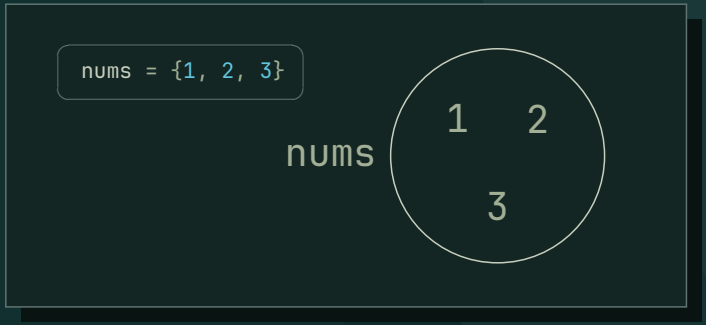

Sets

Data Structures – Intermediate Python

Agenda

- What Are Sets?
  - Properties
  - Benefits
  - Drawbacks
- Set Details
  - Operations
  - Implementation Details
- Working with Sets
  - Math and Syntax
  - Frozen Sets

What Are Sets?

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- Sets cannot contain themselves

Set Properties

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- Items are distinct

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- Items can iterated over
- Set operations include mathematical operations

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- Benefits of mathematical operations
  - Sets can be used in mathematical contexts
  - Mathematical algorithms involving sets can be simpler to implement since sets exist in programming languages

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  - Sets can be slower to iterate over than other data abstractions
- Sets are unordered
  - If order is important, sets can't be considered, even if their operations are useful for this particular problem

Set Details

Set Operations

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- What operations do sets have?

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  - Symmetric difference (linear time)

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- `frozenset`
  - Implementation is the same as set, but without methods that would mutate the set
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Working with Sets

Set Syntax: Creation

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creates a set with the listed items

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empty_set: set[int] = set()
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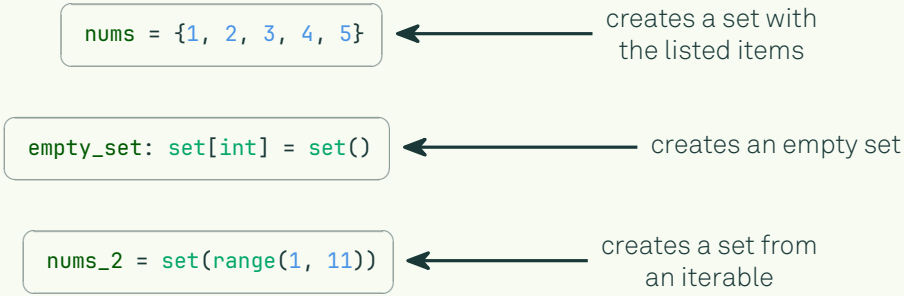
creates an empty set

```
nums_2 = set(range(1, 11))
```

Set Syntax: Creation



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Let $\mathbb{Z}_{\mathrm{e}}$ be the set of even integers.

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$$A = \{1, 2, 3, 4, 5\} \qquad B = \{x \in A \mid x \in \mathbb{Z}_{\text{e}}\}$$

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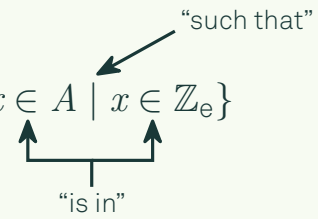

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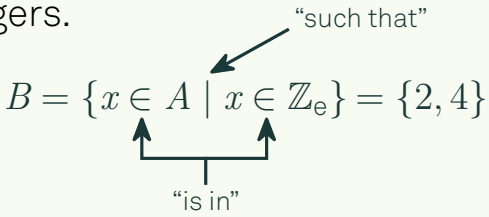

