

# Third-party maxima software

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## Contents

### 1 Array Representation For Expressions

Maxima expressions are normally implemented internally as lisp lists, but they may also be represented by lisp arrays. Each representation has advantages.

### 2 Attributes

A function may possess a list of attributes. The attributes control how the arguments to the function are evaluated and how errors are handled.

- `attributes`
- `set_match_form`
- `set_nowarn`
- `unset_match_form`
- `unset_nowarn`

#### 2.1 Function: `attributes`

`attributes`(*name*)

**Description** Returns a list of the ‘attributes’ of function *name*.

**Arguments** `attributes` requires one argument *name*, which must be a string or a symbol.

See also `unset_match_form`, `set_match_form`, `set_nowarn`, and `unset_nowarn`.

#### 2.2 Function: `set_match_form`

`set_match_form`(*names*)

**Description** Set the ‘match\_form’ attribute for function(s) *names*. If the argument checks for a function call fail, and the attribute ‘match\_form’ is set, then rather than signaling an error, the unevaluated form is returned. Furthermore, if the attribute ‘nowarn’ is not set, then a warning message is printed.

**Arguments** `set_match_form` requires one argument *names*, which must be a string, a symbol, or a list of strings or symbols.

See also `unset_match_form`, `set_nowarn`, `unset_nowarn`, and `attributes`.

## 2.3 Function: `set_nowarn`

`set_nowarn(names)`

**Description** Set the ‘nowarn’ attribute for function(s) *names*. If the argument checks for a function call fail, and the attribute ‘match\_form’ is set, and the attribute ‘nowarn’ is set, then rather than signaling an error, the unevaluated form is returned and no warning message is printed.

**Arguments** `set_nowarn` requires one argument *names*, which must be a string, a symbol, or a list of strings or symbols.

See also `unset_match_form`, `set_match_form`, `unset_nowarn`, and `attributes`.

## 2.4 Function: `unset_match_form`

`unset_match_form(names)`

**Description** Unset the ‘match\_form’ attribute for function(s) *names*. If the argument checks for a function call fail, and the attribute ‘match\_form’ is set, then rather than signaling an error, the unevaluated form is returned. Furthermore, if the attribute ‘nowarn’ is not set, then a warning message is printed.

**Arguments** `unset_match_form` requires one argument *names*, which must be a string, a symbol, or a list of strings or symbols.

See also `set_match_form`, `set_nowarn`, `unset_nowarn`, and `attributes`.

## 2.5 Function: `unset_nowarn`

`unset_nowarn(names)`

**Description** Unset the ‘nowarn’ attribute for function(s) *names*. If the argument checks for a function call fail, and the attribute ‘match\_form’ is set, and the attribute ‘nowarn’ is set, then rather than signaling an error, the unevaluated form is returned and no warning message is printed.

**Arguments** `unset_nowarn` requires one argument *names*, which must be a string, a symbol, or a list of strings or symbols.

See also `unset_match_form`, `set_match_form`, `set_nowarn`, and `attributes`.

# 3 Functions and Variables for Array Representation for Expressions

These functions operate on the the array expression data structure.

- `aeop`
- `aex`
- `aex_cp`
- `aex_get`
- `aex_new`
- `aex_set`
- `aex_shift`
- `aex.unshift`

- aexg
- aexs
- copy\_aex\_type
- iapply
- ilength
- ipart
- ipart\_set
- ireverse
- lex

### 3.1 Function: aeop

**aeop**(*expr*)  
 next package: aex

**Description** op function for aex. returns op if *e* is not an aex.

**Arguments** aeop requires one argument *expr*, which must be non-atomic.

### 3.2 Function: aex

**aex**( :optional *x*)  
 next package: aex

#### Calling

**aex**(*e*) Converts expression *e* to an array representation. The input expression *e* is returned unchanged if it is already an array expression or is a symbol or number or specially represented maxima expression. This function converts only at the first level.

**Arguments** aex requires either zero or one arguments.

**Options** aex takes options with default values: **adj**->**true**.

### 3.3 Function: aex\_cp

**aex\_cp**(*e* :optional *head*)  
 next package: aex

#### Calling

**aex\_cp**(*e*) Returns an aex form copy of *e*. *e* may be in either lex or aex form. Conversion to aex representation occurs only on the first level.

**Arguments** aex\_cp requires either one or two arguments. The first argument *e* must be non-atomic.

**Options** aex\_cp takes options with default values: **adj**->**true**.

### 3.4 Function: aex\_get

**Description** Returns the  $n$ th part of aexpr  $e$ . A value of 0 for  $n$  is not allowed. This is more efficient than `aexg`, which allows  $n$  equal to zero.

#### Examples

```
(%i1) a : aex([5,6,7]), aex_get(a,2);  
(%o1) 7
```

### 3.5 Function: aex\_new

`aex_new( $n$  : optional head)`

next package: aex

**Arguments** `aex_new` requires either one or two arguments. The first argument  $n$  must be a non-negative integer.

### 3.6 Function: aex\_set

**Description** Destructively sets the  $n$ th part of aexpr  $e$  to value  $v$ . A value of 0 for  $n$  is not allowed. This is more efficient than `aexs`. No argument checking is done.

#### Examples

Destructively assign to a part of an expression.

```
(%i1) a : aex([1,2,3]), aex_set(a,1,x), a;  
(%o1) <[1,x,3]>
```

See also `aexs` and `ipart`.

### 3.7 Function: aex\_shift

`aex_shift( $e$ )`

next package: aex

**Description** destructively removes an element from the end of  $e$ . For array representation of expressions we use the words ‘push’ and ‘pop’ for the beginning of and expression, and ‘shift’ and ‘unshift’ for the end of an expression, whether the representation is an array or a list. This is consistent with maxima, but the reverse of the meaning of the terms in perl.

**Arguments** `aex_shift` requires one argument  $e$ , which must be an adjustable array expression.

#### Examples

```
(%i1) a : lrange(10,ot->ar);  
(%o1) <[1,2,3,4,5,6,7,8,9,10]>  
(%i1) b : aex_shift(a);  
(%o1) 10  
(%i2) a;  
(%o2) <[1,2,3,4,5,6,7,8,9]>
```

### 3.8 Function: aex\_unshift

**aex\_unshift**(*v*, *e*)  
next package: aex

**Description** Destructively pushes an element *v* onto the end of *e*. The return value is *v*. For array representation of expressions we use the words ‘push’ and ‘pop’ for the beginning of and expression, and ‘shift’ and ‘unshift’ for the end of an expression, whether the representation is an array or a list. This is consistent with maxima, but the reverse of the meaning of the terms in perl.

**Arguments** **aex\_unshift** requires two arguments. The second argument *e* must be an adjustable array expression.

**Examples**

```
(%i1) a : lrange(10,ot->ar), aex_unshift("dog",a), a;  
(%o1) <[1,2,3,4,5,6,7,8,9,10,"dog"]>
```

### 3.9 Function: aexg

**Description** **aexg**(*e*,*n*) returns the *n*th part of aexpr *e*. If *n* is 0, the head of *e* is returned. No argument checking is performed.

See also **aex\_get**, **ipart**, **inpart**, and **part**.

### 3.10 Function: aexs

**Description** destructively sets the *n*th part of aexpr *e* to value *v*. A value of 0 for *n* returns the head (or op) of *e*.

### 3.11 Function: copy\_aex\_type

**copy\_aex\_type**(*ein*)  
next package: aex

**Description** Create a new aex with same head,length,adjustability,etc. but contents of expression are not copied.

**Arguments** **copy\_aex\_type** requires one argument *ein*, which must be an array-representation expression.

### 3.12 Function: iapply

**iapply**(*fun*, *arg*)  
next package: aex

**Description** **iapply** is like maxima **apply**, but it supports aex lists. *arg* is converted to an ml if it is an aex expression. By default, output is ml regardless of the input representation.

**Arguments** **iapply** requires two arguments. The first argument *fun* must be a function. The second argument *arg* must be non-atomic.

**Options** **iapply** takes options with default values: **adj->true**, **ot->ml**.

**Examples**

```
(%i1) iapply(%ff,lrange(4));
(%o1) %ff(1,2,3,4)
```

```
(%i1) iapply(%ff,lrange(4,[ot->ar]));
(%o1) %ff(1,2,3,4)
```

```
(%i1) iapply(%ff,lrange(4,[ot->ar]), [ot->ar] );
(%o1) %ff<1,2,3,4>
```

```
(%i1) iapply(%ff,lrange(4), [ot->ar] );
(%o1) %ff<1,2,3,4>
```

### 3.13 Function: ilength

**ilength**(*e*)

next package: aex

**Description** Returns the length of the expression *e*. This is like maxima **length**, but here, *e* can be either an aex or a lex.

**Arguments** **ilength** requires one argument *e*, which must be a subscripted variable or non-atomic.

### 3.14 Function: ipart

**Calling**

**ipart**(*e, ind1, ind2, ...*) Returns the part of expression *e* specified by indices. *e* may be a mixed (lex and aex) representation expression. When used as an lvalue, **ipart** can be used to assign to a part of an expression. If an index is negative, then it counts from the end of the list. If *e* is an ordinary maxima list (lex), then using a negative index is potentially slower than using a positive index because the entire list must first be traversed in order to determine it's length. If *e* is in aex representation, then this inefficiency is not present.

**Examples**

Destructively assign to a part of an expression.

```
(%i1) (a : [1,2,3], ipart(a,1) : 7, a);
(%o1) [7,2,3]
```

**Implementation** Some tests were performed with large lists of numbers. If we set **a:lrange(10<sup>7</sup>)**, then the times required for **ipart(a,10<sup>7</sup>)**, **ipart(a,-1)**, **ipart(a,10<sup>7</sup>)**, and **part(a,10<sup>7</sup>)** were 30, 60, 90, and 90 ms.

