(definitionURL='#1')()/>"
647            . "<ltx:XMArg>#2</ltx:XMArg>"
648            . "<ltx:XMArg>#3</ltx:XMArg>"
649            . "</ltx:XMApp>");
650 DefConstructor('\CfactorofOp []',
651              "<ltx:XMTok meaning='factorof' role='ID' ?#1(definitionURL='#1')()/>");
652 DefConstructor('\Cfactorof [] {}{}',
653              "<ltx:XMApp>"
654            . "<ltx:XMTok meaning='factorof' role='RELOP' ?#1(definitionURL='#1')()/>"
655            . "<ltx:XMArg>#2</ltx:XMArg>"
656            . "<ltx:XMArg>#3</ltx:XMArg>"
657            . "</ltx:XMApp>");
658 ⟨/ltxml⟩
659 ⟨∗sty⟩
660
661 \def\CMathML@intOp{\int}
662 \newcommand{\CintOp}{\CMathML@intOp}
```

```
663 \def\CMathML@int#1{\CMathML@intOp{#1}}
664 \newcommand{\Cint}[2][]{\CMathML@int{#2}}
665 \def\CMathML@intLimits#1#2#3#4{\CMathML@intOp_{#2}^{#3}{#4}d{#1}} %bvars,llimit, ulimit,body
666 \newcommand{\CintLimits}[5][]{\CMathML@intLimits{#2}{#3}{#4}{#5}}
667 \def\CMathML@intSet#1#2{\CMathML@intOp_{#1}{#2}}% set,function
668 \newcommand{\CintDA}[3][]{\CMathML@intSet{#2}{#3}}
669 \def\CMathML@intCond#1#2#3{\CMathML@intOp_{#2}{#3}d{#1}} %bvars, condition, body
670 \newcommand{\CintCond}[4][]{\CMathML@intCond{#2}{#3}{#4}}
671
672 ⟨/sty⟩
673 ⟨∗ltxml⟩
674 DefConstructor('\CintOp []',
675             "<ltx:XMTok meaning='int' role='ID' ?#1(definitionURL='#1')()/>");
676 DefConstructor('\Cint [] {}',
677             "<ltx:XMApp>"
678           . "<ltx:XMTok meaning='int' role='INTOP' ?#1(definitionURL='#1')()/>"
679           . "<ltx:XMArg>#2</ltx:XMArg>"
680           . "</ltx:XMApp>");
681 DefConstructor('\CintLimits [] {}{}{}{}',
682             "<ltx:XMApp>"
683           . "<ltx:XMTok meaning='int' role='INTOP' ?#1(definitionURL='#1')()/>"
684           . "<ltx:XMArg>#2</ltx:XMArg>"
685           . "<ltx:XMArg>#3</ltx:XMArg>"
686           . "<ltx:XMArg>#4</ltx:XMArg>"
687           . "<ltx:XMArg>#5</ltx:XMArg>"
688           . "</ltx:XMApp>");
689 DefConstructor('\CintDA [] {}{}',
690             "<ltx:XMApp>"
691           . "<ltx:XMTok meaning='int' role='INTOP' ?#1(definitionURL='#1')()/>"
692           . "<ltx:XMArg>#2</ltx:XMArg>"
693           . "<ltx:XMArg>#3</ltx:XMArg>"
694           . "</ltx:XMApp>");
695 DefConstructor('\CintCond [] {}{}{}',
696             "<ltx:XMApp>"
697           . "<ltx:XMTok meaning='int' role='INTOP' ?#1(definitionURL='#1')()/>"
698           . "<ltx:XMArg>#2</ltx:XMArg>"
699           . "<ltx:XMArg>#3</ltx:XMArg>"
700           . "<ltx:XMArg>#4</ltx:XMArg>"
701           . "</ltx:XMApp>");
702 ⟨/ltxml⟩
703 ⟨∗sty⟩
704 \def\CMathML@diff#1{#1'}
705 \newcommand{\Cdiff}[2][]{\CMathML@diff{#2}}
706 \def\CMathML@ddiff#1#2{{d{#2}(#1)\over{d{#1}}}}
707 \newcommand{\Cddiff}[3][]{\CMathML@ddiff{#2}{#3}}
708 \def\CMathML@partialdiff#1#2#3{{\partial^{#1}\over\partial{#2}}{#3}}% degree, bvars, body
709 \newcommand{\Cpartialdiff}[4][]{\CMathML@partialdiff{#2}{#3}{#4}}
710 \newcommand{\Cdegree}[2]{#1^{#2}}
711 ⟨/sty⟩
712 ⟨∗ltxml⟩
713 DefConstructor('\Cdiff [] {}',
714             "<ltx:XMApp>"
715           . "<ltx:XMTok role='OPFUNCTION' meaning='diff' ?#1(definitionURL='#1')()/>"
716           . "<ltx:XMArg>#2</ltx:XMArg>"
717           . "</ltx:XMApp>");
718 DefConstructor('\Cddiff [] {}{}',
719             "<ltx:XMApp>"
720           . "<ltx:XMTok role='OPFUNCTION' meaning='diff' ?#1(definitionURL='#1')()/>"
```

```
721                 . "<ltx:XMArg>#2</ltx:XMArg>"
722                 . "<ltx:XMArg>#3</ltx:XMArg>"
723                 . "</ltx:XMApp>");
724 DefConstructor('\Cpartialdiff [] {}{}{}',
725                 "<ltx:XMApp>"
726                 . "<ltx:XMTok role='OPFUNCTION' meaning='diff' ?#1(definitionURL='#1')()/>"
727                 . "<ltx:XMArg>#3</ltx:XMArg>"
728                 . "?#2(<ltx:XMArg>#2</ltx:XMArg>)()"
729                 . "<ltx:XMArg>#4</ltx:XMArg>"
730                 . "</ltx:XMApp>");
731 DefConstructor('\Cdegree {}{}',
732                 "<ltx:XMApp>"
733                 . "<ltx:XMTok role='OPFUNCTION' meaning='degree'/>"
734                 . "<ltx:XMArg>#2</ltx:XMArg>"
735                 . "<ltx:XMArg>#1</ltx:XMArg>"
736                 . "</ltx:XMApp>");
737 ⟨/ltxml⟩

738 ⟨∗sty⟩
739 \def\CMathML@limit#1#2#3{\lim_{#1\rightarrow{#2}}{#3}}
740 \newcommand{\Climit}[4][]{\CMathML@limit{#2}{#3}{#4}}   % bvar, lowlimit, scope
741 \def\CMathML@limitCond#1#2#3{\lim_{#2}{#3}}
742 \newcommand{\ClimitCond}[4][]{\CMathML@limitCond{#2}{#3}{#4}}   % bvars, condition, scope
743 ⟨/sty⟩
744 ⟨∗ltxml⟩
745 DefConstructor('\Climit [] {}{}{}',
746                 "<ltx:XMApp>"
747                 . "<ltx:XMTok role='OPFUNCTION' meaning='limit' ?#1(definitionURL='#1')()/>"
748                 . "<ltx:XMArg>#2</ltx:XMArg>"
749                 . "<ltx:XMArg>#3</ltx:XMArg>"
750                 . "<ltx:XMArg>#4</ltx:XMArg>"
751                 . "</ltx:XMApp>");
752 DefConstructor('\ClimitCond [] {}{}{}',
753                 "<ltx:XMApp>"
754                 . "<ltx:XMTok role='OPFUNCTION' meaning='limit' ?#1(definitionURL='#1')()/>"
755                 . "<ltx:XMArg>#2</ltx:XMArg>"
756                 . "<ltx:XMArg>#3</ltx:XMArg>"
757                 . "<ltx:XMArg>#4</ltx:XMArg>"
758                 . "</ltx:XMApp>");
759 ⟨/ltxml⟩