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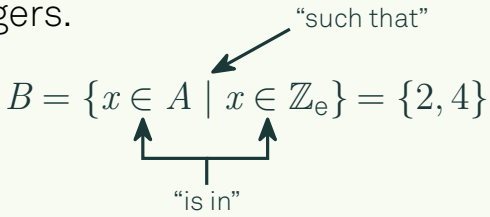


```
a = {1, 2, 3, 4, 5}
b = {x for x in a if x % 2 == 0}
print(b)
```

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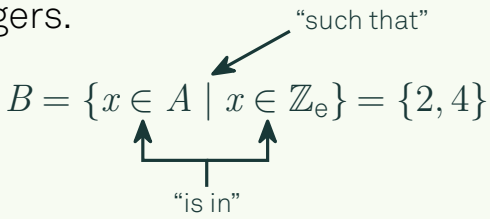
$$A = \{1, 2, 3, 4, 5\}$$




```
a = {1, 2, 3, 4, 5}
b = {x for x in a if x % 2 == 0}
print(b)
```

```
{2, 4}
```

Set Syntax: Adding

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```
a = {1, 2, 3}
print(a)
a.add(4)
print(a)
```

Set Syntax: Adding

```
1  a = {1, 2, 3}
2  print(a)
3  a.add(4)
4  print(a)
```

```
{1, 2, 3}
{1, 2, 3, 4}
```

Set Syntax: Adding

```
1  a = {1, 2, 3}
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3  a.add(4)
4  print(a)
```

```
{1, 2, 3}
{1, 2, 3, 4}
```

```
5  a.add(1)
6  print(a)
```

Set Syntax: Adding

```
1  a = {1, 2, 3}
2  print(a)
3  a.add(4)
4  print(a)
```

```
{1, 2, 3}
{1, 2, 3, 4}
```

```
5  a.add(1)
6  print(a)
```

```
{1, 2, 3, 4}

Process finished with exit code 0
```

Set Syntax: Cardinality

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- The *cardinality* of a set is the number of elements in the set

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```
a = {1, 2, 3, 4, 5}
print(f"|a| = {len(a)}")
```

Set Syntax: Cardinality

- The *cardinality* of a set is the number of elements in the set

$$A = \{1, 2, 3, 4, 5\} \qquad |A| = 5$$

```
a = {1, 2, 3, 4, 5}
print(f"|a| = {len(a)}")
```

```
|a| = 5
```

Set Syntax: Membership

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- *Membership* of a set means that an element is part of a set

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$$A = \{1, 2, 3, 4, 5\} \qquad 3 \in A$$

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$$A = \{1, 2, 3, 4, 5\} \qquad 3 \in A \qquad 7 \notin A$$

Set Syntax: Membership

- *Membership* of a set means that an element is part of a set

$$A = \{1, 2, 3, 4, 5\} \qquad 3 \in A \qquad 7 \notin A$$

```
a = {1, 2, 3, 4, 5}
print(f"3 in a: {3 in a}")
print(f"7 in a: {7 not in a}")
```

Set Syntax: Membership

- *Membership* of a set means that an element is part of a set

$$A = \{1, 2, 3, 4, 5\} \qquad 3 \in A \qquad 7 \notin A$$

```
a = {1, 2, 3, 4, 5}
print(f"3 in a: {3 in a}")
print(f"7 in a: {7 not in a}")
```

```
3 in a: True
7 not in a: True
```

Set Syntax: Removing

Set Syntax: Removing

```
a = {1, 2, 3, 4, 5}
print(a)
a.remove(1)
print(a)
```

Set Syntax: Removing

```
1  a = {1, 2, 3, 4, 5}
2  print(a)
3  a.remove(1)
4  print(a)
```

```
{1, 2, 3, 4, 5}
{2, 3, 4, 5}
```

Set Syntax: Removing

```
1  a = {1, 2, 3, 4, 5}
2  print(a)
3  a.remove(1)
4  print(a)
```

```
{1, 2, 3, 4, 5}
{2, 3, 4, 5}
```

```
5  a.remove(7)
```