### 3.15 Function: ipart\_set

**Calling**

**ipart\_set**(*e, val, ind1, ind2, ...*) Set part of *e* specified by the final arguments to *val*. *e* is a mixed representation expression.

### 3.16 Function: ireverse

**ireverse**(*e*)

next package: aex

**Description** ireverse is like maxima reverse, but it works on both aex and list objects. ireverse tries to be identical to maxima reverse for a non-aex argument.

**Arguments** ireverse requires one argument *e*, which must be non-atomic.

**Options** ireverse takes options with default values: `adj->true`, `ot->ml`.

**Examples**

```
(%i1) ireverse(lrange(4));  
(%o1) [4,3,2,1]
```

```
(%i1) ireverse(lrange(4), [ot->ar] );  
(%o1) <[4,3,2,1]>
```

```
(%i1) ireverse(lrange(4, [ot->ar]) );  
(%o1) <[4,3,2,1]>
```

```
(%i1) ireverse(lrange(4, [ot->ar]), [ot->ml] );  
(%o1) [4,3,2,1]
```

### 3.17 Function: lex

**Calling**

**lex**(*e*) converts the aex expression *e* to lex. If *e* is not an aex expression, *e* is returned. Conversion is only done on the first level.

## 4 Functions and Variables for Combinatorics

- `ae_random.permutation`
- `cycles_to_perm`
- `inverse_permutation`
- `perm_to_cycles`
- `perm_to_transpositions`
- `permutation_p`
- `permutation_p1`
- `random_cycle`
- `random_permutation_sym`
- `signature_permutation`
- `transpositions_to_perm`

## 4.1 Function: `ae_random_permutation`

`ae_random_permutation(a)`

next package: `discrete_aex`

**Description** returns *a* with subexpressions permuted randomly.

**Arguments** `ae_random_permutation` requires one argument *a*, which must be non-atomic.

**Options** `ae_random_permutation` takes options with default values: `adj->true`, `ot->ml`.

See also `random_cycle`, `random_permutation_sym`, `signature_permutation`, `perm_to_cycles`, and `cycles_to_perm`.

## 4.2 Function: `cycles_to_perm`

`cycles_to_perm(cycles)`

next package: `discrete_aex`

**Description** Returns a permutation from its cycle decomposition *cycles*, which is a list of lists. Here ‘permutation’ means a permutation of a list of the integers from 1 to some number *n*. The default output representation is `aex`.

**Arguments** `cycles_to_perm` requires one argument *cycles*, which must be a list (lex or `aex`).

**Options** `cycles_to_perm` takes options with default values: `adj->true`, `ot->ml`.

See also `random_cycle`, `random_permutation_sym`, `ae_random_permutation`, `signature_permutation`, and `perm_to_cycles`.

## 4.3 Function: `inverse_permutation`

`inverse_permutation(perm)`

next package: `discrete_aex`

**Description** Returns the inverse permutation of *perm*.

**Arguments** `inverse_permutation` requires one argument *perm*, which must be a list (lex or `aex`).

**Options** `inverse_permutation` takes options with default values: `adj->true`, `ot->ml`.

**Examples**

```
(%i1) inverse_permutation([5,1,4,2,6,8,7,3,10,9]);  
(%o1) <[2,4,8,3,1,5,7,6,10,9]>  
(%i1) inverse_permutation(inverse_permutation([5,1,4,2,6,8,7,3,10,9]),ot->ml);  
(%o1) [5,1,4,2,6,8,7,3,10,9]
```

## 4.4 Function: `perm_to_cycles`

`perm_to_cycles(ain)`

next package: `discrete_aex`

**Description** Returns a cycle decomposition of the input permutation *ain*. The input must be a permutation of *n* integers from 1 through *n*.

**Arguments** `perm_to_cycles` requires one argument *ain*, which must be a list (lex or `aex`).

**Options** `perm_to_cycles` takes options with default values: `adj->true`, `ot->ml`.

**Examples**



```
(%i1) perm_to_cycles([5,4,3,2,1,10,6,7,8,9]);  
(%o1) [[7,8,9,10,6],[3],[4,2],[5,1]]
```

See also `random_cycle`, `random_permutation_sym`, `ae_random_permutation`, `signature_permutation`, and `cycles_to_perm`.

#### 4.5 Function: `perm_to_transpositions`

`perm_to_transpositions(ain)`

next package: `discrete_aex`

**Description** Returns a list representing the permutation *ain* as a product of transpositions. The output representation type is applied at both levels.

**Arguments** `perm_to_transpositions` requires one argument *ain*, which must be a list (lex or aex).

**Options** `perm_to_transpositions` takes options with default values: `adj->true`, `ot->m1`.

#### 4.6 Function: `permutation_p`

`permutation_p(ain)`

next package: `discrete_aex`

##### Calling

`permutation_p(list)` Returns true if the list *list* of length *n* is a permutation of the integers from 1 through *n*. Otherwise returns false.

**Arguments** `permutation_p` requires one argument.

**Implementation** Separate routines for aex and lex input are used.

#### 4.7 Function: `permutation_p1`

`permutation_p1(ain)`

next package: `discrete_aex`

**Description** This is the same as `permutation_p`, but, if the input is a list, it assumes all elements in the input list are fixnum integers, while `permutation_p` does not.

**Arguments** `permutation_p1` requires one argument.

**Implementation** Some variables are declared fixnum, but this does not seem to improve performance with respect to `permutationp`.

#### 4.8 Function: `random_cycle`

`random_cycle(n)`

next package: `discrete_aex`

##### Calling

`random_cycle(n)` Returns a random cycle of length *n*. The return value is a list of the integers from 1 through *n*, representing an element of the symmetric group  $S_n$  that is a cycle.

**Arguments** `random_cycle` requires one argument  $n$ , which must be a positive integer.

**Options** `random_cycle` takes options with default values: `adj->true`, `ot->m1`.

See also `random_permutation_sym`, `ae_random_permutation`, `signature_permutation`, `perm_to_cycles`, and `cycles_to_perm`.

**Implementation** This function uses Sattolo's algorithm.

## 4.9 Function: `random_permutation_sym`

`random_permutation_sym`( $n$ )

next package: `discrete_aex`

**Calling**

**`random_permutation_sym`**( $n$ ) Returns a random permutation of the integers from 1 through  $n$ . This represents a random element of the symmetric group  $S_n$ .

**Arguments** `random_permutation_sym` requires one argument  $n$ , which must be a positive integer.

**Options** `random_permutation_sym` takes options with default values: `adj->true`, `ot->m1`.

See also `random_cycle`, `ae_random_permutation`, `signature_permutation`, `perm_to_cycles`, and `cycles_to_perm`.

## 4.10 Function: `signature_permutation`

`signature_permutation`( $ain$ )

next package: `discrete_aex`

**Calling**

**`signature_permutation`**( $list$ ) returns the sign, or signature, of the symmetric permutation  $list$ , which must be represented by a permutation the integers from 1 through  $n$ , where  $n$  is the length of the list.

**Arguments** `signature_permutation` requires one argument  $ain$ , which must be a list (lex or aex).

See also `random_cycle`, `random_permutation_sym`, `ae_random_permutation`, `perm_to_cycles`, and `cycles_to_perm`.

## 4.11 Function: `transpositions_to_perm`

`transpositions_to_perm`( $ain$ )

next package: `discrete_aex`

**Description** Returns the permutation specified by the list of transpositions  $ain$ .

**Arguments** `transpositions_to_perm` requires one argument  $ain$ , which must be a list (lex or aex).

**Options** `transpositions_to_perm` takes options with default values: `adj->true`, `ot->m1`.

**Implementation** Input is converted to lex on both levels. Default output is aex.

# 5 Functions and Variables for Documentation

- `doc_system_list`
- `print_entry_latex`
- `print_maxdoc_entry`

- `print_maxdoc_sections`
- `print_sections_latex`
- `read_docs_with_pager`
- `set_all_doc_systems`
- `simple_doc_add`
- `simple_doc_delete`
- `simple_doc_get`
- `simple_doc_init`
- `simple_doc_print`

## 5.1 Variable: `doc_system_list`

**Description** A list of the documentation system that will be searched by ? and ??. This can be set to all available systems with the function `set_all_doc_systems`. Also, if this variable is false, then all documentation is enabled.

## 5.2 Function: `print_entry_latex`

`print_entry_latex(item)`  
 next package: `defmfun1`

**Arguments** `print_entry_latex` requires one argument *item*, which must be a string.

## 5.3 Function: `print_maxdoc_entry`

`print_maxdoc_entry(item)`  
 next package: `defmfun1`

**Arguments** `print_maxdoc_entry` requires one argument *item*, which must be a string.

## 5.4 Function: `print_maxdoc_sections`

`print_maxdoc_sections()`  
 next package: `defmfun1`

**Description** Print all sections of maxdoc documentation. This does not include other documentation databases, such as the main maxima documentation.

**Arguments** `print_maxdoc_sections` requires zero arguments.

## 5.5 Function: `print_sections_latex`

`print_sections_latex`( :optional *filename*)

next package: `defmfun1`

**Description** Print all sections of maxdoc documentation currently loaded in latex format to the file *filename*. This does not include other documentation databases, such as the main maxima documentation.

**Arguments** `print_sections_latex` requires either zero or one arguments. If present, the argument *filename* must be a string.

