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# **Sage Reference Manual: Standard Semirings**

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**The Sage Development Team**

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# CONTENTS

<b>1</b>	<b>Non Negative Integer Semiring</b>	<b>1</b>
<b>2</b>	<b>Tropical Semirings</b>	<b>3</b>
<b>3</b>	<b>Indices and Tables</b>	<b>7</b>
	<b>Python Module Index</b>	<b>9</b>
	<b>Index</b>	<b>11</b>



## NON NEGATIVE INTEGER SEMIRING

```
sage.rings.semirings.non_negative_integer_semiring.NN = Non negative integer semiring
```

```
class sage.rings.semirings.non_negative_integer_semiring.NonNegativeIntegerSemiring
    Bases: sage.sets.non_negative_integers.NonNegativeIntegers
```

A class for the semiring of the non negative integers

This parent inherits from the infinite enumerated set of non negative integers and endows it with its natural semiring structure.

EXAMPLES:

```
sage: NonNegativeIntegerSemiring()
Non negative integer semiring
```

For convenience, NN is a shortcut for `NonNegativeIntegerSemiring()`:

```
sage: NN == NonNegativeIntegerSemiring()
True

sage: NN.category()
Category of facade infinite enumerated commutative semirings
```

Here is a piece of the Cayley graph for the multiplicative structure:

```
sage: G = NN.cayley_graph(elements=range(9), generators=[0,1,2,3,5,7])
sage: G
Looped multi-digraph on 9 vertices
sage: G.plot()
Graphics object consisting of 48 graphics primitives
```

This is the Hasse diagram of the divisibility order on NN.

```
sage: Poset(NN.cayley_graph(elements=[1..12], generators=[2,3,5,7,11])).show()
```

Note: as for `NonNegativeIntegers`, NN is currently just a “facade” parent; namely its elements are plain Sage Integers with `Integer Ring` as parent:

```
sage: x = NN(15); type(x)
<type 'sage.rings.integer.Integer'>
sage: x.parent()
Integer Ring
sage: x+3
18
```

**additive\_semigroup\_generators()**

Returns the additive semigroup generators of `self`.

EXAMPLES:

```
sage: NN.additive_semigroup_generators()
Family (0, 1)
```

## TROPICAL SEMIRINGS

AUTHORS:

- Travis Scrimshaw (2013-04-28) - Initial version

```
class sage.rings.semirings.tropical_semiring.TropicalSemiring(base,
                                                             use_min=True)
    Bases: sage.structure.parent.Parent, sage.structure.unique_representation.UniqueRepresentation
```

The tropical semiring.

Given an ordered additive semigroup  $R$ , we define the tropical semiring  $T = R \cup \{+\infty\}$  by defining tropical addition and multiplication as follows:

$$a \oplus b = \min(a, b), \quad a \odot b = a + b.$$

In particular, note that there are no (tropical) additive inverses (except for  $\infty$ ), and every element in  $R$  has a (tropical) multiplicative inverse.

There is an alternative definition where we define  $T = R \cup \{-\infty\}$  and alter tropical addition to be defined by

$$a \oplus b = \max(a, b).$$

To use the max definition, set the argument `use_min = False`.

**Warning:** `zero()` and `one()` refer to the tropical additive and multiplicative identities respectively. These are **not** the same as calling `T(0)` and `T(1)` respectively as these are **not** the tropical additive and multiplicative identities respectively.

Specifically do not use `sum(...)` as this converts 0 to 0 as a tropical element, which is not the same as `zero()`. Instead use the `sum` method of the tropical semiring:

```
sage: T = TropicalSemiring(QQ)

sage: sum([T(1), T(2)]) # This is wrong
0
sage: T.sum([T(1), T(2)]) # This is correct
1
```

Be careful about using code that has not been checked for tropical safety.

INPUT:

- `base` – the base ordered additive semigroup  $R$

- `use_min` – (default: `True`) if `True`, then the semiring uses  $a \oplus b = \min(a, b)$ ; otherwise uses  $a \oplus b = \max(a, b)$

EXAMPLES:

```
sage: T = TropicalSemiring(QQ)
sage: elt = T(2); elt
2
```

Recall that tropical addition is the minimum of two elements:

```
sage: T(3) + T(5)
3
```

Tropical multiplication is the addition of two elements:

```
sage: T(2) * T(3)
5
sage: T(0) * T(-2)
-2
```

We can also do tropical division and arbitrary tropical exponentiation:

```
sage: T(2) / T(1)
1
sage: T(2) ^ (-3/7)
-6/7
```

Note that “zero” and “one” are the additive and multiplicative identities of the tropical semiring. In general, they are **not** the elements 0 and 1 of  $R$ , respectively, even if such elements exist (e.g., for  $R = \mathbf{Z}$ ), but instead the (tropical) additive and multiplicative identities  $+\infty$  and 0 respectively:

```
sage: T.zero() + T(3) == T(3)
True
sage: T.one() * T(3) == T(3)
True
sage: T.zero() == T(0)
False
sage: T.one() == T(1)
False
```

### Element

alias of *TropicalSemiringElement*

### additive\_identity()

Return the (tropical) additive identity element  $+\infty$ .

