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# **dwave-neal Documentation**

*Release 0.4.6*

**D-Wave Systems Inc**

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An implementation of a simulated annealing sampler.



# CHAPTER 1

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## Example Usage

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```
import neal

sampler = neal.SimulatedAnnealingSampler()

h = {0: -1, 1: -1}
J = {(0, 1): -1}
response = sampler.sample_ising(h, J)
```





## 2.1 Introduction

*Samplers* are processes that sample from low energy states of a problem's objective function. A binary quadratic model (BQM) sampler samples from low energy states in models such as those defined by an Ising equation or a Quadratic Unconstrained Binary Optimization (QUBO) problem and returns an iterable of samples, in order of increasing energy. A *dimod sampler* provides 'sample\_qubo' and 'sample\_ising' methods as well as the generic BQM sampler method.

The `SimulatedAnnealingSampler` sampler implements the simulated annealing algorithm, based on the technique of cooling metal from a high temperature to improve its structure (annealing). This algorithm often finds good solutions to hard optimization problems.

## 2.2 Reference Documentation

**Release** 0.4.6

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### 2.2.1 Simulated Annealing Sampler

A *dimod sampler* that uses the simulated annealing algorithm.

#### Class

**class** `SimulatedAnnealingSampler`

Simulated annealing sampler.

Also aliased as `Neal`.

## Examples

This example solves a simple Ising problem.

```
>>> import neal
>>> sampler = neal.SimulatedAnnealingSampler()
>>> h = {'a': 0.0, 'b': 0.0, 'c': 0.0}
>>> J = (('a', 'b'): 1.0, ('b', 'c'): 1.0, ('a', 'c'): 1.0)
>>> response = sampler.sample_ising(h, J)
>>> for sample in response: # doctest: +SKIP
...     print(sample)
... {'a': -1, 'b': 1, 'c': -1}
... {'a': -1, 'b': 1, 'c': 1}
... {'a': 1, 'b': 1, 'c': -1}
... {'a': 1, 'b': -1, 'c': -1}
... {'a': 1, 'b': -1, 'c': -1}
... {'a': 1, 'b': -1, 'c': -1}
... {'a': 1, 'b': -1, 'c': -1}
... {'a': -1, 'b': 1, 'c': 1}
... {'a': 1, 'b': 1, 'c': -1}
... {'a': -1, 'b': -1, 'c': 1}
... {'a': -1, 'b': 1, 'c': 1}
```

## Sampler Properties

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<i>SimulatedAnnealingSampler.properties</i>	A dict containing any additional information about the sampler.
<i>SimulatedAnnealingSampler.parameters</i>	A dict where keys are the keyword parameters accepted by the sampler methods (allowed kwargs) and values are lists of <i>SimulatedAnnealingSampler.properties</i> relevant to each parameter.

---

### neal.sampler.SimulatedAnnealingSampler.properties

`SimulatedAnnealingSampler.properties = None`  
A dict containing any additional information about the sampler.

## Examples

This example looks at the values set for a sampler property.

```
>>> import neal
>>> sampler = neal.SimulatedAnnealingSampler()
>>> sampler.properties['beta_schedule_options']
('linear', 'geometric')
```

Type dict

### neal.sampler.SimulatedAnnealingSampler.parameters

`SimulatedAnnealingSampler.parameters = None`  
A dict where keys are the keyword parameters accepted by the sampler methods (allowed kwargs) and values

are lists of `SimulatedAnnealingSampler.properties` relevant to each parameter.

See `SimulatedAnnealingSampler.sample()` for a description of the parameters.

## Examples

This example looks at a sampler's parameters and some of their values.