760 ⟨∗sty⟩
761 \def\CMathML@tendstoOp{\rightarrow}
762 \newcommand{\CtendstoOp}{\CMathML@tendstoOp}
763 \def\CMathML@tendsto#1#2{#1\CMathML@tendstoOp{#2}}
764 \newcommand{\Ctendsto}[3][]{\CMathML@tendsto{#2}{#3}}
765 \def\CMathML@tendstoAboveOp{\searrow}
766 \newcommand{\CtendstoAboveOp}{\CMathML@tendstoAboveOp}
767 \def\CMathML@tendstoAbove#1#2{#1\searrow{#2}}
768 \newcommand{\CtendstoAbove}[3][]{\CMathML@tendstoAbove{#2}{#3}}
769 \def\CMathML@tendstoBelowOp{\nearrow}
770 \newcommand{\CtendstoBelowOp}{\CMathML@tendstoBelowOp}
771 \def\CMathML@tendstoBelow#1#2{#1\CMathML@tendstoBelowOp{#2}}
772 \newcommand{\CtendstoBelow}[3][]{\CMathML@tendstoBelow{#2}{#3}}
773 ⟨/sty⟩
774 ⟨∗ltxml⟩
775 DefConstructor('\CtendstoOp []',
776                 "<ltx:XMTok meaning='tendsto' role='ID' ?#1(definitionURL='#1')()/>");
777 DefConstructor('\Ctendsto [] {}{}',
778                 "<ltx:XMApp>"
```

```
779                    . "<ltx:XMTok role='RELOP' meaning='tendsto' ?#1(definitionURL='#1')()/>"
780                    . "<ltx:XMArg>#2</ltx:XMArg>"
781                    . "<ltx:XMArg>#3</ltx:XMArg>"
782                    . "</ltx:XMApp>");
783 DefConstructor('\CtendstoAboveOp []',
784                    "<ltx:XMTok meaning='tendsto' role='ID' ?#1(definitionURL='#1')()/>");
785 DefConstructor('\CtendstoAbove [] {}{}',
786                    "<ltx:XMApp>"
787                    . "<ltx:XMTok role='RELOP'meaning='tendsto' type='above' ?#1(definitionURL='#1')()/>"
788                    . "<ltx:XMArg>#2</ltx:XMArg>"
789                    . "<ltx:XMArg>#3</ltx:XMArg>"
790                    . "</ltx:XMApp>");
791 DefConstructor('\CtendstoBelowOp []',
792                    "<ltx:XMTok meaning='tendsto' role='ID' ?#1(definitionURL='#1')()/>");
793 DefConstructor('\CtendstoBelow [] {}{}',
794                    "<ltx:XMApp>"
795                    . "<ltx:XMTok role='RELOP' meaning='tendsto' type='below' ?#1(definitionURL='#1')()/>"
796                    . "<ltx:XMArg>#2</ltx:XMArg>"
797                    . "<ltx:XMArg>#3</ltx:XMArg>"
798                    . "</ltx:XMApp>");
799 ⟨/ltxml⟩

800 ⟨∗sty⟩
801 \def\CMathML@divergence#1{\nabla\cdot{#1}}
802 \newcommand{\Cdivergence}[2][]{\CMathML@divergence{#2}}
803 \def\CMathML@grad#1{\nabla{#1}}
804 \newcommand{\Cgrad}[2][]{\CMathML@grad{#2}}
805 \def\CMathML@curl#1{\nabla\times{#1}}
806 \newcommand{\Ccurl}[2][]{\CMathML@curl{#2}}
807 \def\CMathML@laplacian#1{\nabla^2#1}
808 \newcommand{\Claplacian}[2][]{\CMathML@laplacian{#2}}
809 ⟨/sty⟩
810 ⟨∗ltxml⟩
811 DefConstructor('\Cdivergence [] {}',
812                    "<ltx:XMApp>"
813                    . "<ltx:XMTok role='OPFUNCTION' meaning='divergence' ?#1(definitionURL='#1')()/>"
814                    . "<ltx:XMArg>#2</ltx:XMArg>"
815                    . "</ltx:XMApp>");
816 DefConstructor('\Cgrad [] {}',
817                    "<ltx:XMApp>"
818                    . "<ltx:XMTok role='OPFUNCTION' meaning='grad' ?#1(definitionURL='#1')()/>"
819                    . "<ltx:XMArg>#2</ltx:XMArg>"
820                    . "</ltx:XMApp>");
821 DefConstructor('\Curl [] {}',
822                    "<ltx:XMApp>"
823                    . "<ltx:XMTok role='OPFUNCTION' meaning='url' ?#1(definitionURL='#1')()/>"
824                    . "<ltx:XMArg>#2</ltx:XMArg>"
825                    . "</ltx:XMApp>");
826 DefConstructor('\Claplacian [] {}',
827                    "<ltx:XMApp>"
828                    . "<ltx:XMTok role='OPFUNCTION' meaning='laplacian' ?#1(definitionURL='#1')()/>"
829                    . "<ltx:XMArg>#2</ltx:XMArg>"
830                    . "</ltx:XMApp>");
831 ⟨/ltxml⟩
```

3.5 Sets and their Operations

```
832 ⟨∗sty⟩
833 \def\CMathML@set#1{\left\{#1\right\}}
834 \newcommand{\Cset}[2][]{\CMathML@set{#2}}
```

```
835 \def\CMathML@setRes#1#2{\{#1|#2\}}
836 \newcommand{\CsetRes}[3][]{\CMathML@setRes{#2}{#3}}
837 \def\CMathML@setCond#1#2#3{\{#2|#3\}}
838 \newcommand{\CsetCond}[4][]{\CMathML@setCond{#2}{#3}{#4}}
839 \def\CMathML@setDA#1#2#3{\{#1\in{#2}|#3\}}
840 \newcommand{\CsetDA}[4][]{\CMathML@setDA{#2}{#3}{#4}}
841 \def\CMathML@listOp{\mbox{list}}
842 \newcommand{\ClistOp}{\CMathML@listOp}
843 \def\CMathML@list#1{\CMathML@listOp({#1})}
844 \newcommand{\Clist}[2][]{\CMathML@list{#2}}
845 \def\CMathML@unionOp{\cup}
846 \newcommand{\CunionOp}{\CMathML@unionOp}
847 \def\CMathML@union#1{\assoc[p=500]{\CMathML@unionOp}{#1}}
848 \newcommand{\Cunion}[2][]{\CMathML@union{#2}}
849 \def\CMathML@intersectOp{\cap}
850 \newcommand{\CintersectOp}{\CMathML@intersectOp}
851 \def\CMathML@intersect#1{\assoc[p=400]{\CMathML@intersectOp}{#1}}
852 \newcommand{\Cintersect}[2][]{\CMathML@intersect{#2}}
853 \def\CMathML@inOp{\in}
854 \newcommand{\CinOp}{\CMathML@inOp}
855 \def\CMathML@in#1#2{#1\CMathML@inOp{#2}}
856 \newcommand{\Cin}[3][]{\CMathML@in{#2}{#3}}
857 \def\CMathML@notinOp{\notin}
858 \newcommand{\CnotinOp}{\CMathML@notinOp}
859 \def\CMathML@notin#1#2{#1\CMathML@notinOp{#2}}
860 \newcommand{\Cnotin}[3][]{\CMathML@notin{#2}{#3}}
861 \def\CMathML@setdiffOp{\setminus}
862 \newcommand{\CsetdiffOp}{\CMathML@setdiffOp}
863 \def\CMathML@setdiff#1#2{#1\CMathML@setdiffOp{#2}}
864 \newcommand{\Csetdiff}[3][]{\CMathML@setdiff{#2}{#3}}
865 \def\CMathML@cardOp{\#}
866 \newcommand{\CcardOp}{\CMathML@cardOp}
867 \def\CMathML@card#1{\CMathML@cardOp #1}
868 \newcommand{\Ccard}[2][]{\CMathML@card{#2}}
869 \def\CMathML@cartesianproductOp{\times}
870 \newcommand{\CcartesianproductOp}{\CMathML@cartesianproductOp}
871 \def\CMathML@cartesianproduct#1{\assoc[p=400]{\CMathML@cartesianproductOp}{#1}}
872 \newcommand{\Ccartesianproduct}[2][]{\CMathML@cartesianproduct{#2}}
873 \def\CMathML@subsetOp{\subseteq}
874 \newcommand{\CsubsetOp}{\CMathML@subsetOp}
875 \def\CMathML@subset#1{\assoc[p=700]{\CMathML@subsetOp}{#1}}
876 \newcommand{\Csubset}[2][]{\CMathML@subset{#2}}
877 \def\CMathML@prsubsetOp{\subset}
878 \newcommand{\CprsubsetOp}{\CMathML@prsubsetOp}
879 \def\CMathML@prsubset#1{\assoc[p=700]{\CMathML@prsubsetOp}{#1}}
880 \newcommand{\Cprsubset}[2][]{\CMathML@prsubset{#2}}
881 \def\CMathML@notsubsetOp{\not\subseteq}
882 \newcommand{\CnotsubsetOp}{\CMathML@notsubsetOp}
883 \def\CMathML@notsubset#1#2{#1\CMathML@notsubsetOp{#2}}
884 \newcommand{\Cnotsubset}[3][]{\CMathML@notsubset{#2}{#3}}
885 \def\CMathML@notprsubsetOp{\not\subset}
886 \newcommand{\CnotprsubsetOp}{\CMathML@notprsubsetOp}
887 \def\CMathML@notprsubset#1#2{#1\CMathML@notprsubsetOp{#2}}
888 \newcommand{\Cnotprsubset}[3][]{\CMathML@notprsubset{#2}{#3}}
889 ⟨/sty⟩
890 ⟨∗ltxml⟩
891 DefConstructor('\Cset [] {}',
892                "<ltx:XMApp>"
```

