CHAPTER 1

SET THEORY

[Part 2: Operation on Set]

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Union

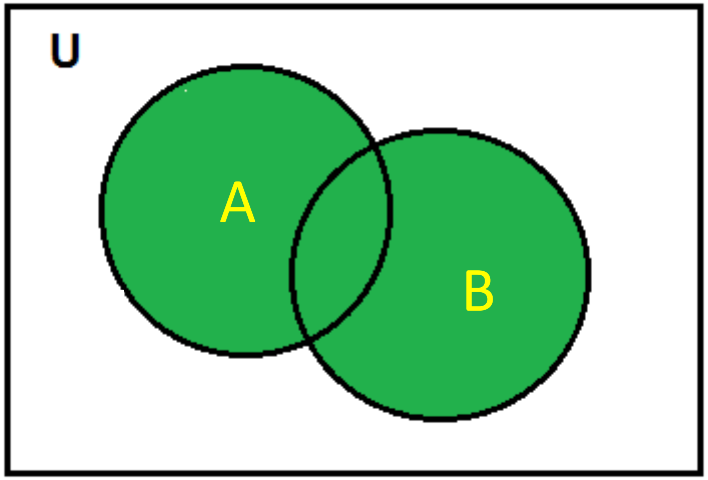
- The union of two sets A and B, denoted by $A \cup B$, is defined to be the set

$$A \cup B = \{ x \mid x \in A \text{ or } x \in B \}$$

- The union consists of all elements belonging to either A or B (or both)

Union

- Venn diagram of $A \cup B$



Example

$A=\{1, 2, 3, 4, 5\}$, $B=\{2, 4, 6\}$ and $C=\{8, 9\}$

$A \cup B =$ $\{1, 2, 3, 4, 5, 6\}$

$A \cup C =$ $\{1, 2, 3, 4, 5, 8, 9\}$

$B \cup C =$ $\{2, 4, 6, 8, 9\}$

$A \cup B \cup C =$ $\{1, 2, 3, 4, 5, 6, 8, 9\}$

- If A and B are finite sets, the cardinality of $A \cup B$,

$$|A \cup B| = |A| + |B| - |A \cap B|$$

Intersection

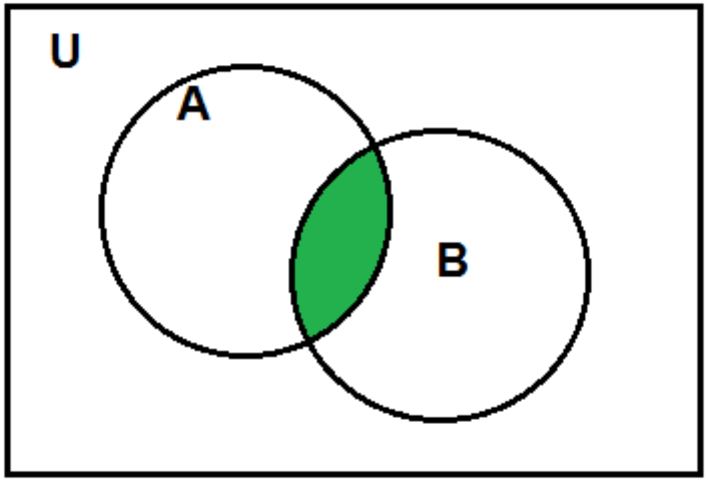
- The intersection of two sets A and B, denoted by $A \cap B$, is defined to be the set

$$A \cap B = \{ x \mid x \in A \text{ and } x \in B \}$$

- The intersection consists of all elements belonging to both A and B.