EXAMPLES:

```
sage: T = TropicalSemiring(QQ)
sage: T.zero()
+infinity
```

### gens()

Return the generators of `self`.

EXAMPLES:



```
sage: T = TropicalSemiring(QQ)
sage: T.gens()
(1, +infinity)
```

**infinity()**

Return the (tropical) additive identity element  $+\infty$ .

EXAMPLES:

```
sage: T = TropicalSemiring(QQ)
sage: T.zero()
+infinity
```

**multiplicative\_identity()**

Return the (tropical) multiplicative identity element 0.

EXAMPLES:

```
sage: T = TropicalSemiring(QQ)
sage: T.one()
0
```

**one()**

Return the (tropical) multiplicative identity element 0.

EXAMPLES:

```
sage: T = TropicalSemiring(QQ)
sage: T.one()
0
```

**zero()**

Return the (tropical) additive identity element  $+\infty$ .

EXAMPLES:

```
sage: T = TropicalSemiring(QQ)
sage: T.zero()
+infinity
```

**class** sage.rings.semiringsemirings.tropical\_semiring.TropicalSemiringElement

Bases: sage.structure.element.Element

An element in the tropical semiring over an ordered additive semigroup  $R$ . Either in  $R$  or  $\infty$ . The operators  $+$ ,  $\cdot$  are defined as the tropical operators  $\oplus$ ,  $\odot$  respectively.

**lift()**

Return the value of `self` lifted to the base.

EXAMPLES:

```
sage: T = TropicalSemiring(QQ)
sage: elt = T(2)
sage: elt.lift()
2
sage: elt.lift().parent() is QQ
True
sage: T.additive_identity().lift().parent()
The Infinity Ring
```

**multiplicative\_order()**

Return the multiplicative order of `self`.

EXAMPLES:

```
sage: T = TropicalSemiring(QQ)
sage: T.multiplicative_identity().multiplicative_order()
1
sage: T.additive_identity().multiplicative_order()
+Infinity
```

**class** `sage.rings.semirings.tropical_semiring.TropicalToTropical`

Bases: `sage.categories.map.Map`

Map from the tropical semiring to itself (possibly with different bases). Used in coercion.

## INDICES AND TABLES

- [Index](#)
- [Module Index](#)
- [Search Page](#)



## PYTHON MODULE INDEX

### r

`sage.rings.semirings.non_negative_integer_semiring`, 1  
`sage.rings.semirings.tropical_semiring`, 3



## INDEX

### A

`additive_identity()` (*sage.rings.semiring.tropical\_semiring.TropicalSemiring method*), 4

`additive_semigroup_generators()` (*sage.rings.semiring.non\_negative\_integer\_semiring.NonNegativeIntegerSemiring method*), 1

### E

`Element` (*sage.rings.semiring.tropical\_semiring.TropicalSemiring attribute*), 4

### G

`gens()` (*sage.rings.semiring.tropical\_semiring.TropicalSemiring method*), 4

### I

`infinity()` (*sage.rings.semiring.tropical\_semiring.TropicalSemiring method*), 5

### L

`lift()` (*sage.rings.semiring.tropical\_semiring.TropicalSemiringElement method*), 5

### M

`multiplicative_identity()` (*sage.rings.semiring.tropical\_semiring.TropicalSemiring method*), 5

`multiplicative_order()` (*sage.rings.semiring.tropical\_semiring.TropicalSemiringElement method*), 5

### N

`NN` (*in module sage.rings.semiring.non\_negative\_integer\_semiring*), 1

`NonNegativeIntegerSemiring` (*class in sage.rings.semiring.non\_negative\_integer\_semiring*), 1

### O

`one()` (*sage.rings.semiring.tropical\_semiring.TropicalSemiring method*), 5

### S

`sage.rings.semiring.non_negative_integer_semiring` (*module*), 1

`sage.rings.semiring.tropical_semiring` (*module*), 3

### T

`TropicalSemiring` (*class in sage.rings.semiring.tropical\_semiring*), 3

`TropicalSemiringElement` (*class in sage.rings.semiring.tropical\_semiring*), 5

`TropicalToTropical` (*class in sage.rings.semiring.tropical\_semiring*), 6

## Z

`zero()` (*sage.rings.semiring.tropical\_semiring.TropicalSemiring method*), [5](#)