Set Theory

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Contents

1 Definitions

1.1 Set

A *set* is a collection of unordered elements.

1.2 Cardinality

The *cardinality* of a set A, denoted $|A|$, is the amount of elements it contians.

1.3 Subset

If A and B are sets, then A is a *subset* of B ($A \subseteq B$), if all the elements of A are also in B.

For every set A, $A \subseteq A$.

1.4 Proper Subset

Given two sets A and B, if $A \subseteq B$ but $A \neq B$, then A is a *proper* (or *strict*) subset of B

$$A \subset B$$

1.5 Empty Set

The empty set $\emptyset$ is a subset of all other sets.

$$|\emptyset| = 0$$

For every set A

$$\emptyset \subseteq A$$

1.6 Power Set

If B is a set, then the *power set* $\mathcal{P}(B)$ is defined as the set of all subsets of B

$$\mathcal{P}(B) = \{A \mid A \subseteq B\}$$

Note that $B \in \mathcal{P}(B)$.

The cardinality of $\mathcal{P}(A)$ is given by

$$|\mathcal{P}(A)| = 2^{|A|}$$

1.7 Union

If A and B are sets, then their *union* is

$$A \cup B = \{x \mid x \in A \vee x \in B\}$$

1.8 Intersection

If A and B are sets, then their *intersection* is

$$A \cap B = \{x \mid x \in A \wedge x \in B\}$$

1.9 Difference

If A and B are sets, then their *difference* is

$$A \backslash B = \{x \,|\, x \in A \wedge x \notin B \vee x \in B \wedge x \notin A\}$$

Note that

$$A \backslash B = B \backslash A \iff A = B$$

1.10 Subset in terms of relationships

$$A \subseteq B \iff A \cup B = B \iff A \cap B = A \iff A \backslash B = \emptyset$$

1.11 Disjoint Sets

If A and B are sets and $A \cap B = \emptyset$, then A and B are disjoint sets.

1.12 Cartesian Product

If A and B are sets, then their *cartesian product* is

$$A \times B = \{(x, y) \,|\, x \in A \wedge y \in B\}$$

which is the set of all possible *ordered pairs*.

More generally, given n sets $A_1, A_2, \ldots, A_2$, their cartesian product $A_1 \times A_2 \times \cdots \times A_n$ is the set of ordered n-tuples $(a_1, a_2, \ldots, a_n)$ with $a_i \in A_i$.

1.13 Cartesian Power

Given a set A, $A^n = \underbrace{A \times A \times \cdots \times A}_{n}$.

The n-dimensional plane of real numbers is a cartesian power $\mathbb{R}^n$.

1.14 Complement

If A is a set, its *complement* is

$$\bar{A} = \{x \,|\, x \notin A\}$$

1.15 Binary Relation

If A and B are sets, a function $f : A \to B$ defines a *binary relation* R

$$R = \{(a, b) \,|\, f(a) = b\}$$

Note that $R \subseteq A \times B$

1.16 Injection

A function $f : A \to B$ is *injective* iff

$$\forall a, b \in A, f(a) = f(b) \implies a = b$$

1.17 Surjectivity

A function $f : A \to B$ is *surjectiv* iff

$$\forall b \in B \exists a \,|\, f(a) = b$$

1.18 Bijectivity

A function $f : A \to B$ is *bijective* iff it has a one-to-one correspondence between each element of A and B. Every bijection is both surjective and injective.

1.19 Reflexive relation

A binary relation R for $f : A \to A$ is *reflexive* iff

$$\forall a \in A, (a, a) \in R$$

1.20 Symmetric relation

A binary relation R for $f : A \to A$ is *symmetric* iff

$$\forall (a, b) \in R, (b, a) \in R$$

1.21 Transitive relation

A binary relation R for $f : A \to A$ is *transitive*

$$\forall a, b, c \in A, (a, b) \in R \wedge (b, c) \in R \implies (a, c) \in R$$

1.22 Equivalence relation

An *equivalence relation* is a binary relation $\sim$ on a set A that is

1. *Reflexive*: $\forall a \in A, a \sim a$
2. *Symmetric*: $\forall a, b \in A, a \sim b \iff b \sim a$
3. *Transitive*: $\forall a, b, c \in A, a \sim b \wedge b \sim c \implies a \sim c$

1.23 Equivalence class

Let $\sim$ be an equivalence relation on a set A. Given an element $a \in A$, the equivalence class of a, is defined as

$$[a]_\sim = \{x \in A \,|\, a \sim x\}$$

By the symmetric property we have $a \in [a]_\sim$.

Let $b \in [a]_\sim$, meaning $a \sim b$. $\forall c \in [b]_\sim$, meaning $b \sim c$, we have $a \sim c$ by the transitive property. Thus, $c \in [a]_\sim$ and $[b]_\sim \subseteq [a]_\sim$. By the symmetric property we also have $b \sim a$, $\forall d \in [a]_\sim$, meaning $a \sim d$, we have $b \sim d$ by the transitive property. Thus, $d \in [b]_\sim$ and $[a]_\sim \subseteq [b]_\sim$. Hence,

$$b \in [a]_\sim \implies [a]_\sim = [b]_\sim$$

This means that every element of an equivalence class has the same equivalence class. Thus, if two classes share an element they are the same

$$[a]_\sim \cap [b]_\sim \neq \emptyset \implies [a]_\sim = [b]_\sim$$