FOUNDATION OF MATHEMATICS I

CHAPTER TWO SETS THEORY

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Definition 2.2.12. Let A and B be subsets of a set X. The set $B - A$, called the **difference** of B and A, is the set of all elements in B which are not in A.
Thus,

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

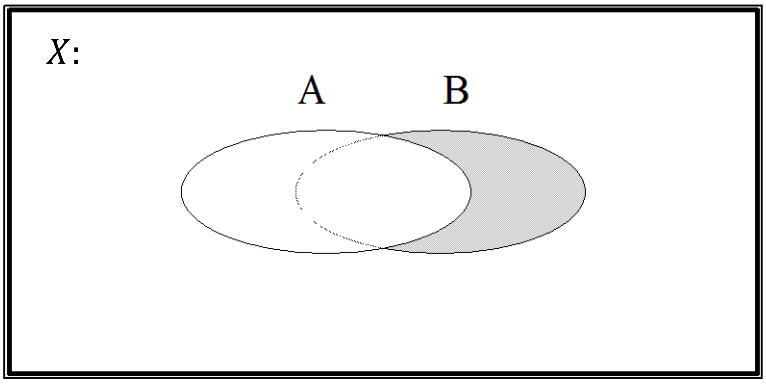
Example 2.2.13.

(i) Let $B = \{2,3,6,10,13,15\}$ and $A = \{2,10,15,21,22\}$.Then

$$B - A = \{3,6,13\}.$$

(ii) $\mathbb{Z} - \mathbb{Z}_o = \mathbb{Z}_e$.

(iii) Given that the box below represents X, the shaded area represents $B - A$.



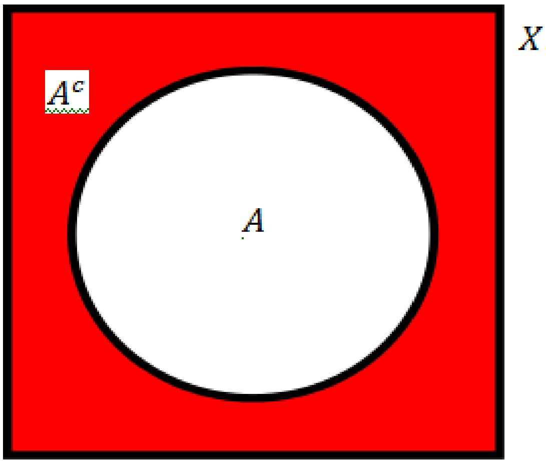
Theorem 2.2.14. Let A and B be subsets of a set X. Then

(i) $A - A = \emptyset$, $A - \emptyset = A$ and $\emptyset - A = \emptyset$

Definition 2.2.15. If $A \subseteq X$, then $X - A$ is called the **complement** of A with respect to X and denoted that by the symbol

$$X \backslash A \text{ or } A^c.$$

Thus, $A^c = \{x \in X \mid x \notin A\}$.



Theorem 2.2.16. Let A and B be subsets of a set X. Then

(i) $A^{cc} = A$.

(ii) $X^c = \emptyset$; $\emptyset^c = X$.

(iii) $A \cup A^c = X$, $A \cap A^c = \emptyset$ (Inverse Laws)

(iv) If $A \subseteq B$, then $B^c \subseteq A^c$.

(v) $A \cap B = \emptyset \Leftrightarrow A \subseteq B^c$.

Proof. Exercise.

Theorem 2.2.17. Let A and B be subsets of a set X. Then

(i) $\left.\begin{array}{l}(A \cup B)^c = A^c \cap B^c \\ (A \cap B)^c = A^c \cup B^c\end{array}\right\},$ (De Morgan's Law)

(ii) Let A and B be subsets of a set X. Then, $A - B = A \cap B^c$.

(iii) $A^c - B^c = B - A$.

Proof.