Intersection

- Venn diagram of $A \cap B$



Example

A={1, 2, 3, 4, 5, 6}, B={2, 4, 6, 8, 10} and
C={ 1, 2, 8, 10 }

$A \cap B$ = {2, 4, 6}

$A \cap C$ = {1, 2}

$C \cap B$ = {2, 8, 10}

$A \cap B \cap C$ = {2}

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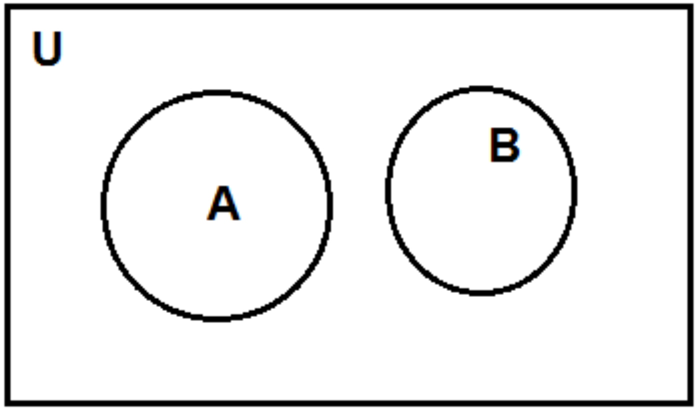
Disjoint

- Two sets *A* and *B* are said to be disjoint if,

$$A \cap B = \varnothing$$

Disjoint

- Venn diagram, $A \cap B = \varnothing$



Example

$A = \{1, 3, 5, 7, 9, 11\}$

$B = \{2, 4, 6, 8, 10\}$

$A \cap B = \varnothing$

Difference

- The set

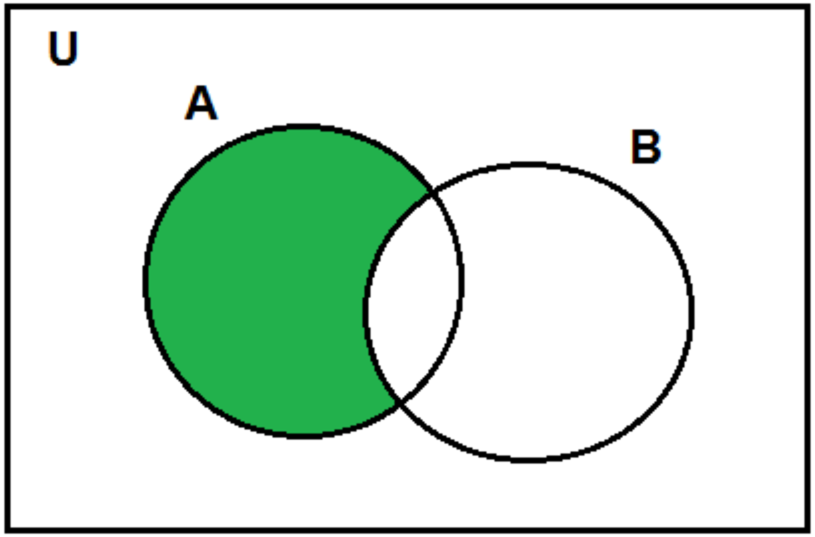
  $A - B = \{x \mid x \in A \text{ and } x \notin B\}$

  is called the **difference**.

- The difference $A - B$ consists of all elements in A that are not in B.

Difference

- Venn diagram of $A - B$



Example

$A = \{ 1, 2, 3, 4, 5, 6, 7, 8 \}$

$B = \{ 2, 4, 6, 8 \}$

$A - B = \{ 1, 3, 5, 7 \}$

Complement

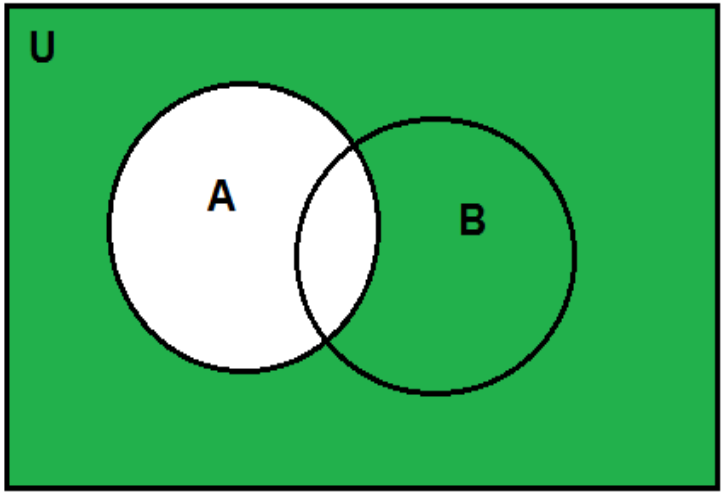
- The complement of a set A with respect to a universal set U, denoted by A' is defined to be