```
893                  . "<ltx:XMTok meaning='set' role='CONSTRUCTOR' ?#1(definitionURL='#1')()/>"
894                  . "#2"
895                  . "</ltx:XMApp>",
896          afterDigest=>sub { remove_math_commas($_[1], 2); });
897 DefConstructor('\CsetRes [] {}{}',
898                  "<ltx:XMApp role='BIGOP'>"
899                  . "<ltx:XMTok role='BIGOP' meaning='set' ?#1(definitionURL='#1')()/>"
900                  . "<ltx:XMArg role='BVAR'>#2</ltx:XMArg>"
901                  . "<ltx:XMArg role='CONDITION'>#3</ltx:XMArg>"
902                  . "<ltx:XMArg role='SCOPE'>#2</ltx:XMArg>"
903                  . "</ltx:XMApp>");
904 DefConstructor('\CsetCond [] {}{}{}',
905                  "<ltx:XMApp role='BIGOP'>"
906                  . "<ltx:XMTok role='BIGOP' meaning='set' ?#1(definitionURL='#1')()/>"
907                  . "<ltx:XMArg role='BVAR'>#2</ltx:XMArg>"
908                  . "<ltx:XMArg role='CONDITION'>#3</ltx:XMArg>"
909                  . "<ltx:XMArg role='SCOPE'>#4</ltx:XMArg>"
910                  . "</ltx:XMApp>");
911 DefConstructor('\CsetDA [] {}{}{}',
912                  "<ltx:XMApp>"
913                  . "<ltx:XMTok role='BIGOP' meaning='set' ?#1(definitionURL='#1')()/>"
914                  . "<ltx:XMArg role='BVAR'>#2</ltx:XMArg>"
915                  . "<ltx:XMArg role='DOMAINOFAPPLICATION'>#3</ltx:XMArg>"
916                  . "<ltx:XMArg role='SCOPE'>#4</ltx:XMArg>"
917                  . "</ltx:XMApp>");
918 DefConstructor('\ClistOp []',
919                  "<ltx:XMTok meaning='list' role='ID' ?#1(definitionURL='#1')()/>");
920 DefConstructor('\Clist [] {}',
921                  "<ltx:XMApp>"
922                  . "<ltx:XMTok meaning='list' role='CONSTRUCTOR' ?#1(definitionURL='#1')()/>"
923                  . "#2"
924                  . "</ltx:XMApp>",
925          afterDigest=>sub { remove_math_commas($_[1], 2); });
926 DefConstructor('\CunionOp []',
927                  "<ltx:XMTok meaning='union' role='ID' ?#1(definitionURL='#1')()/>");
928 DefConstructor('\Cunion [] {}',
929                  "<ltx:XMApp>"
930                  . "<ltx:XMTok meaning='union' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
931                  . "#2"
932                  . "</ltx:XMApp>",
933          afterDigest=>sub { remove_math_commas($_[1], 2); });
934 DefConstructor('\CintersectOp []',
935                  "<ltx:XMTok meaning='intersect' role='ID' ?#1(definitionURL='#1')()/>");
936 DefConstructor('\Cintersect [] {}',
937                  "<ltx:XMApp>"
938                  . "<ltx:XMTok meaning='intersect' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
939                  . "#2"
940                  . "</ltx:XMApp>",
941          afterDigest=>sub { remove_math_commas($_[1], 2); });
942 DefConstructor('\CinOp []',
943                  "<ltx:XMTok meaning='in' role='ID' ?#1(definitionURL='#1')()/>");
944 DefConstructor('\Cin [] {}{}',
945                  "<ltx:XMApp>"
946                  . "<ltx:XMTok meaning='in' role='RELOP' ?#1(definitionURL='#1')()/>"
947                  . "<ltx:XMArg>#2</ltx:XMArg>"
948                  . "<ltx:XMArg>#3</ltx:XMArg>"
949                  . "</ltx:XMApp>");
950 DefConstructor('\CnotinOp []',
```

```
951                    "<ltx:XMTok meaning='notin' role='ID' ?#1(definitionURL='#1')()/>");
952 DefConstructor('\Cnotin [] {}{}',
953                    "<ltx:XMApp>"
954                  . "<ltx:XMTok meaning='notin' role='RELOP' ?#1(definitionURL='#1')()/>"
955                  . "<ltx:XMArg>#2</ltx:XMArg>"
956                  . "</ltx:XMApp>");
957 DefConstructor('\CsubsetOp []',
958                    "<ltx:XMTok meaning='subset' role='ID' ?#1(definitionURL='#1')()/>");
959 DefConstructor('\Csubset [] {}',
960                    "<ltx:XMApp>"
961                  . "<ltx:XMTok meaning='subset' role='RELOP' ?#1(definitionURL='#1')()/>"
962                  . "#2"
963                  . "</ltx:XMApp>",
964         afterDigest=>sub { remove_math_commas($_[1], 2); });
965 DefConstructor('\CprsubsetOp []',
966                    "<ltx:XMTok meaning='prsubset' role='ID' ?#1(definitionURL='#1')()/>");
967 DefConstructor('\Cprsubset [] {}',
968                    "<ltx:XMApp>"
969                  . "<ltx:XMTok meaning='prsubset' role='RELOP' ?#1(definitionURL='#1')()/>"
970                  . "#2"
971                  . "</ltx:XMApp>",
972         afterDigest=>sub { remove_math_commas($_[1], 2); });
973 DefConstructor('\CnotsubsetOp []',
974                    "<ltx:XMTok meaning='notsubset' role='ID' ?#1(definitionURL='#1')()/>");
975 DefConstructor('\Cnotsubset [] {}{}',
976                    "<ltx:XMApp>"
977                  . "<ltx:XMTok meaning='notsubset' role='RELOP' ?#1(definitionURL='#1')()/>"
978                  . "<ltx:XMArg>#2</ltx:XMArg>"
979                  . "<ltx:XMArg>#3</ltx:XMArg>"
980                  . "</ltx:XMApp>");
981 DefConstructor('\CnotprsubsetOp []',
982                    "<ltx:XMTok meaning='notprsubset' role='ID' ?#1(definitionURL='#1')()/>");
983 DefConstructor('\Cnotprsubset [] {}{}',
984                    "<ltx:XMApp>"
985                  . "<ltx:XMTok meaning='notprsubset' role='RELOP' ?#1(definitionURL='#1')()/>"
986                  . "<ltx:XMArg>#2</ltx:XMArg>"
987                  . "<ltx:XMArg>#3</ltx:XMArg>"
988                  . "</ltx:XMApp>");
989 DefConstructor('\CsetdiffOp []',
990                    "<ltx:XMTok meaning='setdiff' role='ID' ?#1(definitionURL='#1')()/>");
991 DefConstructor('\Csetdiff [] {}{}',
992                    "<ltx:XMApp>"
993                  . "<ltx:XMTok meaning='setdiff' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
994                  . "<ltx:XMArg>#2</ltx:XMArg>"
995                  . "<ltx:XMArg>#3</ltx:XMArg>"
996                  . "</ltx:XMApp>");
997 DefConstructor('\CcardOp []',
998                    "<ltx:XMTok meaning='card' role='ID' ?#1(definitionURL='#1')()/>");
999 DefConstructor('\Ccard [] {}',
1000                    "<ltx:XMApp>"
1001                  . "<ltx:XMTok meaning='card' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1002                  . "<ltx:XMArg>#2</ltx:XMArg>"
1003                  . "</ltx:XMApp>");
1004 DefConstructor('\CcartesianproductOp []',
1005                    "<ltx:XMTok meaning='cartesianproduct' role='ID' ?#1(definitionURL='#1')()/>");
1006 DefConstructor('\Ccartesianproduct [] {}',
1007                    "<ltx:XMApp>"
1008                  . "<ltx:XMTok meaning='cartesianproduct' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
```