```
>>> import neal
>>> sampler = neal.SimulatedAnnealingSampler()
>>> for kwarg in sorted(sampler.parameters):
...     print(kwarg)
beta_range
beta_schedule_type
num_reads
seed
sweeps
>>> sampler.parameters['beta_range']
[]
>>> sampler.parameters['beta_schedule_type']
['beta_schedule_options']
```

Type dict

## Methods

<code>SimulatedAnnealingSampler.sample(bqm[, ...])</code>	Sample from a binary quadratic model using an implemented sample method.
<code>SimulatedAnnealingSampler.sample_ising(h, J, ...)</code>	Samples from an Ising model using an implemented sample method.
<code>SimulatedAnnealingSampler.sample_qubo(Q, ...)</code>	Samples from a QUBO using an implemented sample method.

## neal.sampler.SimulatedAnnealingSampler.sample

`SimulatedAnnealingSampler.sample(bqm, beta_range=None, num_reads=10, sweeps=1000, beta_schedule_type='geometric', seed=None, interrupt_function=None, initial_states=None)`

Sample from a binary quadratic model using an implemented sample method.

### Parameters

- **bqm** (`dimod.BinaryQuadraticModel`) – The binary quadratic model to be sampled.
- **beta\_range** (`tuple, optional`) – A 2-tuple defining the beginning and end of the beta schedule, where beta is the inverse temperature. The schedule is applied linearly in beta. Default range is set based on the total bias associated with each node.
- **num\_reads** (`int, optional, default=10`) – Each read is the result of a single run of the simulated annealing algorithm.
- **sweeps** (`int, optional, default=1000`) – Number of sweeps or steps.
- **beta\_schedule\_type** (`string, optional, default='geometric'`) – Beta schedule type, or how the beta values are interpolated between the given 'beta\_range'.

Supported values are:

- linear
- geometric
- **seed** (*int*, *optional*) – Seed to use for the PRNG. Specifying a particular seed with a constant set of parameters produces identical results. If not provided, a random seed is chosen.
- **initial\_states** (*tuple(numpy.ndarray, dict)*, *optional*) – A tuple where the first value is a numpy array of initial states to seed the simulated annealing runs, and the second is a dict defining a linear variable labelling.
- **interrupt\_function** (*function*, *optional*) – If provided, `interrupt_function` is called with no parameters between each sample of simulated annealing. If the function returns True, then simulated annealing will terminate and return with all of the samples and energies found so far.

**Returns** A `dimod` `Response` object.

**Return type** `dimod.Response`

## Examples

This example runs simulated annealing on a binary quadratic model with some different input parameters.

```
>>> import dimod
>>> import neal
...
>>> sampler = neal.SimulatedAnnealingSampler()
>>> bqm = dimod.BinaryQuadraticModel({'a': .5, 'b': -.5}, {'(a', 'b)': -1}, 0.0,
↳dimod.SPIN)
>>> # Run with default parameters
>>> response = sampler.sample(bqm)
>>> # Run with specified parameters
>>> response = sampler.sample(bqm, seed=1234, beta_range=[0.1, 4.2],
...                               num_reads=1, sweeps=20,
...                               beta_schedule_type='geometric')
>>> # Reuse a seed
>>> a1 = next((sampler.sample(bqm, seed=88).samples())['a'])
>>> a2 = next((sampler.sample(bqm, seed=88).samples())['a'])
>>> a1 == a2
True
```

### `neal.sampler.SimulatedAnnealingSampler.sample_ising`

`SimulatedAnnealingSampler.sample_ising` (*h, J, \*\*parameters*)  
 Samples from an Ising model using an implemented sample method.

### `neal.sampler.SimulatedAnnealingSampler.sample_qubo`

`SimulatedAnnealingSampler.sample_qubo` (*Q, \*\*parameters*)  
 Samples from a QUBO using an implemented sample method.

## Alias

### Neal

alias of `neal.sampler.SimulatedAnnealingSampler`

## 2.3 Installation

To install:

```
pip install dwave-neal
```

To build from source:

```
pip install -r requirements.txt
python setup.py build_ext --inplace
python setup.py install
```

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## CHAPTER 3

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