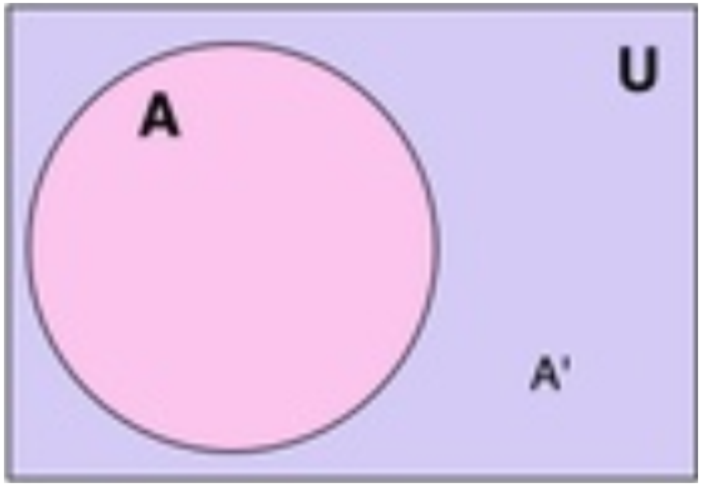
$$A' = \{x \in U \mid x \notin A\}$$

$$A' = U - A$$

Complement

Venn diagram of A'





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Example

Let U be a universal set,

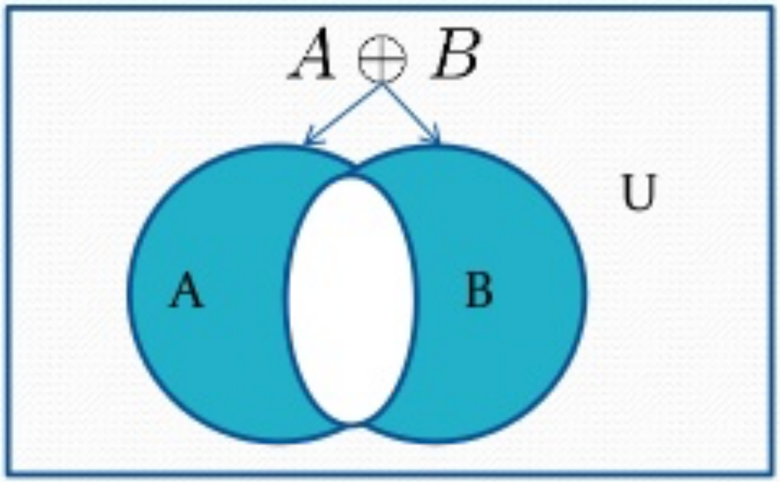
$U = \{ 1, 2, 3, 4, 5, 6, 7 \}$

$A = \{ 2, 4, 6 \}$

$A' = U - A = \{ 1, 3, 5, 7 \}$

Symmetric Difference

The symmetric difference of set *A* and set *B*, denoted by $A \oplus B$ is the set **$(A - B) \cup (B - A)$**



Venn Diagram

Example

$$U = \{0,1,2,3,4,5,6,7,8,9,10\}$$

$$A = \{1,2,3,4,5\};\ B = \{4,5,6,7,8\}$$

$$A \oplus B = (A - B) \cup (B - A) = \{1,2,3,6,7,8\}$$

B-A ={6,7,8}

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

Set Identities

(or Properties of Set)

Let all sets referred to below be subsets of a universal set *U*.