## 5.6 Option variable: `read_docs_with_pager`

default value `true`.

**Description** If `read_docs_with_pager` is true then documentation printed by `describe()` or `?` or `??` is read with a pager. This will most likely only work with a command line interface under linux/unix with certain lisp implementations.

## 5.7 Function: `set_all_doc_systems`

`set_all_doc_systems`()

next package: `defmfun1`

**Description** Enable all documentation databases for `describe`, `?` and `??`. This sets `doc_system_list` to a list of all doc systems.

**Arguments** `set_all_doc_systems` requires zero arguments.

## 5.8 Function: `simple_doc_add`

`simple_doc_add`(*name*, *content*)

next package: `defmfun1`

**Description** Adds documentation string *content* for item *name*. These documentation strings are accessible via `'?'` and `'??'`.

**Arguments** `simple_doc_add` requires two arguments. The first argument *name* must be a string. The second argument *content* must be a string.

See also `simple_doc_init`, `simple_doc_delete`, `simple_doc_get`, and `simple_doc_print`.

## 5.9 Function: `simple_doc_delete`

`simple_doc_delete`(*name*)

next package: `defmfun1`

**Description** Deletes the `simple_doc` documentation string for item *name*.

**Arguments** `simple_doc_delete` requires one argument *name*, which must be a string.

See also `simple_doc_init`, `simple_doc_add`, `simple_doc_get`, and `simple_doc_print`.

## 5.10 Function: `simple_doc_get`

`simple_doc_get(name)`

next package: `defmfun1`

**Description** Returns the `simple_doc` documentation string for item *name*.

**Arguments** `simple_doc_get` requires one argument *name*, which must be a string.

See also `simple_doc_init`, `simple_doc_add`, `simple_doc_delete`, and `simple_doc_print`.

## 5.11 Function: `simple_doc_init`

`simple_doc_init()`

next package: `defmfun1`

**Description** Initialize the `simple_doc` documentation database.

**Arguments** `simple_doc_init` requires zero arguments.

See also `simple_doc_add`, `simple_doc_delete`, `simple_doc_get`, and `simple_doc_print`.

## 5.12 Function: `simple_doc_print`

`simple_doc_print(name)`

next package: `defmfun1`

**Description** Prints the `simple_doc` documentation string for item *name*.

**Arguments** `simple_doc_print` requires one argument *name*, which must be a string.

See also `simple_doc_init`, `simple_doc_add`, `simple_doc_delete`, and `simple_doc_get`.

# 6 Functions and Variables for Equations

- `nelder_mead`

## 6.1 Function: `nelder_mead`

`nelder_mead(expr, vars, init)`

next package: `nelder_mead`

**Description** The Nelder-Mead optimization algorithm.

**Arguments** `nelder_mead` requires three arguments. The second argument *vars* must be a list of symbols. The third argument *init* must be a list of numbers.

### Examples

Find the minimum of a function at a non-analytic point.

```
(%i1) nelder_mead(if x<0 then -x else x^2, [x], [4]);  
(%o1) [x = 9.536387892694629e-11]
```

```
(%i1) f(x) := if x<0 then -x else x^2$  
(%i2) nelder_mead(f, [x], [4]);  
(%o2) [x = 9.536387892694628e-11]
```

```
(%i3) nelder_mead(f(x), [x], [4]);  
(%o3) [x = 9.536387892694628e-11]
```

```
(%i1) nelder_mead(x^4+y^4-2*x*y-4*x-3*y, [x,y], [2,2]);  
(%o1) [x = 1.157212489168102,y = 1.099342680267472]
```

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## 7 Functions and Variables for Function Definition

- `comp_load`
- `compile_file1`

### 7.1 Function: `comp_load`

**comp\_load**(*fname* :optional *pathlist*)  
next package: aex

**Description** Compile and load a lisp file. Maxima does not load it by default with `compile_file`. If the input filename does not end with “.lisp”, it will be appended. If *pathlist* is specified, then *fname* is only searched for in directories in *pathlist*.

**Arguments** `comp_load` requires either one or two arguments. The first argument *fname* must be a string. The second argument *pathlist* must be a string or a list of strings.

### 7.2 Function: `compile_file1`

**compile\_file1**(*input-file* :optional *bin-file*, *translation-output-file*)  
next package: aex

**Description** This is copied from maxima `compile_file`, with changes. Sometimes a loadable binary file is apparently compiled, but an error flag is set and `compile_file` returns false for the output binary filename. Here we return the binary filename in any case.

**Arguments** `compile_file1` requires between one and three arguments. The first argument *input-file* must be a string.

## 8 Functions and Variables for Input and Output

- `pager_command`
- `pager_string`
- `restore`
- `restore_fast`
- `store`
- `store_fast`

## 8.1 Option variable: `pager_command`

default value `/usr/bin/less`.

**Description** The pathname to the pager program used for reading paged output, eg for documentation.

See also `read_docs_with_pager`.

## 8.2 Function: `pager_string`

`pager_string(s)`

next package: `aex`

**Description** Read the string *s* in the pager given by the maxima variable `pager_command`. This works at least with `gcl` under linux.

**Arguments** `pager_string` requires one argument *s*, which must be a string.

## 8.3 Function: `restore`

`restore(file)`

next package: `store`

### Calling

`restore(file)` Reads and returns expressions from the file *file*.

**Description** Reads maxima expressions from file *file* created by the function `store`.

**Arguments** `restore` requires one argument *file*, which must be a string.

See also `store`, `store_fast`, and `restore_fast`.

## 8.4 Function: `restore_fast`

`restore_fast(file)`

next package: `store`

### Calling

`restore_fast(file)` Reads and returns expressions from the file *file*. No checking for circular references is done.

**Description** Reads maxima expressions from file *file* created by the function `store`, or `store_fast`. No checks for circular references are done.

**Arguments** `restore_fast` requires one argument *file*, which must be a string.

See also `store`, `restore`, and `store_fast`.

## 8.5 Function: `store`

`store(file :rest exprs)`

next package: `store`

### Calling

`store(file, expr1, expr2, ...)` stores the expressions to the file *file*.

**Description** Stores maxima expressions *exprs* in *file* in binary format. Many types of lisp expressions and subexpressions are supported: numbers, strings, list, arrays, hashtables, structures,....

**Arguments** `store` requires one or more arguments. The first argument *file* must be a string.

#### Examples

Save a graph to a file. This cannot be done with the command `jsave`.

```
(%i1) load(graphs)$
(%i2) c : petersen_graph();
(%o2) GRAPH(10 vertices, 15 edges)
(%i3) factor(graph_charpoly(c,x));
(%o3) (x-3)*(x-1)^5*(x+2)^4
(%i4) store("graph.cls",c)$
(%i5) factor(graph_charpoly( restore("graph.cls"), x));
(%o5) (x-3)*(x-1)^5*(x+2)^4
```

See also `restore`, `store_fast`, and `restore_fast`.

**Implementation** `store` uses the `cl-store` library. See the `cl-store` documentation for more information.

## 8.6 Function: store\_fast

`store_fast(file :rest exprs)`

next package: `store`

#### Calling

`store_fast(file, expr1, expr2, ...)` stores the expressions to the file *file*. No checking for circular references is done.

**Description** Stores maxima expressions *exprs* in *file* in binary format. This is like `store`, except that no checks for circular references are done.

**Arguments** `store_fast` requires one or more arguments. The first argument *file* must be a string.

See also `store`, `restore`, and `restore_fast`.

## 9 Functions and Variables for Lists

These functions manipulate lists. They build lists, take them apart, select elements, etc.

- `aelistp`
- `constant_list`
- `count`
- `drop_while`
- `every1`
- `fold`
- `fold_list`
- `icons`



- `imap`
- `length_while`
- `lrange`
- `nest`
- `nest_list`
- `nest_while`
- `nreverse`
- `partition_list`
- `select`
- `sequence specifier`
- `table`
- `take`
- `take_while`
- `tuples`

## 9.1 Function: `aelistp`

**Description** Returns true if *e* is a list, either ml or ar representation.

**Examples**

```
(%i1) aelistp([1,2,3]);
(%o1) true
(%i1) aelistp( aex([1,2,3]));
(%o1) true
(%i2) aelistp(3);
(%o2) false
(%i3) aelistp(x);
(%o3) false
(%i4) x:lrange(10), aelistp(x);
(%o4) true
(%i5) aelistp(%f(y));
(%o5) false
(%i6) aelistp( aex( %f(y) ));
(%o6) false
```

## 9.2 Function: `constant_list`

**`constant_list`**(*expr*, *list*)

next package: `lists_aex`

**Description** Returns a list of *n* elements, each of which is an independent copy of *expr*. `constant_list(expr, [n,m,...])` returns a nested list of dimensions *n,m,...* where each leaf is an independent copy of *expr* and the copies of

each list at each level are independent. If a third argument is given, then it is used as the op, rather than 'list', at every level.

**Arguments** `constant_list` requires either two or three arguments. The second argument *spec* must be a positive integer or a list of positive integers.

**Options** `constant_list` takes options with default values: `adj->true`, `ot->ml`.

See also `makelist`, `lrange`, and `table`.

### 9.3 Function: count

`count`(*expr*, *item*)  
next package: lists\_aex

**Description** Counts the number of items in *expr* matching *item*. If *item* is a lambda function then *compile* must be true.

**Arguments** `count` requires two arguments. The first argument *expr* must be non-atomic and either aex or represented by a lisp list.