Set Syntax: Removing

```
1  a = {1, 2, 3, 4, 5}
2  print(a)
3  a.remove(1)
4  print(a)
```

```
{1, 2, 3, 4, 5}
{2, 3, 4, 5}
```

```
5  a.remove(7)
```

```
Traceback (most recent call last):
  File "project/src/main.py", line 5, in <module>
    a.remove(7)
    ~~~~~~~~^^^
KeyError: 7
```

Set Syntax: Removing

Set Syntax: Removing

```
a = {1, 2, 3, 4, 5}
print(a)
print(a.pop())
print(a)
a.clear()
print(a)
```

Set Syntax: Removing

```python
a = {1, 2, 3, 4, 5}
print(a)
print(a.pop())
print(a)
a.clear()
print(a)
```

```
{1, 2, 3, 4, 5}
1
{2, 3, 4, 5}
set()
```

Set Syntax: Removing

```
1  a = {1, 2, 3, 4, 5}
2  print(a)
3  print(a.pop())
4  print(a)
5  a.clear()
6  print(a)
```

```
{1, 2, 3, 4, 5}
1
{2, 3, 4, 5}
set()
```

```
7  print(a.pop())
```

Set Syntax: Removing

```python
a = {1, 2, 3, 4, 5}
print(a)
print(a.pop())
print(a)
a.clear()
print(a)
```

```
{1, 2, 3, 4, 5}
1
{2, 3, 4, 5}
set()
```

```python
print(a.pop())
```

```
Traceback (most recent call last):
  File "project/src/main.py", line 7, in <module>
    print(a.pop())
          ~~~~~^^
KeyError: 'pop from an empty set'
```

Set Syntax: Removing

Set Syntax: Removing

```
a = {1, 2, 3, 4, 5}
print(a)
a.discard(1)
print(a)
a.discard(7)
print(a)
```

Set Syntax: Removing

```
a = {1, 2, 3, 4, 5}
print(a)
a.discard(1)
print(a)
a.discard(7)
print(a)
```

```
{1, 2, 3, 4, 5}
{2, 3, 4, 5}
{2, 3, 4, 5}

Process finished with exit code 0
```

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$$A = \{1, 2, 3\}$$
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$$A \subseteq B \quad B \not\subseteq A$$

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"is a subset of" → $A \subseteq B$

"is not a subset of" → $B \not\subseteq A$

$$A = \{1, 2, 3\}$$

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Set Syntax: Comparing

- Set A is a *subset* of set B if B contains all the elements of A
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"is a subset of" "is not a subset of"

$$A = \{1, 2, 3\} \qquad A \subseteq B \qquad B \not\subseteq A$$

$$B = \{1, 2, 3, 4, 5\} \qquad B \supseteq A \qquad A \not\supseteq B$$

Set Syntax: Comparing

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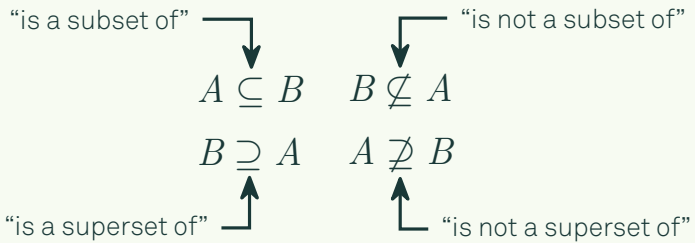

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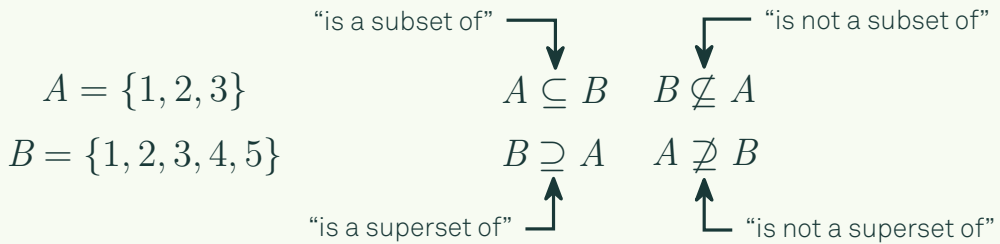