1. Commutative laws: For all sets A and B,

   a) $A \cap B = B \cap A$

   b) $A \cup B = B \cup A$

Set Identities (cont'd)

2) Associative laws: For all sets A, B and C,

a) $A \cap (B \cap C) = (A \cap B) \cap C$

b) $A \cup (B \cup C) = (A \cup B) \cup C$

Set Identities (cont'd)

3) Distributive laws: For all sets A, B and C,

a) $A \cup (B \cap C) = (A \cup B) \cap (A \cup C)$

b) $A \cap (B \cup C) = (A \cap B) \cup (A \cap C)$

Set Identities (cont'd)

4) Identity laws: For all sets A,

a) $A \cup \varnothing = A$

b) $A \cap U = A$

Set Identities (cont'd)

5) Complement laws: For all sets A,

a) $A \cap A' = \emptyset$

b) $A \cup A' = U$

6) Double Complement law: For all sets A,

$(A')' = A$

Set Identities (cont'd)

7) Idempotent laws: For all sets A,

a) $A \cup A = A$

b) $A \cap A = A$

8) Universal bound laws: For all sets A,

$(A')' = A$

Set Identities (cont'd)

9) De Morgan's laws:

a) $(A \cap B)' = A' \cup B'$

b) $(A \cup B)' = A' \cap B'$

Set Identities (cont'd)

10) Absorption laws: For all sets A and B,

a) $A \cup (A \cap B) = A$

b) $A \cap (A \cup B) = A$

Set Identities (cont'd)

11) Complements of U and $\varnothing$:

a) $\varnothing' = U$

b) $U' = \varnothing$

12) Set difference laws: For all sets A and B,

$$A - B = A \cap B'$$

Set Identities (cont'd)

13) Properties of empty set

$$A \cup \varnothing = A$$

$$A \cap \varnothing = \varnothing$$

Example

- Let A, B and C denote the subsets of a set S and let C' denote a complement of C in S.

- If $A \cap C = B \cap C$ and $A \cap C' = B \cap C'$, then prove that $A = B$

Example

Given: $A \cap C = B \cap C$ and $A \cap C' = B \cap C'$

Property (law) applied

$$
\begin{aligned}
A &= A \cap S && \text{[universal set]} \\
&= A \cap (C \cup C') && \text{[complement]} \\
&= (A \cap C) \cup (A \cap C') && \text{[distributive]} \\
&= (B \cap C) \cup (B \cap C') && \text{given conditions} \\
&= B \cap (C \cup C') && \text{[distributive law]} \\
&= B \cap S && \text{[universal set]} \\
&= B
\end{aligned}
$$

Example

By referring to the properties of set operations (Set Identities), show that:

$$A - (A \cap B) = A - B$$

Solution

From set identities: $A - B = A \cap B'$

	Property (law) applied
$A - (A \cap B) = A \cap (A \cap B)'$	[set difference laws]
$= A \cap (A' \cup B')$	[De Morgan's laws]
$= (A \cap A') \cup (A \cap B')$	[distributive laws]
$= \varnothing \cup (A \cap B')$	[complement laws]
$= (A \cap B') \cup \varnothing$	[commutative]
$= A \cap B'$	[Identity laws]
$= A - B$	

Generalized Unions and Intersections

The ***union*** of a collection of sets is the set that contains those elements that are members of at least one set in the collection.

Notation:

$$\bigcup_{i=1}^{n} A_i = A_1 \cup A_2 \cup \ldots \cup A_n = \{x \in U \mid x \in A_i \text{ for at least one } i = 0,1,2,.....,n\}$$

$$\bigcup_{i=1}^{\infty} A_i = A_1 \cup A_2 \cup \ldots \cup A_n = \{x \in U \mid x \in A_i \text{ for at least one nonnegative integer } i\}$$

Generalized Unions and Intersections

(cont'd)

The ***intersection*** of a collection of sets is the set that contains those elements that are members of all the sets in the collection.