```
1009                    . "#2"
1010                    . "</ltx:XMApp>",
1011          afterDigest=>sub { remove_math_commas($_[1], 2); });
```
1012 ⟨/ltxml⟩

The next set of macros are needed, since they are presentational.

1013 ⟨∗sty⟩
```
1014 \def\CMathML@supsetOp{\supseteq}
1015 \newcommand{\CsupsetOp}{\CMathML@supsetOp}
1016 \def\CMathML@supset#1{\assoc[p=700]{\CMathML@supsetOp}{#1}}
1017 \newcommand{\Csupset}[2][]{\CMathML@supset{#2}}
1018 \def\CMathML@prsupsetOp{\supset}
1019 \newcommand{\CprsupsetOp}{\CMathML@prsupsetOp}
1020 \def\CMathML@prsupset#1{\assoc[p=700]{\CMathML@prsupsetOp}{#1}}
1021 \newcommand{\Cprsupset}[2][]{\CMathML@prsupset{#2}}
1022 \def\CMathML@notsupsetOp{\not\supseteq}
1023 \newcommand{\CnotsupsetOp}{\CMathML@notsupsetOp}
1024 \def\CMathML@notsupset#1#2{#1\CMathML@notsupsetOp{#2}}
1025 \newcommand{\Cnotsupset}[3][]{\CMathML@notsupset{#2}{#3}}
1026 \def\CMathML@notprsupsetOp{\not\supset}
1027 \newcommand{\CnotprsupsetOp}{\CMathML@notprsupsetOp}
1028 \def\CMathML@notprsupset#1#2{#1\CMathML@notprsupsetOp{#2}}
1029 \newcommand{\Cnotprsupset}[3][]{\CMathML@notprsupset{#2}{#3}}
```
1030 ⟨/sty⟩

elements. Fortunately, we can just turn them around. [10]

EdNote(10)

1031 ⟨∗ltxml⟩
```
1032 DefConstructor('\CsupsetOp []',
1033              "<ltx:XMTok meaning='supset' role='ID' ?#1(definitionURL='#1')()/>");
1034 DefConstructor('\CprsupsetOp []',
1035              "<ltx:XMTok meaning='prsupset' role='ID' ?#1(definitionURL='#1')()/>");
1036 DefConstructor('\CnotsupsetOp []',
1037              "<ltx:XMTok meaning='notsupset' role='ID' ?#1(definitionURL='#1')()/>");
1038 DefConstructor('\CnotprsupsetOp []',
1039              "<ltx:XMTok meaning='notprsupset' role='ID' ?#1(definitionURL='#1')()/>");
1040 DefMacro('\Csupset[]{}','\Csubset[#1]{#2}');
1041 DefMacro('\Cprsupset[]{}','\Cprsubset[#1]{#2}');
1042 DefMacro('\Cnotsupset[]{}{}','\Cnotsubset[#1]{#3}{#2}');
1043 DefMacro('\Cnotprsupset[]{}{}','\Cnotprsubset[#1]{#3}{#2}');
```
1044 ⟨/ltxml⟩

1045 ⟨∗sty⟩
```
1046 \def\CMathML@UnionDAOp{\bigwedge}
1047 \newcommand{\CUnionDAOp}{\CMathML@UnionDAOp}
1048 \def\CMathML@UnionDA#1#2{\CMathML@UnionDAOp_{#1}{#2}} % set, scope
1049 \newcommand{\CUnionDA}[3][]{\CMathML@UnionDA{#2}{#3}}
1050 \def\CMathML@UnionCond#1#2#3{\CMathML@UnionDAOp_{#2}{#3}} % bvars,condition, scope
1051 \newcommand{\CUnionCond}[4][]{\CMathML@UnionCond{#2}{#2}{#3}}
1052 \def\CMathML@IntersectDAOp{\bigvee}
1053 \newcommand{\CIntersectDAOp}{\CMathML@IntersectDAOp}
1054 \def\CMathML@IntersectDA#1#2{\CMathML@IntersectDAOp_{#1}{#2}} % set, scope
1055 \newcommand{\CIntersectDa}[3][]{\CMathML@IntersectDA{#2}{#3}}
1056 \def\CMathML@IntersectCond#1#2#3{\CMathML@IntersectDAOp_{#2}{#3}}% bvars,condition, scope
1057 \newcommand{\CIntersectCond}[4][]{\CMathML@IntersectCond{#2}{#3}{#4}}
1058 \def\CMathML@CartesianproductDAOp{\bigoplus}
1059 \newcommand{\CCartesianproductDAOp}{\CMathML@CartesianproductDAOp}
1060 \def\CMathML@CartesianproductDA#1#2{\CMathML@CartesianproductDAOp_{#1}{#2}} % set, scope
1061 \newcommand{\CCartesianproductDA}[3][]{\CMathML@CartesianproductDA{#2}{#3}}
```

---

[10]EDNOTE: ooooops, this does not work for the associative ones.