- $\varnothing$ is a subset of *every set*

Set Syntax: Comparing

```
a = {1, 2, 3}
b = {1, 2, 3, 4, 5}
print(f"a is a subset of b (method): {a.issubset(b)}")
print(f"a is a subset of b (operator): {a ⩽ b}")
print(f"b is a superset of a (method): {b.issuperset(a)}")
print(f"b is a superset of a (operator): {b ⩾ a}")
```

Set Syntax: Comparing

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a = {1, 2, 3}
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print(f"b is a superset of a (operator): {b ⩾ a}")
```

```
a is a subset of b (method): True
a is a subset of b (operator): True
b is a superset of a (method): True
b is a superset of a (operator): True
```

Why Two Ways?

- Operator version must compare two sets
- Method version compares a set with anything iterable

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a = {1, 2, 3}
lst = [1, 2, 3, 4, 5]
print(a.issubset(lst))
# print(a ⩽ lst) # TypeError: comparison must be between two sets
```

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```

```
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```

- This is the case for all set comparisons and operations

Why Two Ways?

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- The operator version is preferred since it’s short and simple

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- The operator version is preferred since it's short and simple
- Forcing the operation version to work with only sets prevents error-prone code caused by the other uses of these operators

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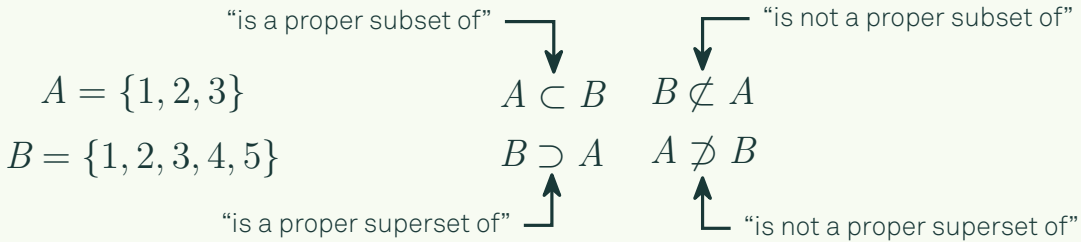
"is a proper subset of" "is not a proper subset of"

$$A = \{1, 2, 3\} \qquad A \subset B \qquad B \not\subset A$$

$$B = \{1, 2, 3, 4, 5\} \qquad B \supset A \qquad A \not\supset B$$

Set Syntax: Comparing

- Set A is a *proper subset* of set B if $A \subseteq B$ and $A \neq B$
- If A is a proper subset of B, then B is a *proper superset* of A



Set Syntax: Comparing

```
a = {1, 2, 3}
b = {1, 2, 3, 4, 5}
print(f"a is a proper subset of b: {a < b}")
print(f"b is a proper superset of a: {b > a}")
```

Set Syntax: Comparing

```
a = {1, 2, 3}
b = {1, 2, 3, 4, 5}
print(f"a is a proper subset of b: {a < b}")
print(f"b is a proper superset of a: {b > a}")
```

```
a is a proper subset of b: True
b is a proper superset of a: True
```

Set Syntax: Comparing

- Two sets are *disjoint* if they contain no common elements

Set Syntax: Comparing

- Two sets are *disjoint* if they contain no common elements

```
a = {1, 2, 3}
b = {4, 5, 6}
print(a.isdisjoint(b))
```

Set Syntax: Comparing

- Two sets are *disjoint* if they contain no common elements