**Options** `count` takes options with default values: `compile->true`.

**Examples**

```
(%i1) count([1,2,"dog"], 'numberp);
(%o1) 2
(%i1) count([1,2,"dog"], "dog");
(%o1) 1
(%i2) count(lrange(10^4), lambda([x], is(mod(x,3) = 0)));
(%o2) 3333
(%i3) count( %ff(1,2,"dog"), "dog");
(%o3) 1
(%i4) count(lrange(100,ot->ar), 'evenp);
(%o4) 50
```

### 9.4 Function: drop\_while

`drop_while`(*expr*, *test*)  
next package: lists\_aex

**Calling**

**drop\_while**(*expr*, *test*) Tests the elements of *expr* in order, dropping them until *test* fails. The remaining elements are returned in an expression with the same op as that *expr*.

**Arguments** `drop_while` requires two arguments. The first argument *expr* must be non-atomic and represented by a lisp list.

**Options** `drop_while` takes options with default values: `adj->true`, `ot->ml`, `compile->true`.

**Examples**

Drop elements as long as they are negative.

```
(%i1) drop_while([-3,-10,-1,3,6,7,-4], lambda([x], is(x<0)));
(%o1) [3,6,7,-4]
```

## 9.5 Function: every1

**every1**(*expr*, *test*)  
next package: lists\_aex

### Calling

**every1**(*expr*, *test*) Returns true if *test* is true for each element in *expr*. Otherwise, false is returned. This is like **every** but allow a test that takes only one argument. For some inputs, every1 is much faster than every.

**Arguments** **every1** requires two arguments. The first argument *expr* must be non-atomic and represented by a lisp list.

**Options** **every1** takes options with default values: **compile**->**true**.

## 9.6 Function: fold

next package: lists\_aex

**Description** **fold**(*f*, *x*, [*a*, *b*, *c*]) returns *f*(*f*(*f*(*x*, *a*), *b*), *c*).

**Arguments** **fold** requires three arguments. The third argument *v* must be non-atomic.

**Options** **fold** takes options with default values: **adj**->**true**, **ot**->**ml**, **compile**->**true**.

See also **fold\_list** and **nest**.

## 9.7 Function: fold\_list

next package: lists\_aex

**Description** **fold\_list**(*f*, *x*, [*a*, *b*, *c*]) returns [*f*(*x*, *a*), *f*(*f*(*x*, *a*), *b*), *f*(*f*(*f*(*x*, *a*), *b*), *c*)].

**Arguments** **fold\_list** requires three arguments. The third argument *v* must be non-atomic.

**Options** **fold\_list** takes options with default values: **adj**->**true**, **ot**->**ml**, **compile**->**true**.

See also **fold** and **nest**.

## 9.8 Function: icons

**icons**(*x*, *e*)

**Description** **icons** is like maxima **cons**, but less general, and much, much faster. *x* is a maxima object. *e* is a maxima list or list-like object, such as [*a*], or *f*(*a*). It is suitable at a minimum, for pushing a number or list or string onto a list of numbers, or strings or lists. If you find **icons** gives buggy behavior that you are not interested in investigating, use **cons** instead.

**Implementation** In a function that mostly only does icons in a loop, icons defined with **defmfun** rather than **defmfun1** runs almost twice as fast. So icons is defined with **defmfun** rather than **defmfun1**. icons does no argument checking.

## 9.9 Function: imap

**imap**(*f*, *expr*)  
next package: lists\_aex

**Description** Maps functions of a single argument. I guess that `map` handles more types of input without error. But `imap` can be much faster for some inputs.

**Arguments** `imap` requires two arguments. The second argument *expr* must be non-atomic.

**Options** `imap` takes options with default values: `compile->true`.

#### Examples

Map `sqrt` efficiently over a list of floats

```
(%i1) (a : lrange(1.0,4),
      imap(lambda([x],modeddeclare(x,float),sqrt(x)),a));
(%o1) [1.0,1.414213562373095,1.732050807568877,2.0]
```

With `aex` expression, no conversions to `lex` are done.

```
(%i1) (a : lrange(1.0,4,ot->ar),
      imap(lambda([x],modeddeclare(x,float),sqrt(x)),a));
(%o1) <[1.0,1.414213562373095,1.732050807568877,2.0]>
```

## 9.10 Function: length\_while

`length_while(expr, test)`

next package: `lists_aex`

**Description** Computes the length of *expr* while *test* is true.

**Arguments** `length_while` requires two arguments. The first argument *expr* must be non-atomic and represented by a lisp list.

**Options** `length_while` takes options with default values: `compile->true`.

#### Examples

```
(%i1) length_while([-3,-10,-1,3,6,7,-4], lambda([x], is(x<0)));
(%o1) 3
```

## 9.11 Function: lrange

next package: `lists_aex`

#### Calling

`lrange(stop)` returns a list of numbers from 1 through *stop*.

`lrange(start, stop)` returns a list of expressions from *start* through *stop*.

`lrange(start, stop, incr)` returns a list of expressions from *start* through *stop* in steps of *incr*.

**Description** `lrange` is much more efficient than `makelist` for creating ranges, particularly for large lists (e.g.  $10^5$  or more items.) Functions for creating a list of numbers, in order of decreasing speed, are: `lrange`, `table`, `create_list`, `makelist`.

**Arguments** `lrange` requires between one and three arguments. The third argument *incr* must be an expression that is not zero.

**Options** `lrange` takes options with default values: `adj->true`, `ot->m1`.

#### Examples

```
(%i1) lrange(6);
(%o1) [1,2,3,4,5,6]
(%i1) lrange(2,6);
(%o1) [2,3,4,5,6]
(%i2) lrange(2,6,2);
(%o2) [2,4,6]
(%i3) lrange(6,1,-1);
(%o3) [6,5,4,3,2,1]
(%i4) lrange(6,1,-2);
(%o4) [6,4,2]
(%i5) lrange(6,ot->ar);
(%o5) <[1,2,3,4,5,6]>
```

The type of the first element and increment determine the type of the elements.

```
(%i1) lrange(1.0,6);
(%o1) [1.0,2.0,3.0,4.0,5.0,6.0]
(%i1) lrange(1.0b0,6);
(%o1) [1.0b0,2.0b0,3.0b0,4.0b0,5.0b0,6.0b0]
(%i2) lrange(1/2,6);
(%o2) [1/2,3/2,5/2,7/2,9/2,11/2]
(%i3) lrange(6.0,1,-1);
(%o3) [6.0,5.0,4.0,3.0,2.0,1.0]
```

Symbols can be used for limits or increments.

```
(%i1) lrange(x,x+4);
(%o1) [x,x+1,x+2,x+3,x+4]
(%i1) lrange(x,x+4*a,a);
(%o1) [x,x+a,x+2*a,x+3*a,x+4*a]
```

See also `makelist`, `table`, and `constant_list`.

## 9.12 Function: `nest`

next package: `lists_aex`

**Description** `nest(f,x,n)` returns `f(...f(f(x)))...` where there are `n` nested calls of `f`.

**Arguments** `nest` requires three arguments. The first argument `f` must be a function. The third argument `n` must be a non-negative integer.

**Options** `nest` takes options with default values: `adj->true`, `ot->m1`, `compile->true`.

## 9.13 Function: `nest_list`

`nest_list(f, x, n)`

next package: `lists_aex`

**Arguments** `nest_list` requires three arguments. The third argument `n` must be a non-negative integer.

**Options** `nest_list` takes options with default values: `adj->true`, `ot->m1`, `compile->true`.

## Examples

Find the first 10 primes after 100.

```
(%i1) nest_list(next_prime,100,10);  
(%o1) [101,103,107,109,113,127,131,137,139,149]
```

See also `nest`, `fold`, and `fold_list`.

## 9.14 Function: nest\_while

**nest\_while**(*f*, *x*, *test* :optional *min*, *max*)

next package: lists\_aex

### Calling

**nest\_while**(*f*, *x*, *test*) applies *f* to *x* until *test* fails to return true when called on the nested result.

**nest\_while**(*f*, *x*, *test*, *min*) applies *f* at least *min* times.

**nest\_while**(*f*, *x*, *test*, *min*, *max*) applies *f* not more than *max* times.

**Arguments** **nest\_while** requires between three and five arguments. The fourth argument *min* must be a non-negative integer. The fifth argument *max* must be a non-negative integer.

**Options** **nest\_while** takes options with default values: `adj->true`, `ot->ml`, `compile->true`.

**Implementation** This should be modified to allow applying test to more than just the most recent result.

## 9.15 Function: nreverse

**nreverse**(*e*)

next package: lists\_aex

**Description** Destructively reverse the arguments of expression *e*. This is more efficient than using `reverse`.

**Arguments** **nreverse** requires one argument *e*, which must be non-atomic.

### Examples

Be careful not to use *a* after applying **nreverse**. Do assign the result to another variable.

```
(%i1) a : lrange(10), b : nreverse(a);  
(%o1) [10,9,8,7,6,5,4,3,2,1]  
(%i1) a : lrange(10,ot->ar), b : nreverse(a);  
(%o1) <[10,9,8,7,6,5,4,3,2,1]>
```

See also `reverse`.

## 9.16 Function: partition\_list

**partition\_list**(*e*, *nlist* :optional *dlist*)

next package: lists\_aex

### Calling

**partition\_list**(*e*, *n*) partitions *e* into sublists of length *n*

**partition\_list**(*e*, *n*, *d*) partitions *e* into sublists of length *n* with offsets *d*.

**Description** Omitting  $d$  is equivalent to giving  $d$  equal to  $n$ .  $e$  can be any expression, not only a list. If  $n$  is a list, then `partition_list` partitions at successively deeper levels with elements of  $n$ . If  $n$  and  $d$  are lists, the first elements of  $n$  and  $d$  apply at the highest level and so on. If  $n$  is a list and  $d$  is a number, then the offset  $d$  is used with each of the  $n$ .