```
1062 \def\CMathML@CartesianproductCond#1#2#3{\CMathML@CartesianproductDAOp_{#2}{#3}}% bvars,condition, scope
1063 \newcommand{\CCartesianproductCond}[4][]{\CMathML@CartesianproductCond{#2}{#3}{#4}}
1064 ⟨/sty⟩
1065 ⟨∗ltxml⟩
1066 DefConstructor('\CUnionDAOp []',
1067                "<ltx:XMTok meaning='union' role='ID' ?#1(definitionURL='#1')()/>");
1068 DefConstructor('\CUnionDA [] {}{}',
1069                "<ltx:XMApp>"
1070              . "<ltx:XMTok role='BIGOP' meaning='union' ?#1(definitionURL='#1')()/>"
1071              . "<ltx:XMArg>#2</ltx:XMArg>"
1072              . "<ltx:XMArg>#3</ltx:XMArg>"
1073              . "</ltx:XMApp>");
1074 DefConstructor('\CUnionCond [] {}{}{}',
1075                "<ltx:XMApp>"
1076              . "<ltx:XMTok role='BIGOP' meaning='union' ?#1(definitionURL='#1')()/>"
1077              . "<ltx:XMArg>#2</ltx:XMArg>"
1078              . "<ltx:XMArg>#3</ltx:XMArg>"
1079              . "<ltx:XMArg>#4</ltx:XMArg>"
1080              . "</ltx:XMApp>");
1081 DefConstructor('\CIntersectDaOp []',
1082                "<ltx:XMTok meaning='intersect' role='ID' ?#1(definitionURL='#1')()/>");
1083 DefConstructor('\CIntersectDa [] {}{}',
1084                "<ltx:XMApp>"
1085              . "<ltx:XMTok role='BIGOP' meaning='intersect' ?#1(definitionURL='#1')()/>"
1086              . "<ltx:XMArg>#2</ltx:XMArg>"
1087              . "<ltx:XMArg>#3</ltx:XMArg>"
1088              . "</ltx:XMApp>");
1089 DefConstructor('\CIntersectCond [] {}{}{}',
1090                "<ltx:XMApp>"
1091              . "<ltx:XMTok role='BIGOP' meaning='intersect' ?#1(definitionURL='#1')()/>"
1092              . "<ltx:XMArg>#2</ltx:XMArg>"
1093              . "<ltx:XMArg>#3</ltx:XMArg>"
1094              . "<ltx:XMArg>#4</ltx:XMArg>"
1095              . "</ltx:XMApp>");
1096 DefConstructor('\CCartesianproductDaOp []',
1097                "<ltx:XMTok meaning='cartesianproduct' role='ID' ?#1(definitionURL='#1')()/>");
1098 DefConstructor('\CCartesianproductDa [] {}{}',
1099                "<ltx:XMApp>"
1100              . "<ltx:XMTok role='BIGOP' meaning='cartesianproduct' ?#1(definitionURL='#1')()/>"
1101              . "<ltx:XMArg>#2</ltx:XMArg>"
1102              . "<ltx:XMArg>#3</ltx:XMArg>"
1103              . "</ltx:XMApp>");
1104 DefConstructor('\CCartesianproductCond [] {}{}{}',
1105                "<ltx:XMApp>"
1106              . "<ltx:XMTok role='BIGOP' meaning='cartesianproduct' ?#1(definitionURL='#1')()/>"
1107              . "<ltx:XMArg>#2</ltx:XMArg>"
1108              . "<ltx:XMArg>#3</ltx:XMArg>"
1109              . "<ltx:XMArg>#4</ltx:XMArg>"
1110              . "</ltx:XMApp>");
1111 ⟨/ltxml⟩
```

3.6 Sequences and Series

```
1112 ⟨∗sty⟩
1113 \def\CMathML@sumOp{\sum}
1114 \newcommand{\CsumOp}{\CMathML@sumOp}
1115 \def\CMathML@sumLimits#1#2#3#4{\CMathML@sumOp_{#1=#2}^{#3}#4}% bvar, llimit, ulimit, body
1116 \newcommand{\CsumLimits}[5][]{\CMathML@sumLimits{#2}{#3}{#4}{#5}}
1117 \def\CMathML@sumCond#1#2#3{\CMathML@sumOp_{#1\in{#2}}#3}   % bvar, condition, body
```

```
1118 \newcommand{\CsumCond}[4][]{\CMathML@sumCond{#2}{#3}{#4}}
1119 \def\CMathML@sumDA#1#2{\CMathML@sumOp_{#1}#2}              % set, body
1120 \newcommand{\CsumDA}[3][]{\CMathML@sumDA{#2}{#3}}
1121 ⟨/sty⟩
1122 ⟨*ltxml⟩
1123 DefConstructor('\CsumOp []',
1124                 "<ltx:XMTok meaning='sum' role='ID' ?#1(definitionURL='#1')()/>");
1125 DefConstructor('\CsumLimits [] {}{}{}{}',
1126                 "<ltx:XMApp>"
1127                . "<ltx:XMTok meaning='sum' role='SUMOP' ?#1(definitionURL='#1')()/>"
1128                . "<ltx:XMArg>#2</ltx:XMArg>"
1129                . "<ltx:XMArg>#3</ltx:XMArg>"
1130                . "<ltx:XMArg>#4</ltx:XMArg>"
1131                . "#5</ltx:XMApp>");
1132 ⟨/ltxml⟩
```

EdNote(11)   1112

EdNote(12)
```
1133 ⟨*sty⟩
1134 \def\CMathML@prodOp{\prod}
1135 \newcommand{\CprodOp}{\CMathML@prodOp}
1136 \def\CMathML@prodLimits#1#2#3#4{\CMathML@prodOp_{#1=#32^{#3}#4}}% bvar, llimit, ulimit, body
1137 \newcommand{\CprodLimits}[5][]{\CMathML@prodLimits{#2}{#3}{#4}{#5}}
1138 \def\CMathML@prodCond#1#2#3{\CMathML@prodOp_{#1\in{#2}}#3}   % bvar, condition, body
1139 \newcommand{\CprodCond}[4][]{\CMathML@prodCond{#2}{#3}{#4}}
1140 \def\CMathML@prodDA#1#2{\CMathML@prodOp_{#1}#2}              % set, body
1141 \newcommand{\CprodDA}[3]{\CMathML@prodDA{#2}{#3}}
1142 ⟨/sty⟩
1143 ⟨*ltxml⟩
1144 DefConstructor('\CprodOp []',
1145                 "<ltx:XMTok meaning='prod' role='ID' ?#1(definitionURL='#1')()/>");
1146 DefConstructor('\CprodLimits [] {}{}{}{}',
1147                 "<ltx:XMApp>"
1148                . "<ltx:XMTok meaning='prod' role='SUMOP' ?#1(definitionURL='#1')()/>"
1149                . "<ltx:XMArg><ci>#2</ci></ltx:XMArg>"
1150                . "<ltx:XMArg>#3</ltx:XMArg>"
1151                . "<ltx:XMArg>#4</ltx:XMArg>"
1152                . "#5</ltx:XMApp>");
1153 ⟨/ltxml⟩
```

EdNote(13)   13

3.7 Elementary Classical Functions

```
1154 ⟨*sty⟩
1155 \def\CMathML@sin#1{\sin(#1)}
1156 \newcommand{\Csin}[2][]{\CMathML@sin{#2}}
1157 \def\CMathML@cos#1{\cos(#1)}
1158 \newcommand{\Ccos}[2][]{\CMathML@cos{#2}}
1159 \def\CMathML@tan#1{\tan(#1)}
1160 \newcommand{\Ctan}[2][]{\CMathML@tan{#2}}
1161 \def\CMathML@sec#1{\sec(#1)}
1162 \newcommand{\Csec}[2][]{\CMathML@sec{#2}}
1163 \def\CMathML@csc#1{\csc(#1)}
1164 \newcommand{\Ccsc}[2][]{\CMathML@csc{#2}}
1165 \def\CMathML@cot#1{\cot(#1)}
1166 \newcommand{\Ccot}[2][]{\CMathML@cot{#2}}
1167 \def\CMathML@sinh#1{\sinh(#1)}
```

---

[11]EDNOTE: complete the other cases
[12]EDNOTE: add a keyword argument to all newcommands
[13]EDNOTE: complete the other cases