```
a = {1, 2, 3}
b = {4, 5, 6}
print(a.isdisjoint(b))
```

```
True
```

Set Syntax: Set Operations

Set Syntax: Set Operations

- The *union* of sets A and B is a set containing the elements of A and the elements of B

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$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\}$

Set Syntax: Set Operations

- The *union* of sets A and B is a set containing the elements of A and the elements of B

$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\} \qquad A \cup B = \{1, 2, 3, 5, 8\}$

Set Syntax: Set Operations

- The *union* of sets A and B is a set containing the elements of A and the elements of B

$A = \{1, 2, 3\}$ $B = \{1, 2, 5, 8\}$ $A \cup B = \{1, 2, 3, 5, 8\}$

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
print(a.union(b))
print(a | b)  # operator read as "or"
```

Set Syntax: Set Operations

- The *union* of sets A and B is a set containing the elements of A and the elements of B

$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\} \qquad A \cup B = \{1, 2, 3, 5, 8\}$$

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
print(a.union(b))
print(a | b)  # operator read as "or"
```

```
{1, 2, 3, 5, 8}
{1, 2, 3, 5, 8}
```

Set Syntax: Set Operations

- The previous union operations didn't modify the sets. We can use the following union operations to modify a set

Set Syntax: Set Operations

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```
a = {1, 2, 3}
b = {1, 2, 5, 8}
a.update(b)
print(a)
a = {1, 2, 3}
a |= b
print(a)
```

Set Syntax: Set Operations

- The previous union operations didn't modify the sets. We can use the following union operations to modify a set

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
a.update(b)
print(a)
a = {1, 2, 3}
a |= b
print(a)
```

```
{1, 2, 3, 5, 8}
{1, 2, 3, 5, 8}
```

Set Syntax: Set Operations

- The *intersection* of sets A and B is a set containing the elements of A that are also elements of B

Set Syntax: Set Operations

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- The *intersection* of sets A and B is a set containing the elements of A that are also elements of B

$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\} \qquad A \cap B = \{1, 2\}$$

Set Syntax: Set Operations

- The *intersection* of sets A and B is a set containing the elements of A that are also elements of B

$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\} \qquad A \cap B = \{1, 2\}$$

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
print(a.intersection(b))
print(a & b)  # operator read as "and"
```

Set Syntax: Set Operations

- The *intersection* of sets A and B is a set containing the elements of A that are also elements of B

$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\} \qquad A \cap B = \{1, 2\}$$

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
print(a.intersection(b))
print(a & b)  # operator read as "and"
```

```
{1, 2}
{1, 2}
```

Another Example of Why Two Ways

```
nums = {random.randint(1, 100) for _ in range(10)}
print(nums)
# This is clearer than `nums & range(1, 11)`.
if nums.intersection(range(1, 11)):
    print("`nums` has values between 1 and 10")
else:
    print("`nums` doesn't have any values between 1 and 10")
```

Another Example of Why Two Ways

```
nums = {random.randint(1, 100) for _ in range(10)}
print(nums)
# This is clearer than `nums & range(1, 11)`.
if nums.intersection(range(1, 11)):
    print("`nums` has values between 1 and 10")
else:
    print("`nums` doesn't have any values between 1 and 10")
```

```
{66, 70, 8, 43, 76, 13, 88, 26, 94, 31}
`nums` has values between 1 and 10
```

Set Syntax: Set Operations

- The previous intersection operations didn't modify the sets. We can use the following intersection operations to modify a set

Set Syntax: Set Operations

- The previous intersection operations didn't modify the sets. We can use the following intersection operations to modify a set

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
a.intersection_update(b)
print(a)
a = {1, 2, 3}
a &= b
print(a)
```

Set Syntax: Set Operations

- The previous intersection operations didn't modify the sets. We can use the following intersection operations to modify a set

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
a.intersection_update(b)
print(a)
a = {1, 2, 3}
a &= b
print(a)
```