**Arguments** `partition_list` requires either two or three arguments. The first argument  $e$  must be non-atomic. The second argument  $nlist$  must be an integer or a list of integers. The third argument  $dlist$  must be an integer or a list of integers.

#### Examples

Partition the numbers from 1 through 10 into pairs.

```
(%i1) partition_list([1,2,3,4,5,6,7,8,9,10],2);
(%o1) [[1,2],[3,4],[5,6],[7,8],[9,10]]
```

### 9.17 Function: select

`select(expr, test :optional n)`  
 next package: lists\_aex

**Description** Returns a list of all elements of  $expr$  for which  $test$  is true.  $expr$  may have any op. If  $n$  is supplied, then at most  $n$  elements are examined.

**Arguments** `select` requires either two or three arguments. The first argument  $expr$  must be non-atomic and represented by a lisp list. The third argument  $n$  must be a positive integer.

**Options** `select` takes options with default values: `adj->true`, `ot->m1`, `compile->true`.

#### Examples

Select elements less than 3

```
(%i1) select([1,2,3,4,5,6,7], lambda([x], is(x<3)));
(%o1) [1,2]
```

### 9.18 Argument type: sequence specifier

**Description** A sequence specification specifies a subsequence of the elements in an expression. A single positive number  $n$  means the first  $n$  elements.  $-n$  means the last  $n$  elements. A list of three numbers  $[i1,i2,i3]$  means the  $i1$ th through the  $i2$ th stepping by  $i3$ . If  $i1$  or  $i2$  are negative, they count from the end. If  $i3$  is negative, stepping is down and  $i1$  must be greater than or equal to  $i2$ . If  $i3$  is omitted, it is taken to be 1. A sequence specifier can also be one of 'all' 'none' or 'reverse', which mean all elements, no elements or all elements in reverse order respectively.

See also `take` and `string_take`.

### 9.19 Function: table

next package: lists\_aex

#### Calling

`table(expr, [n])` Evaluates expression  $number$  times. If  $number$  is not an integer or a floating point number, then `float` is called. If we have a floating point number, it is truncated into an integer. This type of iterator is the fastest, since no variable is bound.

**table**(*expr*, [*variable*, *initial*, *end*, *step*]) Returns a list of evaluated expressions where *variable* (a symbol) is set to a value. The first element of the returned list is *expression* evaluated with *variable* set to *initial*. The *i*-th element of the returned list is *expression* evaluated with *variable* set to *initial*+(*i* - 1)*step*. The iteration stops once the value is greater (if *step* is positive) or smaller (if *step* is negative) than *end*. Requirement: The difference between *end* and *initial* must return a **numberp** number. *step* must be a nonzero **numberp** number. This allows for iterators of rather general forms like [i, %i - 2, %i, 0.1b0] ...

**table**(*expr*, [*variable*, *initial*, *end*]) This iterator uses a step of 1 and is equal to [*variable*,*initial*,*end*, 1].

**Arguments** **table** requires two or more arguments. The second argument *iterator1* must be a list. Each of the remaining arguments must be a list.

**Options** **table** takes options with default values: adj->true, ot->ml.

**Attributes** **table** has attributes: [hold\_all]

### Examples

Make a list of function values

```
(%i1) table(sin(x), [x, 0, 2*%pi, %pi/4]);
(%o1) [0, 1/sqrt(2), 1, 1/sqrt(2), 0, -1/sqrt(2), -1, -1/sqrt(2), 0]
```

Make a nested list.

```
(%i1) table( x^y, [x, 1, 2], [y, 1, 2]);
(%o1) [[1, 1], [2, 4]]
```

See also **makelist**, **lrange**, and **constant\_list**.

**Author** Ziga Lenarcic.

## 9.20 Function: take

**take**(*e* :rest *v*)

next package: lists\_aex

### Calling

**take**(*e*, *n*) returns a list of the first *n* elements of list or expression *e*.

**take**(*e*, [*n1*, *n2*]) returns a list of the *n1*th through *n2*th elements of list or expression *e*.

**take**(*e*, [*n1*, *n2*, *step*]) returns a list of the *n1*th through *n2*th elements stepping by *step* of list or expression *e*.

**take**(*e*, -*n*) returns the last *n* elements.

**take**(*e*, *spec1*, *spec2*, ...) applies the sequence specifications at successively deeper levels in *e*.

**Description** *e* can have mixed lex and aex expressions on different levels. If more sequence specifications are given, they apply to successively deeper levels in *e*.

**Arguments** **take** requires one or more arguments. The first argument *e* must be non-atomic. Each of the remaining arguments must be a sequence specification.

### Examples

Take the first 3 elements of a list.



```
(%i1) take([a,b,c,d,e],3);
(%o1) [a,b,c]
```

Take the last 3 elements of a list.

```
(%i1) take([a,b,c,d,e],-3);
(%o1) [c,d,e]
```

Take the second through third elements of a list.

```
(%i1) take([a,b,c,d,e],[2,3]);
(%o1) [b,c]
```

Take the second through tenth elements of a list counting by two.

```
(%i1) take([1,2,3,4,5,6,7,8,9,10],[2,10,2]);
(%o1) [2,4,6,8,10]
```

Take the last through first elements of a list counting backwards by one.

```
(%i1) take([a,b,c,d],[-1,1,-1]);
(%o1) [d,c,b,a]
```

Shorthand for the previous example is 'reverse.

```
(%i1) take([a,b,c,d],'reverse);
(%o1) [d,c,b,a]
```

Take the second through third elements at the first level and the last 2 elements at the second level.

```
(%i1) take([[a,b,c],[d,e,f],[g,h,i]],[2,3],-2);
(%o1) [[e,f],[h,i]]
```

## 9.21 Function: take\_while

**take\_while**(*expr*, *test*)  
next package: lists\_aex

### Calling

**take\_while**(*expr*, *test*) collects the elements in *expr* until *test* fails on one of them. The op of the returned expression is the same as the op of *expr*.

**Arguments** **take\_while** requires two arguments. The first argument *expr* must be non-atomic and represented by a lisp list.

**Options** **take\_while** takes options with default values: `adj->true`, `ot->ml`, `compile->true`.

### Examples

Take elements as long as they are negative.

```
(%i1) take_while([-3,-10,-1,3,6,7,-4], lambda([x], is(x<0)));
(%o1) [-3,-10,-1]
```

## 9.22 Function: tuples

**tuples**(*list-or-lists* :optional *n*)  
next package: lists\_aex

### Calling

**tuples**(*list*, *n*) Return a list of all lists of length *n* whose elements are chosen from *list*.

**tuples**([*list1*, *list2*, ...]) Return a list of all lists whose *i*-th element is chosen from *listi*.

**Arguments** **tuples** requires either one or two arguments. The first argument *list-or-lists* must be non-atomic and represented by a lisp list. The second argument *n* must be a non-negative integer.

**Options** **tuples** takes options with default values: **adj**->**true**, **ot**->**ml**.

### Examples

Make all three letter words in the alphabet 'a,b'.

```
(%i1) tuples([a,b],3);  
(%o1) [[a,a,a],[a,a,b],[a,b,a],[a,b,b],[b,a,a],[b,a,b],[b,b,a],[b,b,b]]
```

Take all pairs chosen from two lists.

```
(%i1) tuples([ [0,1] , [x,y,z] ]);  
(%o1) [[0,x],[0,y],[0,z],[1,x],[1,y],[1,z]]
```

**tuples** works for expressions other than lists.

```
(%i1) tuples(f(0,1),3);  
(%o1) [f(0,0,0),f(0,0,1),f(0,1,0),f(0,1,1),f(1,0,0),f(1,0,1),f(1,1,0),f(1,1,1)]
```

## 10 Functions and Variables for Number Theory

- abundant\_p
- aliquot\_sequence
- aliquot\_sum
- amicable\_p
- catalan\_number
- divisor\_function
- divisor\_summatory
- from\_digits
- integer\_digits
- integer\_string
- oeis\_A092143
- perfect\_p

- `prime_pi`
- `prime_pi_soe`
- `prime_twins`
- `primes1`

## 10.1 Function: `abundant_p`

**`abundant_p`**( $n$ )

next package: `discrete_aex`

**Description** Returns true if  $n$  is an abundant number. Otherwise, returns false.

**Arguments** `abundant_p` requires one argument  $n$ , which must be a positive integer.

### Examples

The abundant numbers between 1 and 100

```
(%i1) select(lrange(100),abundant_p);
(%o1) [12,18,20,24,30,36,40,42,48,54,56,60,66,70,72,78,80,84,88,90,96,100]
```

See also `divisor_function`, `aliquot_sum`, `aliquot_sequence`, `divisor_summatory`, and `perfect_p`.

## 10.2 Function: `aliquot_sequence`

**`aliquot_sequence`**( $k, n$ )

next package: `discrete_aex`

**Description** Returns the first  $n$  elements (counting from zero) in the aliquot sequence of  $k$ . The sequence is truncated at an element if it is zero or repeats the previous element.

**Arguments** `aliquot_sequence` requires two arguments. The first argument  $k$  must be a positive integer. The second argument  $n$  must be a non-negative integer.