Notation:

$$\bigcap_{i=1}^{n} A_i = A_1 \cap A_2 \cap \ldots \cap A_n = \{x \in U \mid x \in A_i \text{ for all } i = 0,1,2,\ldots .n\}$$

$$\bigcap_{i=1}^{\infty} A_i = A_1 \cap A_2 \cap \ldots \cap A_n = \{x \in U \mid x \in A_i \text{ for all nonnegative integer } i\}$$

Example

For i = 1, 2, ……, let $A_i = \{i, i+1, i+2, ...)$. Then,

$$\bigcup_{i=1}^{n} A_i = \bigcup_{i=1}^{n} \{i, i+1, i+2, ...\} = \{1, 2, 3, ...\},$$

and

$$\bigcap_{i=1}^{n} A_i = \bigcap_{i=1}^{n} \{i, i+1, i+2, ...\} = \{n, n+1, n+2, ...\} = A_n$$

Cartesian Product

- Let A and B be sets.
- An ordered pair of elements $a \in A$ dan $b \in B$ written (a, b) is a listing of the elements a and b in a specific order.
- The ordered pair (a, b) specifies that a is the first element and b is the second element.

- An ordered pair (a, b) is considered distinct from ordered pair (b, a), unless $a=b$.
- Example $(1, 2) \neq (2, 1)$

- The Cartesian product of two sets A and B, written $A \times B$ is the set,

$$A \times B = \{(a,b) \mid a \in A,\ b \in B\}$$

- For any set A,

$$A \times \emptyset = \emptyset \times A = \emptyset$$

Example

$A = \{a, b\}$, $B = \{1, 2\}$.

$A \times B = \{(a, 1), (a, 2), (b, 1), (b, 2)\}$

$B \times A = \{(1, a), (1, b), (2, a), (2, b)\}$

- if $A \neq B$, then $A \times B \neq B \times A$.
- if $|A| = m$ and $|B| = n$, then $|A \times B| = mn$.

Example

- $A = \{1, 3\}$, $B = \{2, 4, 6\}$.

$$A \times B = \{(1, 2), (1, 4), (1, 6), (3, 2), (3, 4), (3, 6)\}$$
$$B \times A = \{(2, 1), (2, 3), (4, 1), (4, 3), (6, 1), (6, 3)\}$$

$$A \neq B, \; A \times B \neq B \times A$$
$$|A| = 2, \; |B| = 3, \; |A \times B| = 2 \mathbf{x} 3 = 6$$

- The Cartesian product of sets $A_1, A_2, \ldots., A_n$ is defined to be the set of all *n*-tuples $(a_1, a_2, \ldots a_n)$ where $a_i \in A_i$ for $i=1,\ldots,n$;

- It is denoted $A_1 \times A_2 \times \ldots. \times A_n$

$$|A_1 \times A_2 \times \ldots. \times A_n| = |A_1|.|A_2| \ldots. |A_n|$$

Example

- $A = \{a, b\}$, $B = \{1, 2\}$, $C = \{x, y\}$

  $A \times B \times C = \{(a,1,x),(a,1,y), (a,2,x), (a,2,y), (b,1,x), (b,1,y), (b,2,x), (b,2,y)\}$

- $|A \times B \times C| = 2 \text{ x } 2 \text{ x } 2 = 8$

Exercise #1

- Let,

  $U = \{ a, b, c, d, e, f, g, h, i, j, k, l, m \}$

  $A = \{ a, c, f, m \}$

  $B = \{ b, c, g, h, m \}$

- Find:

  i) $A \cup B$ ii) $A \cap B$

  iii) $|A \cup B|$ iv) $A - B$ v) A'

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Exercise #2

Let the universal set, U={1, 2, 3, 4,…..,10}.

Let A={1, 4, 7, 10}, B={1, 2, 3, 4, 5} and C={2, 4, 6, 8}.

List the elements of each set:

a) U'

b) $B' \cap (C - A)$

c) $B - A$

d) $(A \cup B) \cup (C - B)$

e) $(A \cup B) \cap (C - B)$

Exercise # 3

- Let A, B and C be sets such that $A \cap B = A \cap C$ and $A \cup B = A \cup C$
- Prove that $B = C$

Exercise #4

Let A= {w, x}, B={1, 2} and C={KB, SD, PS}.

a) Determine the following set,

i) $A \times B$ ii) $B \times C$ iii) $A \times C$

iv) $A \times B \times C$

v) $B \times C \times A$

vi) $A \times B \times A \times C$

b) Find: $|A \times B|$; $|B \times C|$; $|A \times C|$; $|A \times B \times C|$;

$|B \times C \times A|$; $|A \times B \times A \times C|$