```
{1, 2}
{1, 2}
```

Set Syntax: Set Operations

- The *difference* of sets A and B is a set containing the elements of A that are not elements of B

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$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\}$

Set Syntax: Set Operations

- The *difference* of sets A and B is a set containing the elements of A that are not elements of B

$A = \{1, 2, 3\}$ $B = \{1, 2, 5, 8\}$ $A \setminus B = \{3\}$ $B \setminus A = \{5, 8\}$

Set Syntax: Set Operations

- The *difference* of sets A and B is a set containing the elements of A that are not elements of B

$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\} \qquad A \setminus B = \{3\} \quad B \setminus A = \{5, 8\}$$

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
print(a.difference(b))
print(b.difference(a))
print(a - b)
print(b - a)
```

Set Syntax: Set Operations

- The *difference* of sets A and B is a set containing the elements of A that are not elements of B

$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\} \qquad A \setminus B = \{3\} \quad B \setminus A = \{5, 8\}$$

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
print(a.difference(b))
print(b.difference(a))
print(a - b)
print(b - a)
```

```
{3}
{8, 5}
{3}
{8, 5}
```

Set Syntax: Set Operations

- The previous difference operations didn't modify the sets. We can use the following difference operations to modify a set

Set Syntax: Set Operations

- The previous difference operations didn't modify the sets. We can use the following difference operations to modify a set

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
a.difference_update(b)
print(a)
a = {1, 2, 3}
b -= a
print(b)
```

Set Syntax: Set Operations

- The previous difference operations didn't modify the sets. We can use the following difference operations to modify a set

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
a.difference_update(b)
print(a)
a = {1, 2, 3}
b -= a
print(b)
```

```
{3}
{5, 8}
```

Set Syntax: Set Operations

- The *symmetric difference* of sets A and B is a set containing the elements that are unique to A and unique to B

Set Syntax: Set Operations

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$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\}$$

Set Syntax: Set Operations

- The *symmetric difference* of sets A and B is a set containing the elements that are unique to A and unique to B

$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\}$$

$$A \oplus B = (A \cup B) \setminus (A \cap B) = \{3, 5, 8\}$$

Set Syntax: Set Operations

- The *symmetric difference* of sets A and B is a set containing the elements that are unique to A and unique to B

$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\}$$

$$A \oplus B = (A \cup B) \setminus (A \cap B) = \{3, 5, 8\}$$

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
print(a.symmetric_difference(b))
print(a ^ b)
```

Set Syntax: Set Operations

- The *symmetric difference* of sets A and B is a set containing the elements that are unique to A and unique to B

$$A = \{1, 2, 3\} \quad B = \{1, 2, 5, 8\}$$

$$A \oplus B = (A \cup B) \setminus (A \cap B) = \{3, 5, 8\}$$

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
print(a.symmetric_difference(b))
print(a ^ b)
```

```
{3, 5, 8}
{3, 5, 8}
```

Set Syntax: Set Operations

- The previous symmetric difference operations didn't modify the sets. We can use the following symmetric difference operations to modify a set

Set Syntax: Set Operations

- The previous symmetric difference operations didn't modify the sets. We can use the following symmetric difference operations to modify a set

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
a.symmetric_difference_update(b)
print(a)
a = {1, 2, 3}
a ^= b
print(a)
```

Set Syntax: Set Operations

- The previous symmetric difference operations didn't modify the sets. We can use the following symmetric difference operations to modify a set

```
a = {1, 2, 3}
b = {1, 2, 5, 8}
a.symmetric_difference_update(b)
print(a)
a = {1, 2, 3}
a ^= b
print(a)
```

```
{3, 5, 8}
{3, 5, 8}
```

Set Syntax: Iteration

Set Syntax: Iteration

```
a = {1, 2, 3}
print("Normal iteration: ", end="")
for num in a:
    print(f"{num} ", end="")
```

Set Syntax: Iteration

```python
a = {1, 2, 3}
print("Normal iteration: ", end="")
for num in a:
    print(f"{num} ", end="")
```

```
Normal iteration: 1 2 3
```