### Examples

Perfect numbers give a repeating sequence of period 1.

```
(%i1) imap(lambda([x],aliquot_sequence(x,100)),[6,28,496,8128]);
(%o1) [[6],[28],[496],[8128]]
```

Aspiring numbers are those which are not perfect, but terminate with a repeating perfect number.

```
(%i1) imap(lambda([x],aliquot_sequence(x,100)),[25, 95, 119, 143, 417, 445, 565, 608, 650, 652, 675, 688]);
(%o1) [[25,6],[95,25,6],[119,25,6],[143,25,6],[417,143,25,6],[445,95,25,6],[565,119,25,6],[608,652,496]]
```

See also `divisor_function`, `aliquot_sum`, `divisor_summatory`, `perfect_p`, and `abundant_p`.

### 10.3 Function: aliquot\_sum

**aliquot\_sum**( $n$ )

next package: discrete\_aex

**Description** Returns the aliquot sum of  $n$ . The aliquot sum of  $n$  is the sum of the proper divisors of  $n$ .

**Arguments** **aliquot\_sum** requires one argument  $n$ , which must be a positive integer.

**Attributes** **aliquot\_sum** has attributes: [match\_form]

See also **divisor\_function**, **aliquot\_sequence**, **divisor\_summatory**, **perfect\_p**, and **abundant\_p**.

### 10.4 Function: amicable\_p

**amicable\_p**( $n, m$ )

next package: discrete\_aex

**Description** Returns true if  $n$  and  $m$  are amicable, and false otherwise.

**Arguments** **amicable\_p** requires two arguments. The first argument  $n$  must be a positive integer. The second argument  $m$  must be a positive integer.

#### Examples

The first few amicable pairs.

```
(%i1) map(lambda([x],amicable_p(first(x),second(x))), [[220, 284],  
[1184, 1210], [2620, 2924], [5020, 5564], [6232, 6368]]);  
(%o1) [true,true,true,true,true]
```

### 10.5 Function: catalan\_number

**catalan\_number**( $n$ )

next package: discrete\_aex

**Description** Returns the  $n$ th catalan number.

**Arguments** **catalan\_number** requires one argument.

#### Examples

The catalan number for  $n$  from 1 through 12.

```
(%i1) map(catalan_number,lrange(12));  
(%o1) [1,2,5,14,42,132,429,1430,4862,16796,58786,208012]
```

The  $n$ 'th catalan number.

```
(%i1) catalan_number(n);  
(%o1) binomial(2*n,n)/(n+1)
```

OEIS number: A000108.

## 10.6 Function: divisor\_function

**divisor\_function**(*n* :optional *x*)

next package: discrete\_aex

**Description** The divisor function  $\sigma_x(n)$ . If *x* is omitted it takes the default value 0. Currently, complex values for *x* are not supported.

**Arguments** **divisor\_function** requires either one or two arguments. The first argument *n* must be a non-negative integer. The second argument *x* must be a number.

**Attributes** **divisor\_function** has attributes: [match\_form]

OEIS number: A000005 for *x*=0 and A000203 for *x*=1.

See also **aliquot\_sum**, **aliquot\_sequence**, **divisor\_summatory**, **perfect\_p**, and **abundant\_p**.

## 10.7 Function: divisor\_summatory

**divisor\_summatory**(*x*)

next package: discrete\_aex

**Description** Returns the divisor summatory function  $D(x)$  for *x*. The divisor function  $d(n)$  counts the number of unique divisors of the natural number *n*.  $D(x)$  is the sum of  $d(n)$  over  $n \leq x$

**Arguments** **divisor\_summatory** requires one argument *x*, which must be a non-negative number.

**Attributes** **divisor\_summatory** has attributes: [match\_form]

**Examples**

D(n) for n from 1 through 12

```
(%i1) map(divisor_summatory,lrange(12));  
(%o1) [1,3,5,8,10,14,16,20,23,27,29,35]
```

OEIS number: A006218.

See also **divisor\_function**, **aliquot\_sum**, **aliquot\_sequence**, **perfect\_p**, and **abundant\_p**.

## 10.8 Function: from\_digits

**from\_digits**(*digits* :optional *base*)

next package: discrete\_aex

**Calling**

**from\_digits**(*digits*) returns the integer represented by the decimal digits in the list *digits*.

**from\_digits**(*digits*, *base*) returns the integer represented by the base *base* digits in the list *digits*.

**Description** *base* need not be number, but may be, for instance, a symbol. If *base* is a number it must be an integer between 2 and 36. *digits* may be a string rather than a list.

**Arguments** **from\_digits** requires either one or two arguments. The first argument *digits* must be a list (lex or aex) or a string.

See also **integer\_digits** and **integer\_string**.

## 10.9 Function: integer\_digits

**integer\_digits**(*n* :optional *base*, *len*)

next package: discrete\_aex

### Calling

**integer\_digits**(*n*) returns a list of the base 10 digits of *n*.

**integer\_digits**(*n*, *base*) returns a list of the base *base* digits of *n*.

**integer\_digits**(*n*, *base*, *len*) returns a list of the base *base* digits of *n* padded with 0's so that the total length of the list is *len*.

**Arguments** **integer\_digits** requires between one and three arguments. The first argument *n* must be an integer. The second argument *base* must be a valid radix (an integer between 2 and 36). The third argument *len* must be a non-negative integer.

**Options** **integer\_digits** takes options with default values: **adj**->true, **ot**->ml.

See also **from\_digits** and **integer\_string**.

**Implementation** gcl is much faster than the others. **integer\_digits**(2<sup>10</sup>): typical times for lisps: ccl-1.7-r15184M = 65s, sbcl-1.0.52.0.debian = 1.5s, allegro-8.2 = 23s, Mma-3.0 = 5s, gcl-2.6.7 = 0.11s, Mma-8 = 0.04s. The base is limited to 36 only because we call write-to-string.

## 10.10 Function: integer\_string

**integer\_string**(*n* :optional *base*, *pad*)

next package: discrete\_aex

### Calling

**integer\_string**(*n*) returns a string containing the decimal digits of the integer *n*.

**integer\_string**(*n*, *base*) returns a string containing the base *base* digits of the integer *n*.

**integer\_string**(*n*, *base*, *pad*) pads the string on the left with 0's so that the length of the string is *pad*.

**integer\_string**(*n*, "roman" ) returns a string containing the roman-numeral form of the integer *n*.

**integer\_string**(*n*, "cardinal" ) returns a string containing the english word form of the integer (cardinal number) *n*.

**integer\_string**(*n*, "ordinal" ) returns a string containing the english word form of the ordinal (counting) number *n*.

**Arguments** **integer\_string** requires between one and three arguments. The first argument *n* must be an integer. The second argument *base* must be a valid radix (an integer between 2 and 36) or a string. The third argument *pad* must be a positive integer.

See also **integer\_digits** and **from\_digits**.

## 10.11 Function: oeis\_A092143

**oeis\_A092143**(*n*)

next package: discrete\_aex

**Description** Returns the cumulative product of all divisors of integers from 1 to *n*.

**Arguments** **oeis\_A092143** requires one argument *n*, which must be a positive integer.

## 10.12 Function: `perfect_p`

`perfect_p(n)`

next package: `discrete_aex`

**Description** Returns true if *n* is a perfect number. Otherwise, returns false.

**Arguments** `perfect_p` requires one argument *n*, which must be a positive integer.

See also `divisor_function`, `aliquot_sum`, `aliquot_sequence`, `divisor_summatory`, and `abundant_p`.

**Implementation** This function computes divisors. It would be far more efficient to use a table of known perfect numbers, as very few of them are accessible by current computer hardware.

## 10.13 Function: `prime_pi`

`prime_pi(n)`

next package: `prime_pi`

### Calling

`prime_pi(n)` returns the number of primes less than or equal to *n*.

**Description** Computes the prime counting function. The option *threads* specifies the maximum number of cpu threads to use. The routine may use fewer threads, depending on the value of *n*. The percent of the calculation that is finished is printed during the calculation if the option *status* is true. The status will only work under some terminals.

**Arguments** `prime_pi` requires one argument *n*, which must be equivalent to an unsigned 64 bit integer (ie an integer between 0 and 2 to the power 64) (We need to modify the doc system so we can use notation for powers in arg check strings. .

**Options** `prime_pi` takes options with default values: `status->>false`, `threads->1`.

See also `prime_pi_soe`, `next_prime`, and `prev_prime`.

**Implementation** This algorithm is fast for a general purpose mathematics program. It combines a segmented sieve implemented as a C library with tables.

**Authors** Kim Walisch (C library), Tomas Oliveira e Silva (tables), and John Lapeyre (lisp).

## 10.14 Function: `prime_pi_soe`

`prime_pi_soe(n)`

next package: `discrete_aex`

**Description** The prime counting function. The algorithm is the sieve of Eratosthenes. Internally an array of *n* bits is used.

**Arguments** `prime_pi_soe` requires one argument *n*, which must be a non-negative integer.

See also `prime_pi`, `next_prime`, and `prev_prime`.

**Implementation** This is not the most efficient way to compute primes.

## 10.15 Function: `prime_twins`

`prime_twins(min :optional max)`

next package: `prime_pi`

### Calling

**prime\_twins**( $n$ ) returns the number of prime twins less than or equal to  $n$ .

**prime\_twins**( $nmin, nmax$ ) returns the number of prime twins between  $nmin$  and  $nmax$ .

**Description** The option *ktuplet* counts the *ktuplet*-constellation rather than the twins. *ktuplet* must be an integer between 1 and 7.

**Arguments** **prime\_twins** requires either one or two arguments. The first argument *min* must be equivalent to an unsigned 64 bit integer (ie an integer between 0 and  $2^{64}$ ) (We need to modify the doc system so we can use notation for powers in arg check strings. . The second argument *max* must be equivalent to an unsigned 64 bit integer (ie an integer between 0 and  $2^{64}$ ) (We need to modify the doc system so we can use notation for powers in arg check strings. .