```
1168 \newcommand{\Csinh}[2][]{\CMathML@sinh{#2}}
1169 \def\CMathML@cosh#1{\cosh(#1)}
1170 \newcommand{\Ccosh}[2][]{\CMathML@cosh{#2}}
1171 \def\CMathML@tanh#1{\tanh(#1)}
1172 \newcommand{\Ctanh}[2][]{\CMathML@tanh{#2}}
1173 \def\CMathML@sech#1{\mbox{sech}(#1)}
1174 \newcommand{\Csech}[2][]{\CMathML@sech{#2}}
1175 \def\CMathML@csch#1{\mbox{csch}(#1)}
1176 \newcommand{\Ccsch}[2][]{\CMathML@csch{#2}}
1177 \def\CMathML@coth#1{\mbox{coth}(#1)}
1178 \newcommand{\Ccoth}[2][]{\CMathML@coth{#2}}
1179 \def\CMathML@arcsin#1{\arcsin(#1)}
1180 \newcommand{\Carcsin}[2][]{\CMathML@arcsin{#2}}
1181 \def\CMathML@arccos#1{\arccos(#1)}
1182 \newcommand{\Carccos}[2][]{\CMathML@arccos{#2}}
1183 \def\CMathML@arctan#1{\arctan(#1)}
1184 \newcommand{\Carctan}[2][]{\CMathML@arctan{#2}}
1185 \def\CMathML@arccosh#1{\mbox{arccosh}(#1)}
1186 \newcommand{\Carccosh}[2][]{\CMathML@arccosh{#2}}
1187 \def\CMathML@arccot#1{\mbox{arccot}(#1)}
1188 \newcommand{\Carccot}[2][]{\CMathML@arccot{#2}}
1189 \def\CMathML@arccoth#1{\mbox{arccoth}(#1)}
1190 \newcommand{\Carccoth}[2][]{\CMathML@arccoth{#2}}
1191 \def\CMathML@arccsc#1{\mbox{arccsc}(#1)}
1192 \newcommand{\Carccsc}[2][]{\CMathML@arccsc{#2}}
1193 \def\CMathML@arcsinh#1{\mbox{arcsinh}(#1)}
1194 \newcommand{\Carcsinh}[2][]{\CMathML@arcsinh{#2}}
1195 \def\CMathML@arctanh#1{\mbox{arctanh}(#1)}
1196 \newcommand{\Carctanh}[2][]{\CMathML@arctanh{#2}}
1197
1198 \def\CMathML@exp#1{\exp(#1)}
1199 \newcommand{\Cexp}[2][]{\CMathML@exp{#2}}
1200 \def\CMathML@ln#1{\ln(#1)}
1201 \newcommand{\Cln}[2][]{\CMathML@ln{#2}}
1202 \def\CMathML@log#1#2{\log_{#1}(#2)}
1203 \newcommand{\Clog}[3][]{\CMathML@log{#2}{#3}}
1204 ⟨/sty⟩
1205 ⟨∗ltxml⟩
1206 DefConstructor('\Csin [] {}',
1207                 "<ltx:XMApp>"
1208               . "<ltx:XMTok meaning='sin' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1209               . "<ltx:XMArg>#2</ltx:XMArg>"
1210               . "</ltx:XMApp>");
1211 DefConstructor('\Ccos [] {}',
1212                 "<ltx:XMApp>"
1213               . "<ltx:XMTok meaning='cos' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1214               . "<ltx:XMArg>#2</ltx:XMArg>"
1215               . "</ltx:XMApp>");
1216 DefConstructor('\Ctan [] {}',
1217                 "<ltx:XMApp>"
1218               . "<ltx:XMTok meaning='tan' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1219               . "<ltx:XMArg>#2</ltx:XMArg>"
1220               . "</ltx:XMApp>");
1221 DefConstructor('\Csec [] {}',
1222                 "<ltx:XMApp>"
1223               . "<ltx:XMTok meaning='sec' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1224               . "<ltx:XMArg>#2</ltx:XMArg>"
1225               . "</ltx:XMApp>");
```

```
1226 DefConstructor('\Ccsc [] {}',
1227                  "<ltx:XMApp>"
1228                . "<ltx:XMTok meaning='csc' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1229                . "<ltx:XMArg>#2</ltx:XMArg>"
1230                . "</ltx:XMApp>");
1231 DefConstructor('\Ccot [] {}',
1232                  "<ltx:XMApp>"
1233                . "<ltx:XMTok meaning='cot' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1234                . "<ltx:XMArg>#2</ltx:XMArg>"
1235                . "</ltx:XMApp>");
1236 DefConstructor('\Csinh [] {}',
1237                  "<ltx:XMApp>"
1238                . "<ltx:XMTok meaning='sinh' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1239                . "<ltx:XMArg>#2</ltx:XMArg>"
1240                . "</ltx:XMApp>");
1241 DefConstructor('\Ccosh [] {}',
1242                  "<ltx:XMApp>"
1243                . "<ltx:XMTok meaning='cosh' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1244                . "<ltx:XMArg>#2</ltx:XMArg>"
1245                . "</ltx:XMApp>");
1246 DefConstructor('\Ctanh [] {}',
1247                  "<ltx:XMApp>"
1248                . "<ltx:XMTok meaning='tanh' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1249                . "<ltx:XMArg>#2</ltx:XMArg>"
1250                . "</ltx:XMApp>");
1251 DefConstructor('\Csech [] {}',
1252                  "<ltx:XMApp>"
1253                . "<ltx:XMTok meaning='sech' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1254                . "<ltx:XMArg>#2</ltx:XMArg>"
1255                . "</ltx:XMApp>");
1256 DefConstructor('\Ccsch [] {}',
1257                  "<ltx:XMApp>"
1258                . "<ltx:XMTok meaning='csch' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1259                . "<ltx:XMArg>#2</ltx:XMArg>"
1260                . "</ltx:XMApp>");
1261 DefConstructor('\Ccoth [] {}',
1262                  "<ltx:XMApp>"
1263                . "<ltx:XMTok meaning='coth' role='TRIGFUNCTION' ?#1(definitionURL='#1')()/>"
1264                . "<ltx:XMArg>#2</ltx:XMArg>"
1265                . "</ltx:XMApp>");
1266 DefConstructor('\Carcsin [] {}',
1267                  "<ltx:XMApp>"
1268                . "<ltx:XMTok meaning='arcsin' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1269                . "<ltx:XMArg>#2</ltx:XMArg>"
1270                . "</ltx:XMApp>");
1271 DefConstructor('\Carccos [] {}',
1272                  "<ltx:XMApp>"
1273                . "<ltx:XMTok meaning='arccos' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1274                . "<ltx:XMArg>#2</ltx:XMArg>"
1275                . "</ltx:XMApp>");
1276 DefConstructor('\Carctan [] {}',
1277                  "<ltx:XMApp>"
1278                . "<ltx:XMTok meaning='arctan' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1279                . "<ltx:XMArg>#2</ltx:XMArg>"
1280                . "</ltx:XMApp>");
1281 DefConstructor('\Carcsec [] {}',
1282                  "<ltx:XMApp>"
1283                . "<ltx:XMTok meaning='arcsec' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
```