Set Syntax: Iteration

```python
a = {1, 2, 3}
print("Normal iteration: ", end="")
for num in a:
    print(f"{num} ", end="")
```

```
Normal iteration: 1 2 3
```

```python
print("\nPartial iteration: ")
a_iter = iter(a)
print(f"First value: {next(a_iter)}, other values: ", end="")
for num in a_iter:
    print(f"{num} ", end="")
print()
```

Set Syntax: Iteration

```python
a = {1, 2, 3}
print("Normal iteration: ", end="")
for num in a:
    print(f"{num} ", end="")
```

```
Normal iteration: 1 2 3
```

```python
print("\nPartial iteration: ")
a_iter = iter(a)
print(f"First value: {next(a_iter)}, other values: ", end="")
for num in a_iter:
    print(f"{num} ", end="")
print()
```

```
Partial iteration:
First value: 1, other values: 2 3
```

Set Syntax: Frozen Set

Set Syntax: Frozen Set

- Frozen sets are created using the `frozenset` function

Set Syntax: Frozen Set

- Frozen sets are created using the **`frozenset`** function

```
a = frozenset((1, 2, 3))
print(a)
b = frozenset(['a', 'b', 'c'])
print(b)
unique_letters = frozenset('hello')
print(unique_letters)
```

Set Syntax: Frozen Set

- Frozen sets are created using the **`frozenset`** function

```
a = frozenset((1, 2, 3))
print(a)
b = frozenset(['a', 'b', 'c'])
print(b)
unique_letters = frozenset('hello')
print(unique_letters)
```

```
frozenset({1, 2, 3})
frozenset({'c', 'b', 'a'})
frozenset({'o', 'e', 'l', 'h'})
```

Set Syntax: Frozen Set

- Frozen sets can be stored in other sets, unlike regular sets

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- Frozen sets can be stored in other sets, unlike regular sets

```
a = {frozenset((1, 2, 3)), frozenset((4, 5, 6))}
print(a)
```

Set Syntax: Frozen Set

- Frozen sets can be stored in other sets, unlike regular sets

```
a = {frozenset((1, 2, 3)), frozenset((4, 5, 6))}
print(a)
```

```
{frozenset({1, 2, 3}), frozenset({4, 5, 6})}
```

Set Syntax: Frozen Set

- Frozen sets can do everything regular sets can do, but they can't be modified

Set Syntax: Frozen Set

- Frozen sets can do everything regular sets can do, but they can't be modified
- We can, however, still use all the set operators

Set Syntax: Frozen Set

- Frozen sets can do everything regular sets can do, but they can't be modified
- We can, however, still use all the set operators

```
a = frozenset((1, 2, 3))
b = frozenset((1, 5, 6))
a ⊨ b
print(a)
```

Set Syntax: Frozen Set

- Frozen sets can do everything regular sets can do, but they can't be modified
- We can, however, still use all the set operators

```
a = frozenset((1, 2, 3))
b = frozenset((1, 5, 6))
a |= b
print(a)
```

```
frozenset({1, 2, 3, 5, 6})
```

Set Syntax: Mixing Set Types

- We can use both sets and frozen sets together, but we have to be careful in some places

Set Syntax: Mixing Set Types

- We can use both sets and frozen sets together, but we have to be careful in some places

```
a = frozenset((1, 2, 3))
b = {1, 4, 7}
print(a < b)
print(a | b)  # returns a frozen set
print(b | a)  # returns a set
```

Set Syntax: Mixing Set Types

- We can use both sets and frozen sets together, but we have to be careful in some places

```
a = frozenset((1, 2, 3))
b = {1, 4, 7}
print(a < b)
print(a | b)  # returns a frozen set
print(b | a)  # returns a set
```

```
False
frozenset({1, 2, 3, 4, 7})
{1, 2, 3, 4, 7}
```

Any Questions?