**Options** **prime\_twins** takes options with default values: *ktuplet*->2, *status*->false, *threads*->1.

See also **prime\_pi**, **next\_prime**, **prev\_prime**, and **primep**.

**Implementation** No tables are used in this algorithm.

## 10.16 Function: primes1

**primes1**( $n1$  :optional  $n2$ )  
next package: discrete\_aex

### Calling

**primes1**( $nmax$ ) returns a list of the primes less than or equal to  $nmax$ .

**primes1**( $nmin, nmax$ ) returns a list of the primes between  $nmin$  and  $nmax$ .

**Description** The algorithm is the sieve of Eratosthenes. This is not an efficient algorithm.

**Arguments** **primes1** requires either one or two arguments. The first argument  $n1$  must be a non-negative integer. The second argument  $n2$  must be a non-negative integer.

**Options** **primes1** takes options with default values: *adj*->true, *ot*->m1.

## 11 Functions and Variables for Numerics

These are mathematical functions— cos,sin,etc. —that accept only numerical arguments. Tests of loops in untranslated code show that these are much more efficient than using the standard maxima versions. But, for most applications, the standard maxima versions are probably ok.

- **n\_abs**
- **n\_acos**
- **n\_acosh**
- **n\_asin**
- **n\_asinh**
- **n\_atan**
- **n\_atanh**
- **n\_cos**



- `n_cosh`
- `n_exp`
- `n_expt`
- `n_log`
- `n_sin`
- `n_sinh`
- `n_sqrt`
- `n_tan`
- `n_tanh`

### 11.1 Function: `n_abs`

**Description** `n_abs` calls the lisp numeric function `?abs`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_abs` may be considerably faster in some code, particularly untranslated code.

### 11.2 Function: `n_acos`

**Description** `n_acos` calls the lisp numeric function `?acos`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_acos` may be considerably faster in some code, particularly untranslated code.

### 11.3 Function: `n_acosh`

**Description** `n_acosh` calls the lisp numeric function `?acosh`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_acosh` may be considerably faster in some code, particularly untranslated code.

### 11.4 Function: `n_asin`

**Description** `n_asin` calls the lisp numeric function `?asin`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_asin` may be considerably faster in some code, particularly untranslated code.

### 11.5 Function: `n_asinh`

**Description** `n_asinh` calls the lisp numeric function `?asinh`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_asinh` may be considerably faster in some code, particularly untranslated code.

## 11.6 Function: `n_atan`

**Description** `n_atan` calls the lisp numeric function `?atan`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_atan` may be considerably faster in some code, particularly untranslated code.

## 11.7 Function: `n_atanh`

**Description** `n_atanh` calls the lisp numeric function `?atanh`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_atanh` may be considerably faster in some code, particularly untranslated code.

## 11.8 Function: `n_cos`

**Description** `n_cos` calls the lisp numeric function `?cos`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_cos` may be considerably faster in some code, particularly untranslated code.

## 11.9 Function: `n_cosh`

**Description** `n_cosh` calls the lisp numeric function `?cosh`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_cosh` may be considerably faster in some code, particularly untranslated code.

## 11.10 Function: `n_exp`

**Description** `n_exp` calls the lisp numeric function `?exp`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_exp` may be considerably faster in some code, particularly untranslated code.

## 11.11 Function: `n_expt`

**Description** `n_expt` calls the lisp numeric function `?expt`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_expt` may be considerably faster in some code, particularly untranslated code.

## 11.12 Function: `n_log`

**Description** `n_log` calls the lisp numeric function `?log`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_log` may be considerably faster in some code, particularly untranslated code.

## 11.13 Function: `n_sin`

**Description** `n_sin` calls the lisp numeric function `?sin`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_sin` may be considerably faster in some code, particularly untranslated code.

### 11.14 Function: `n_sinh`

**Description** `n_sinh` calls the lisp numeric function `?sinh`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_sinh` may be considerably faster in some code, particularly untranslated code.

### 11.15 Function: `n_sqrt`

**Description** `n_sqrt` calls the lisp numeric function `?sqrt`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_sqrt` may be considerably faster in some code, particularly untranslated code.

### 11.16 Function: `n_tan`

**Description** `n_tan` calls the lisp numeric function `?tan`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_tan` may be considerably faster in some code, particularly untranslated code.

### 11.17 Function: `n_tanh`

**Description** `n_tanh` calls the lisp numeric function `?tanh`. This function accepts only float or integer arguments from maxima (lisp complex and rationals, as well.). `n_tanh` may be considerably faster in some code, particularly untranslated code.

## 12 Functions and Variables for Predicates

- `cmplength`
- `length0p`
- `length1p`
- `length_eq`
- `type_of`

### 12.1 Function: `cmplength`

**`cmplength`**(*e*, *n*)

next package: `aex`

**Description** return the smaller of *n* and `length(e)`. This is useful if *e* is very large and *n* is small, so that computing the entire length of *e* is inefficient. Expression *e* can be either a list or an array.

**Arguments** `cmplength` requires two arguments. The second argument *n* must be a non-negative integer.

**See also** `length0p`, `length_eq`, and `length1p`.

**Implementation** `cmplength` is implemented with `defmfun1`, which slows things down a bit. So be cautious using it in a tight loop.

## 12.2 Function: length0p

**length0p**(*e*)

next package: aex

**Description** Returns true if *e* is of length 0, false otherwise. This implementation traverse no more elements of *e* than necessary to return the result.

**Arguments** **length0p** requires one argument *e*, which must be a string or non-atomic.

See also **cmplength**, **length\_eq**, and **length1p**.

**Implementation** **length0p** is implemented with **defmfun1**, which slows things down a bit. So be cautious using it in a tight loop.

## 12.3 Function: length1p

**length1p**(*e*)

next package: aex

**Description** Returns true if *e* is of length 1, false otherwise. This implementation traverse no more elements of *e* than necessary to return the result.

**Arguments** **length1p** requires one argument *e*, which must be a string or non-atomic.

See also **length0p**, **cmplength**, and **length\_eq**.

**Implementation** **length1p** is implemented with **defmfun1**, which slows things down a bit. So be cautious using it in a tight loop.

## 12.4 Function: length\_eq

**length\_eq**(*e*, *n*)

next package: aex

**Description** Returns true if *e* is of length *n*, false otherwise. This implementation traverses no more elements of *e* than necessary to return the result.

**Arguments** **length\_eq** requires two arguments. The first argument *e* must be a string or non-atomic. The second argument *n* must be a non-negative integer.

See also **length0p**, **cmplength**, and **length1p**.

**Implementation** **length\_eq** is implemented with **defmfun1**, which slows things down a bit. So be cautious using it in a tight loop.

## 12.5 Function: type\_of

**type\_of**(*e* :optional *verbose*)

next package: aex

**Description** Return something like the ‘type’ of a maxima expression. This is a bit ill defined currently. **type\_of** uses the lisp function **type-of**.

**Arguments** **type\_of** requires either one or two arguments.

**Examples**

```
(%i1) type_of(1);  
(%o1) ?bit
```

```
(%i1) type_of(1.0);
(%o1) ?double\~float
(%i2) type_of(1.0b0);
(%o2) ?bfloat
(%i3) type_of(1/3);
(%o3) /
(%i4) type_of("dog");
(%o4) ?string
(%i5) type_of([1,2,3]);
(%o5) [
(%i6) type_of(aex([1,2,3]));
(%o6) [
(%i7) type_of(%e);
(%o7) ?symbol
(%i8) type_of(%i);
(%o8) ?symbol
(%i9) type_of(%i+1);
(%o9) +
```

`type_of` returns the type of the lisp struct corresponding to a maxima object.

```
(%i1) load(graphs)$
(%i2) type_of(new_graph());
(%o2) graph
```

## 13 Functions and Variables for Program Flow

- `error_str`

### 13.1 Function: `error_str`

`error_str()`  
 next package: `aex`

**Description** Returns the last error message as a string.

**Arguments** `error_str` requires zero arguments.

See also `error` and `errormsg`.

## 14 Functions and Variables for Quicklisp

- `quicklisp_apropos`
- `quicklisp_install`
- `quicklisp_load`
- `quicklisp_start`

## 14.1 Function: quicklisp\_apropos

**quicklisp\_apropos**(*term*)

next package: quicklisp

**Description** Search quicklisp for lisp 'systems' (packages) matching *term*.

**Arguments** quicklisp\_apropos requires one argument *term*, which must be a string.

## 14.2 Function: quicklisp\_install

**quicklisp\_install**()

next package: quicklisp

**Description** Download and install quicklisp from the internet. This is usually done automatically as the final step of building and installing the maxima interface to quicklisp.

**Arguments** quicklisp\_install requires zero arguments.

## 14.3 Function: quicklisp\_load

**quicklisp\_load**(*package\_name*)

next package: quicklisp

**Description** Load the asdf lisp package *package\_name*, or, if not installed, install from the internet and then load.

**Arguments** quicklisp\_load requires one argument *package\_name*, which must be a string.

## 14.4 Function: quicklisp\_start

**quicklisp\_start**()

next package: quicklisp

**Description** Load (setup) quicklisp. It must already be installed.

**Arguments** quicklisp\_start requires zero arguments.

# 15 Functions and Variables for Runtime Environment

- `chdir`
- `dir_exists`
- `dirstack`
- `dont_kill`
- `dont_kill_share`
- `get_dont_kill`
- `mext_clear`
- `mext_info`
- `mext_list`

- `mext_test`
- `popdir`
- `probe_file`
- `pwd`
- `require`
- `truename`

## 15.1 Function: `chdir`

**`chdir`**( :optional *dir*)

mext package: `mext.defmfun1`

### Calling

**`chdir`**() Set the working directory to the value it had when `mext` was loaded.

**`chdir`**(*dir*) Set the working directory to *dir*.

**Description** Set the working directory for maxima/lisp. With some lisps, such as cmu lisp the system directory is changed as well. This should be made uniform across lisp implementations.