```
1284                . "<ltx:XMArg>#2</ltx:XMArg>"
1285                . "</ltx:XMApp>");
1286 DefConstructor('\Carccsc [] {}',
1287                "<ltx:XMApp>"
1288                . "<ltx:XMTok meaning='arccsc' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1289                . "<ltx:XMArg>#2</ltx:XMArg>"
1290                . "</ltx:XMApp>");
1291 DefConstructor('\Carccot [] {}',
1292                "<ltx:XMApp>"
1293                . "<ltx:XMTok meaning='arccot' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1294                . "<ltx:XMArg>#2</ltx:XMArg>"
1295                . "</ltx:XMApp>");
1296 DefConstructor('\Carcsinh [] {}',
1297                "<ltx:XMApp>"
1298                . "<ltx:XMTok meaning='arcsinh' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1299                . "<ltx:XMArg>#2</ltx:XMArg>"
1300                . "</ltx:XMApp>");
1301 DefConstructor('\Carccosh [] {}',
1302                "<ltx:XMApp>"
1303                . "<ltx:XMTok meaning='arccosh' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1304                . "<ltx:XMArg>#2</ltx:XMArg>"
1305                . "</ltx:XMApp>");
1306 DefConstructor('\Carctanh [] {}',
1307                "<ltx:XMApp>"
1308                . "<ltx:XMTok meaning='arctanh' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1309                . "<ltx:XMArg>#2</ltx:XMArg>"
1310                . "</ltx:XMApp>");
1311 DefConstructor('\Carcsech [] {}',
1312                "<ltx:XMApp>"
1313                . "<ltx:XMTok meaning='arcsech' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1314                . "<ltx:XMArg>#2</ltx:XMArg>"
1315                . "</ltx:XMApp>");
1316 DefConstructor('\Carccsch [] {}',
1317                "<ltx:XMApp>"
1318                . "<ltx:XMTok meaning='arccsch' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1319                . "<ltx:XMArg>#2</ltx:XMArg>"
1320                . "</ltx:XMApp>");
1321 DefConstructor('\Carccoth [] {}',
1322                "<ltx:XMApp>"
1323                . "<ltx:XMTok meaning='arccoth' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1324                . "<ltx:XMArg>#2</ltx:XMArg>"
1325                . "</ltx:XMApp>");
1326 DefConstructor('\Cexp [] {}',
1327                "<ltx:XMApp>"
1328                . "<ltx:XMTok meaning='exp' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1329                . "<ltx:XMArg>#2</ltx:XMArg>"
1330                . "</ltx:XMApp>");
1331 DefConstructor('\Cln [] {}',
1332                "<ltx:XMApp>"
1333                . "<ltx:XMTok meaning='ln' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1334                . "<ltx:XMArg>#2</ltx:XMArg>"
1335                . "</ltx:XMApp>");
1336 DefConstructor('\Clog [] {}{}',
1337                "<ltx:XMApp>"
1338                . "<ltx:XMTok meaning='log' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1339                . "<ltx:XMArg>#2</ltx:XMArg>"
1340                . "<ltx:XMArg>#3</ltx:XMArg>"
1341                . "</ltx:XMApp>");
```

1342 ⟨/ltxml⟩

3.8 Statistics

```
1343 ⟨*sty⟩
1344 \def\CMathML@mean#1{\mbox{mean}(#1)}
1345 \newcommand{\Cmean}[2][]{\CMathML@mean{#2}}
1346 \def\CMathML@sdev#1{\mbox{std}(#1)}
1347 \newcommand{\Csdev}[2][]{\CMathML@sdev{#2}}
1348 \def\CMathML@var#1{\mbox{var}(#1)}
1349 \newcommand{\Cvar}[2][]{\CMathML@var{#2}}
1350 \def\CMathML@median#1{\mbox{median}(#1)}
1351 \newcommand{\Cmedian}[2][]{\CMathML@median{#2}}
1352 \def\CMathML@mode#1{\mbox{mode}(#1)}
1353 \newcommand{\Cmode}[2][]{\CMathML@mode{#2}}
1354 \def\CMathML@moment#1#2{\langle{#2}^{#1}\rangle}% degree, momentabout, scope
1355 \newcommand{\Cmoment}[3][]{\CMathML@moment{#2}{#3}}
1356 \def\CMathML@momentA#1#2{\langle{#2}^{#1}\rangle}% degree, momentabout, scope
1357 \newcommand{\CmomentA}[4][]{\CMathML@momentA{#2}{#3}{#4}}
1358 ⟨/sty⟩
1359 ⟨*ltxml⟩
1360 DefConstructor('\Cmean [] {}',
1361                 "<ltx:XMApp>"
1362              . "<ltx:XMTok meaning='mean' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1363              . "<ltx:XMArg>#2</ltx:XMArg>"
1364              . "</ltx:XMApp>");
1365 DefConstructor('\Csdev [] {}',
1366                 "<ltx:XMApp>"
1367              . "<ltx:XMTok meaning='sdev' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1368              . "<ltx:XMArg>#2</ltx:XMArg>"
1369              . "</ltx:XMApp>");
1370 DefConstructor('\Cvar [] {}',
1371                 "<ltx:XMApp>"
1372              . "<ltx:XMTok meaning='var' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1373              . "<ltx:XMArg>#2</ltx:XMArg>"
1374              . "</ltx:XMApp>");
1375 DefConstructor('\Cmedian [] {}',
1376                 "<ltx:XMApp>"
1377              . "<ltx:XMTok meaning='median' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1378              . "<ltx:XMArg>#2</ltx:XMArg>"
1379              . "</ltx:XMApp>");
1380 DefConstructor('\Cmode [] {}',
1381                 "<ltx:XMApp>"
1382              . "<ltx:XMTok meaning='mode' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1383              . "<ltx:XMArg>#2</ltx:XMArg>"
1384              . "</ltx:XMApp>");
1385 DefConstructor('\Cmoment [] {}',
1386                 "<ltx:XMApp>"
1387              . "<ltx:XMTok meaning='moment' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1388              . "<ltx:XMArg>#2</ltx:XMArg>"
1389              . "</ltx:XMApp>");
1390 ⟨/ltxml⟩
```

EdNote(14)   1415
EdNote(15)

3.9 Linear Algebra

1391 ⟨*sty⟩

---

[14]EDNOTE: we do not seem to need the momentabout.
[15]EDNOTE: moment and momentA have funny elided arguments

```
1392 \def\CMathML@vector#1{(#1)}
1393 \newcommand{\Cvector}[2][]{\CMathML@vector{#2}}
1394 \def\CMathML@matrix#1#2{\left(\begin{array}{#1}#2\end{array}\right)}% row pattern, body
1395 \newcommand{\Cmatrix}[3][]{\CMathML@matrix{#2}{#3}}
1396 \def\CMathML@determinant#1{\left|#1\right|}
1397 \newcommand{\Cdeterminant}[2][]{\CMathML@determinant{#2}}
1398 \def\CMathML@transpose#1{#1^\top}
1399 \newcommand{\Ctranspose}[2][]{\CMathML@transpose{#2}}
1400 \def\CMathML@selector#1#2{#1_{#2}}
1401 \newcommand{\Cselector}[3][]{\CMathML@selector{#2}{#3}}
1402 \def\CMathML@vectproductOp{\cdot}
1403 \newcommand{\CvectproductOp}{\CMathML@vectproductOp}
1404 \def\CMathML@vectproduct#1#2{#1\CMathML@vectproductOp{#2}}
1405 \newcommand{\Cvectproduct}[3][]{\CMathML@vectproduct{#2}{#3}}
1406 \def\CMathML@scalarproduct#1#2{{#1}#2}
1407 \newcommand{\Cscalarproduct}[3][]{\CMathML@scalarproduct{#2}{#3}}
1408 \def\CMathML@outerproductOp{\times}
1409 \newcommand{\CouterproductOp}{\CMathML@outerproductOp}
1410 \def\CMathML@outerproduct#1#2{#1\CMathML@outerproductOp{#2}}
1411 \newcommand{\Couterproduct}[3][]{\CMathML@outerproduct{#2}{#3}}
1412 ⟨/sty⟩
1413 ⟨*ltxml⟩
1414 DefConstructor('\Cvector [] {}',
1415                 "<ltx:XMApp>"
1416               . "<ltx:XMTok role='CONSTRUCTOR' meaning='vector' ?#1(definitionURL='#1')()/>"
1417               . "#2"
1418               . "</ltx:XMApp>",
1419         afterDigest=>sub { remove_math_commas($_[1], 2); });
1420 DefConstructor('\Cmatrix [] {}{}',
1421                 "<ltx:XMApp>"
1422               . "<ltx:XMTok role='CONSTRUCTOR' meaning='matrix' ?#1(definitionURL='#1')()/>"
1423               . "<ltx:XMArg>#2</ltx:XMArg>"
1424               . "<ltx:XMArg>#3</ltx:XMArg>"
1425               . "</ltx:XMApp>");
1426 DefConstructor('\Cdeterminant [] {}',
1427                 "<ltx:XMApp>"
1428               . "<ltx:XMTok meaning='determinant' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1429               . "<ltx:XMArg>#2</ltx:XMArg>"
1430               . "</ltx:XMApp>");
1431 DefConstructor('\Ctranspose [] {}',
1432                 "<ltx:XMApp>"
1433               . "<ltx:XMTok meaning='transpose' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1434               . "<ltx:XMArg>#2</ltx:XMArg>"
1435               . "</ltx:XMApp>");
1436 DefConstructor('\Cselector [] {}{}',
1437                 "<ltx:XMApp>"
1438               . "<ltx:XMTok meaning='selector' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1439               . "<ltx:XMArg>#2</ltx:XMArg>"
1440               . "<ltx:XMArg>#3</ltx:XMArg>"
1441               . "</ltx:XMApp>");
1442 DefConstructor('\CvectorproductOp []',
1443               "<ltx:XMTok meaning='vectorproduct' role='ID' ?#1(definitionURL='#1')()/>");
1444 DefConstructor('\Cvectorproduct [] {}{}',
1445                 "<ltx:XMApp>"
1446               . "<ltx:XMTok meaning='vectorproduct' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1447               . "<ltx:XMArg>#2</ltx:XMArg>"
1448               . "<ltx:XMArg>#3</ltx:XMArg>"
1449               . "</ltx:XMApp>");
```