(i) Let $x \in (A \cup B)^c$

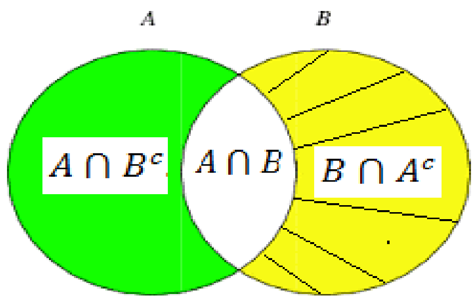
$\Leftrightarrow x \notin (A \cup B)$	Def. of complement
$\Leftrightarrow \sim(x \in A \cup B)$	Def. of $\notin$
$\Leftrightarrow \sim(x \in A \vee x \in B)$	Def. of A ∪ B
$\Leftrightarrow \sim(x \in A) \wedge \sim(x \in B)$	De Morgan's Law
$\Leftrightarrow x \notin A \wedge x \notin B$	Def of $\notin$
$\Leftrightarrow x \in A^c \wedge x \in B^c$	Def. of complement
$\Leftrightarrow x \in A^c \cap B^c$	Def. of ∩

Hence $(A \cup B)^c = A^c \cap B^c$.

(ii) $A - B = \{x \in X \mid x \in A \text{ and } x \notin B\}$

$= \{x \in X \mid x \in A \text{ and } x \in B^c\}$ Def. of complement of B^c

$= A \cap B^c$ Def. of complement intersection



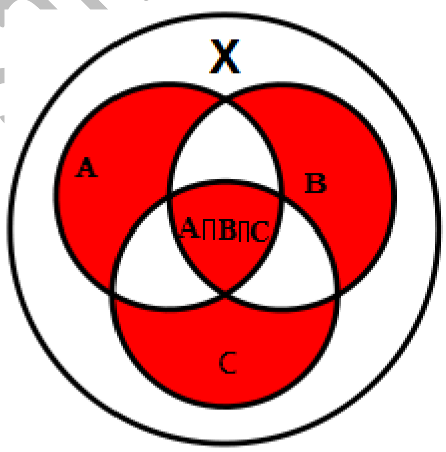
(iii) Exercise.

Definition 2.2.18. Let A and B be subsets of a set X. The set

$$A \triangle B = (A - B) \cup (B - A)$$

is called the **symmetric difference.**

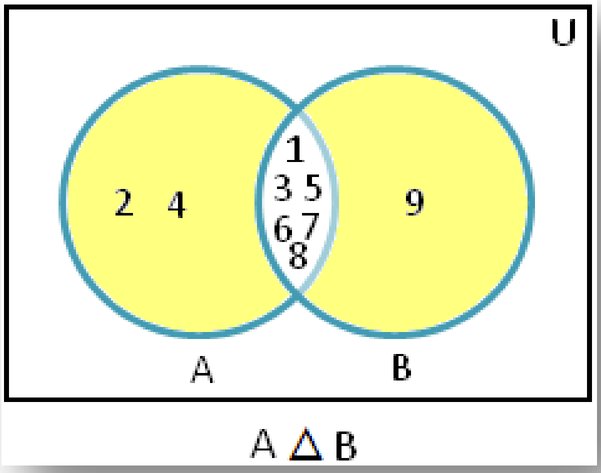
Sometimes the symbol $A \oplus B$ is used for symmetric difference.



Example 2.2.19. Let $A = \{1,2,3,4,5,6,7,8\}$ and $B = \{1,3,5,6,7,8,9\}$ are subsets of $U = \{1,2,3,4,5,6,7,8,9,10\}$.

$A - B = \{2,4\}$

$B - A = \{9\}$
$A \vartriangle B = (A - B) \cup (B - A) = \{2,4,9\}$.



Theorem 2.2.20. Let A, B and C are subsets of X. Then

(i) $A \vartriangle \emptyset = A$.
(ii) $A \vartriangle B = \emptyset \Leftrightarrow A = B$.
(iii) $A \vartriangle B = B \vartriangle A$.
(iv) $A \vartriangle A = \emptyset$.

Proof. Exercise.