**Arguments** `chdir` requires either zero or one arguments. If present, the argument *dir* must be a string.

## 15.2 Function: `dir_exists`

**`dir_exists`**(*dir*)

mext package: `mext.defmfun1`

**Description** Returns the pathname as a string if *dir* exists, and **false** otherwise.

**Arguments** `dir_exists` requires one argument *dir*, which must be a string.

## 15.3 Function: `dirstack`

**`dirstack`**()

mext package: `mext.defmfun1`

**Description** Return a list of the directories on the directory stack. This list is manipulated with `chdir`, `updir`, and `popdir`.

**Arguments** `dirstack` requires zero arguments.

## 15.4 Function: `dont_kill`

**`dont_kill`**( :rest *item*)

mext package: `mext.defmfun1`

**Description** Add the *items* to the list of symbols that are not killed by `kill(all)`. This facility is part of the maxima core, but is apparently unused. Maybe putting a property in the symbol's property list would be better.

**Arguments** `dont_kill` requires zero or more arguments.

**Attributes** `dont_kill` has attributes: `[hold.all]`

### 15.5 Function: dont\_kill\_share

**dont\_kill\_share**(*package*)

mext package: mext.defmfun1

**Description** Prevent symbols in maxima share package *package* from being killed by **kill**.

**Arguments** **dont\_kill\_share** requires one argument *package*, which must be a string or a symbol.

### 15.6 Function: get\_dont\_kill

**get\_dont\_kill**()

mext package: mext.defmfun1

**Description** Returns the list of symbols that are not killed by **kill(all)**. Items are added to this list with **dont\_kill**.

**Arguments** **get\_dont\_kill** requires zero arguments.

### 15.7 Function: mext\_clear

**mext\_clear**()

mext package: mext.defmfun1

**Description** Clears the list of mext packages that have been loaded with **require**. Subsequent calls to **require** will reload the packages.

**Arguments** **mext\_clear** requires zero arguments.

### 15.8 Function: mext\_info

**mext\_info**(*distname*)

mext package: mext.defmfun1

**Description** Print information about installed mext distribution *distname*. The list of installed distributions is built by calling **mext\_list**.

**Arguments** **mext\_info** requires one argument *distname*, which must be a string or a symbol.

### 15.9 Function: mext\_list

**mext\_list**()

mext package: mext.defmfun1

**Description** Returns a list of all installed mext distributions.

**Arguments** **mext\_list** requires zero arguments.

### 15.10 Function: mext\_test

**mext\_test**( :optional *dist*s)

mext package: mext.defmfun1

**Description** Run the test suites for a mext distribution or list of distributions. With no argument, a subfolder named **rtests** is searched for in the current directory.

**Arguments** **mext\_test** requires either zero or one arguments. If present, the argument *dist*s must be a string, a symbol, or a list of strings or symbols.



## 15.11 Function: popdir

**popdir**( :optional *n*)

mext package: mezt\_defmfun1

**Description** Pop a value from the current directory stack and chdir to this value. If *n* is given, pop *n* values and chdir to the last value popped.

**Arguments** popdir requires either zero or one arguments. If present, the argument *n* must be a non-negative integer.

## 15.12 Function: probe\_file

### Calling

**probe\_file**(*filespec*) returns a string representing a canonical pathname to the file specified by *filespec*. False is returned if the file can't be found.

**Description** Probe\_File tries to find a canonical pathname for a filespecified by the string *filespec*.

### Examples

```
(%i1) probe_file("a/b.txt");  
(%o1) "/home/username/c/a/b.txt"
```

## 15.13 Function: pwd

**pwd**()

mext package: mezt\_defmfun1

**Description** Return the current working directory.

**Arguments** pwd requires zero arguments.

## 15.14 Function: require

**require**(*distname* :optional *force*)

mext package: mezt\_defmfun1

**Description** Load the mezt package *distname* and register that it has been loaded. **require**('all) will load all installed mezt packages. If *force* is true, then *distname* is loaded even if it has been loaded previously.

**Arguments** require requires either one or two arguments. The first argument *distname* must be a string or a symbol.

## 15.15 Function: truename

### Calling

**truename**(*filespec*) returns a string representing a canonical pathname to the file specified by *filespec*

**Description** Truename tries to find a canonical pathanme for a file specified by the string *filespec*.

## 16 Functions and Variables for Strings

- `string_drop`
- `string_reverse`
- `string_take`
- `with_output_to_string`

### 16.1 Function: `string_drop`

`string_drop(s, spec)`

next package: `lists_aex`

**Arguments** `string_drop` requires two arguments. The first argument *s* must be a string. The second argument *spec* must be a sequence specification.

**Examples**

```
(%i1) string_drop("abracadabra",1);  
(%o1) bracadabra
```

```
(%i1) string_drop("abracadabra",-1);  
(%o1) abracadabr
```

```
(%i1) string_drop("abracadabra",[2,10]);  
(%o1) aa
```

### 16.2 Function: `string_reverse`

`string_reverse(s)`

next package: `lists_aex`

**Calling**

`string_reverse(s)` returns a copy of string *s* with the characters in reverse order.

**Arguments** `string_reverse` requires one argument *s*, which must be a string.

### 16.3 Function: `string_take`

`string_take(s, spec)`

next package: `lists_aex`

**Calling**

`string_take(s, n)` returns a string of the first *n* characters of the string *s*.

`string_take(s, -n)` returns a string of the last *n* characters of *s*.

**Arguments** `string_take` requires two arguments. The first argument *s* must be a string. The second argument *spec* must be a sequence specification.

**Examples**

```
(%i1) string_take("dog-goat-pig-zebra",[5,12]);  
(%o1) goat-pig
```

## 16.4 Function: with\_output\_to\_string

**Description** Evaluates *expr\_1*, *expr\_2*, *expr\_3*, ...

**Examples**

```
(%i1) sreverse(with_output_to_string(for i:5 thru 10 do print("i! for i=",i,i!)));
(%o1)
0088263 01 =i rof !i
088263 9 =i rof !i
02304 8 =i rof !i
0405 7 =i rof !i
027 6 =i rof !i
021 5 =i rof !i
```

See also `with_stdout`.

## 17 Miscellaneous Functions

- `examples`
- `examples_add`

### 17.1 Function: examples

**examples**(*item*)

next package: `defmfun1`

**Calling**

**examples**(*item*) Print examples for the topic *item*. Note these examples are different from those extracted from the maxima manual with the command **example**.

**Arguments** `examples` requires one argument *item*, which must be a string or a symbol.

### 17.2 Function: examples\_add

**examples\_add**(*item*, *text*, *protected-var-list*, *code*)

next package: `defmfun1`

**Calling**

**examples\_add**(*item*, *text*, *protected-var-list*, *code*) Add an example for item *item*. *text* will be printed before the example is displayed. *protected-var-list* is string giving a list of variables such as "[x,y]" that appear in the example code. The example code will be wrapped in a block that makes *protected-var-list* local. *code* may be a string or list of strings that is/are the example code.

**Arguments** `examples_add` requires four arguments. The first argument *item* must be a string or a symbol. The second argument *text* must be a string. The third argument *protected-var-list* must be a string. The fourth argument *code* must be a string or a list of strings.

**Examples**

Add an example for the function 'last'.

```
(%i1) examples_add("last", "Return the last item in a list.", "[a,b,c,d]", "last([a,b,c,d])") ;
(%o1) done
```

## 18 Miscellaneous utilities

## 19 Options

Options to a function in the aex-maxima distribution are passed as follows:

`funcname(x,y, [optname -i optval, optname2 -i optval2])` or `funcname(x,y, optname -i optval, optname2 -i optval2)`

The standard options described in this section are some options that are supported by many functions in the aex-maxima distribution.

- `adj`
- `compile`
- `foptions`
- `ot`

### 19.1 Option: `adj`

**Description** This option takes values of `true` or `false`. If `true`, then the output aex expression is adjustable, that is, the underlying array can be extended in size. If `false`, then the output aex expression is not adjustable. The non-adjustable array may have some advantages in efficiency, but I have not observed them, and this may be lisp-implementation dependent.

### 19.2 Option: `compile`

**Description** If this option is true, then lambda functions passed as arguments to a function will be automatically translated or compiled. If it is false they will be used as interpreted maxima code. Compiling lambda functions usually greatly decreases the execution time of the function if the lambda function is called many times.

### 19.3 Function: `foptions`

`foptions`(*name*)

**Description** Return a list of allowed options to `defmfun1` function *name*. I would prefer to call this `options`, but that name is taken by an unused, undocumented function.

**Arguments** `foptions` requires one argument *name*, which must be a string or a symbol.

### 19.4 Option: `ot`

**Description** With a value `ar` this option causes the function to return an array-representation expression. With a value `ml` a standard lisp list representation is returned. The array-representation is not a maxima array, but rather a more-or-less arbitrary maxima expression that is stored internally as an array. For certain operations, such as random access to elements of the expression, an array representation is faster than the standard list representation. One disadvantage of the array representations is that creating an array is relatively slow. For instance, execution time may be large if a function returns an expression with many small subexpressions that are in the array-representation. The majority of the maxima system does not understand array-representation, so conversion back to list-representation may be necessary.