```
1450 DefConstructor('\Cscalarproduct [] {}{}',
1451                "<ltx:XMApp>"
1452              . "<ltx:XMTok meaning='scalarproduct' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1453              . "<ltx:XMArg>#2</ltx:XMArg>"
1454              . "<ltx:XMArg>#3</ltx:XMArg>"
1455              . "</ltx:XMApp>");
1456 DefConstructor('\CouterproductOp []',
1457                "<ltx:XMTok meaning='outerproduct' role='ID' ?#1(definitionURL='#1')()/>");
1458 DefConstructor('\Couterproduct [] {}{}',
1459                "<ltx:XMApp>"
1460              . "<ltx:XMTok meaning='outerproduct' role='OPFUNCTION' ?#1(definitionURL='#1')()/>"
1461              . "<ltx:XMArg>#2</ltx:XMArg>"
1462              . "<ltx:XMArg>#3</ltx:XMArg>"
1463              . "</ltx:XMApp>");#$
1464 ⟨/ltxml⟩
```

3.10   Constant and Symbol Elements

```
1465 ⟨*sty⟩
1466 \def\CMathML@integers{{\mathbb{Z}}}
1467 \newcommand{\Cintegers}[1][]{\CMathML@integers}
1468 \def\CMathML@reals{{\mathbb{R}}}
1469 \newcommand{\Creals}[1][]{\CMathML@reals}
1470 \def\CMathML@rationals{{\mathbb{Q}}}
1471 \newcommand{\Crationals}[1][]{\CMathML@rationals}
1472 \def\CMathML@naturalnumbers{{\mathbb{N}}}
1473 \newcommand{\Cnaturalnumbers}[1][]{\CMathML@naturalnumbers}
1474 \def\CMathML@complexes{{\mathbb{C}}}
1475 \newcommand{\Ccomplexes}[1][]{\CMathML@complexes}
1476 \def\CMathML@primes{{\mathbb{P}}}
1477 \newcommand{\Cprimes}[1][]{\CMathML@primes}
1478 \def\CMathML@exponemtiale{e}
1479 \newcommand{\Cexponemtiale}[1][]{\CMathML@exponemtiale}
1480 \def\CMathML@imaginaryi{i}
1481 \newcommand{\Cimaginaryi}[1][]{\CMathML@imaginaryi}
1482 \def\CMathML@notanumber{{\mathrm{NaN}}}
1483 \newcommand{\Cnotanumber}[1][]{\CMathML@notanumber}
1484 \def\CMathML@true{{\mathrm{true}}}
1485 \newcommand{\Ctrue}[1][]{\CMathML@true}
1486 \def\CMathML@false{{\mathrm{false}}}
1487 \newcommand{\Cfalse}[1][]{\CMathML@false}
1488 \def\CMathML@emptyset{\emptyset}
1489 \newcommand{\Cemptyset}[1][]{\CMathML@emptyset}
1490 \def\CMathML@pi{\pi}
1491 \newcommand{\Cpi}[1][]{\CMathML@pi}
1492 \def\CMathML@eulergamma{\gamma}
1493 \newcommand{\Ceulergamma}[1][]{\CMathML@eulergamma}
1494 \def\CMathML@infinit{\infty}
1495 \newcommand{\Cinfinit}[1][]{\CMathML@infinit}
1496 ⟨/sty⟩
1497 ⟨*ltxml⟩
1498 DefConstructor('\Cintegers []',
1499                "<ltx:XMTok meaning='integers' role='ID' ?#1(definitionURL='#1')()/>");
1500 DefConstructor('\Creals []',
1501                "<ltx:XMTok meaning='reals' role='ID' ?#1(definitionURL='#1')()/>");
1502 DefConstructor('\Crationals []',
1503                "<ltx:XMTok meaning='rationals' role='ID' ?#1(definitionURL='#1')()/>");
1504 DefConstructor('\Cnaturalnumbers []',
1505                "<ltx:XMTok meaning='naturalnumbers' role='ID' ?#1(definitionURL='#1')()/>");
```

```
1506 DefConstructor('\Ccomplexes []',
1507             "<ltx:XMTok meaning='complexes' role='ID' ?#1(definitionURL='#1')()/>");
1508 DefConstructor('\Cprimes []',
1509             "<ltx:XMTok meaning='primes'  role='ID' ?#1(definitionURL='#1')()/>");
1510 DefConstructor('\Cexponentiale []',
1511             "<ltx:XMTok meaning='exponentiale' role='ID' ?#1(definitionURL='#1')()/>");
1512 DefConstructor('\Cimaginaryi []',
1513             "<ltx:XMTok meaning='imaginaryi' role='ID' ?#1(definitionURL='#1')()/>");
1514 DefConstructor('\Cnotanumber []',
1515             "<ltx:XMTok meaning='notanumber' role='ID' ?#1(definitionURL='#1')()/>");
1516 DefConstructor('\Ctrue []',
1517             "<ltx:XMTok meaning='true' role='ID' ?#1(definitionURL='#1')()/>");
1518 DefConstructor('\Cfalse []',
1519             "<ltx:XMTok meaning='false' role='ID' ?#1(definitionURL='#1')()/>");
1520 DefConstructor('\Cemptyset []',
1521             "<ltx:XMTok meaning='emptyset' role='ID' ?#1(definitionURL='#1')()/>");
1522 DefConstructor('\Cpi []',
1523             "<ltx:XMTok meaning='pi' role='ID' ?#1(definitionURL='#1')()/>");
1524 DefConstructor('\Ceulergamma []',
1525             "<ltx:XMTok meaning='eulergamma' role='ID' ?#1(definitionURL='#1')()/>");
1526 DefConstructor('\Cinfinit []',
1527             "<ltx:XMTok meaning='infinit' role='ID' ?#1(definitionURL='#1')()/>");
1528 ⟨/ltxml⟩
```

3.11 Extensions

\Ccomplement

```
1529 ⟨*styx⟩
1530 \def\CMathML@complement#1{#1^c}
1531 \newcommand{\Ccomplement}[2][]{\CMathML@complement{#2}}
1532 ⟨/styx⟩
1533 ⟨*ltxmlx⟩
1534 DefConstructor('\Ccomplement [] {}',
1535             "<ltx:XMApp>"
1536           . "<ltx:XMTok meaning='complement' role='CSYMBOL'/>"
1537           . "<ltx:XMArg>#2</ltx:XMArg>"
1538           . "</ltx:XMApp>");
1539 ⟨/ltxmlx⟩
```

3.12 Finale

Finally, we need to terminate the file with a success mark for perl.

```
1540 ⟨ltxml⟩1;
```

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Numbers written in italic refer to the page where the corresponding entry is described; numbers underlined refer to the code line of the definition; numbers in roman refer to the code lines where the entry is used.