Theorem 2.2.21. (Properties of $\cup$, $\cap$, $-$, $\vartriangle$ and $P(X)$)

(i) $A - (B \cap C) = (A - B) \cup (A - C)$ De Morgan's Low on $-$
$A - (B \cup C) = (A - B) \cap (A - C)$.
(ii) $A - (A \cap B) = (A - B) = (A \cup B) - B$
$A - (A \cup B) = \emptyset$.
(iii) $(A \cap B) - C = (A - C) \cap (B - C)$
$(A \cup B) - C = (A - C) \cup (B - C)$.
(iv) $(A - B) \cap (C - D) = (C - B) \cap (A - D)$.
(v) If $A \subseteq B$, then $P(A) \subseteq P(B)$.
(vi) $P(A \cap B) = P(A) \cap P(B)$.

(vii) $P(A) \cup P(B) \subseteq P(A \cup B)$. The converse is not true.
(viii) $A = B \Leftrightarrow P(A) = P(B)$.
(ix) $A \cap B = \emptyset \Leftrightarrow P(A) \cap P(B) = \emptyset$.
(x) $A \vartriangle B = (A \cup B) - (A \cap B)$.
(xi) $A \vartriangle (B \vartriangle C) = (A \vartriangle B) \vartriangle C$. Associative Law of $\vartriangle$
(xii) $A \vartriangle C = B \vartriangle C \implies A = B$.
(xiii) If $A \subseteq B$ and $C = B - A$, then $A = B - C$.
(xiv) $A \cap (B - C) = (A \cap B) - (A \cap C)$.
(xv) $(A - B) \cap (C - D) = (A \cap C) - (B \cup D)$.
(xvi) $A \cap (B \vartriangle C) = (A \cap B) \vartriangle (A \cap C)$. Dist. of $\cap$ on $\vartriangle$

Proof.
(i) $A - (B \cap C) = A \cap (B \cap C)^c$ Theorem 2.2.17(ii)
$= A \cap (B^c \cup C^c)$ De Morgan's Law
$= (A \cap B^c) \cup (A \cap C^c)$ Dist. Law
$= (A - B) \cup (A - C)$. Theorem 2.2.17(ii)

(vii) Let $H \in P(A) \cap P(B)$
$\implies H \in P(A) \wedge H \in P(B)$ Def. $\cap$
$\implies H \subseteq A \wedge H \subseteq B$ Def. of power set
$\implies H \subseteq (A \cap B)$ Def. $\cap$
$\implies H \in P(A \cap B)$ Def. of power set

(x) $x \in A \vartriangle B \Leftrightarrow x \in (A - B) \cup (B - A)$ Def. of $\vartriangle$
$\Leftrightarrow x \in (A - B) \vee (B - A)$ Def. $\cup$
$\Leftrightarrow (x \in A \wedge x \notin B) \vee (x \in B \wedge x \notin A)$ Def. of difference
$\Leftrightarrow (x \in A \vee x \in B) \wedge (x \notin B \vee x \in B)$ Dist. Law of
$\wedge$
$(x \in A \vee \notin A) \wedge (x \notin B \vee x \notin A)$

$\Leftrightarrow (x \in A \vee x \in B) \wedge T$ Tautology
$\wedge$
$T \wedge (x \notin B \vee x \notin A)$

$\Leftrightarrow x \in A \vee x \in B$ Identity Law of $\wedge$
$\wedge\ x \in B^c \vee x \in A^c$

$\Leftrightarrow$	$x \in (A \vee B)$ $\wedge$ $x \in (B^c \vee A^c)$	
$\Leftrightarrow$	$x \in (A \cup B)$ $\cap$ $x \in (B^c \cup A^c) = (A \cap B)^c$	Def. of ∪ and De Morgan's Law
$\Leftrightarrow$	$x \in (A \cup B) \cap (A \cap B)^c$	
$\Leftrightarrow$	$x \in (A \cup B) - (A \cap B)$	Theorem 2.2.17(ii)