Logic and Set Theory

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0 Miscellaneous

Some introductory speech

1 Propositional logic

Let P denote a set of *primitive proposition*, unless otherwise stated, $P = \{p_1, p_2, ...\}$.

Definition. The *language* or *set of propositions* $L = L(P)$ is defined inductively by:
(1) $p \in L \; \forall p \in P$;
(2) $\perp \in L$, where $\perp$ is read as 'false';
(3) If $p, q \in L$, then $(p \implies q) \in L$. For example, $(p_1 \implies L)$, $((p_1 \implies p_2) \implies (p_1 \implies p_3))$.

Note that at this point, each proposition is only a finite string of symbols from the alphabet $(,), \implies, \perp, p_1, p_2, ...$ and do not really mean anything (until we define so).
By *inductively define*, we mean more precisely that we set $L_1 = P \cup \{\perp\}$, and $L_{n+1} = L_n \cup \{(p \implies q) : p, q \in L_n\}$, and then put $L = L_1 \cup L_2 \cup ....$

Each proposition is built up *uniquely* from 1) and 2) using 3). For example, $((p_1 \implies p_2) \implies (p_1 \implies p_3))$ came from $(p_1 \implies p_2)$ and $(p_1 \implies p_3)$. We often omit outer brackets or use different brackets for clarity.

Now we can define some useful things:
• $\neg p$ (not p), as an abbreviation for $p \implies L$;
• $p \vee q$ (p or q), as an abbreviation for $(\neg p) \implies q$;
• $p \wedge q$ (p and q), as an abbreviation for $(p \implies (\neg q))$.

These definitions 'make sense' in the way that we expect them to.

Definition. A *valuation* is a function $v : L \to \{0, 1\}$ s.t.
(1) $v(\perp) = 0$; (2)

$$v(p \implies q) = \begin{cases} 0 & v(p) = 1, v(q) = 0 \\ 1 & else \end{cases} \quad \forall p, q \in L$$

Remark. On $\{0, 1\}$, we could define a constant $\perp$ by $\perp = 0$, and an operation $\implies$ by $a \implies b = 0$ if $a = 1, b = 0$ and 1 otherwise. Then a valuation is a function $L \to \{0, 1\}$ that preserves the structure ($\perp$ and $\implies$), i.e. a homomorphism.