Harold's Philosophical Logic
Cheat Sheet

18 November 2026

Describes Classical Propositional and First-Order Logic only.

The 7 Basic Logical Symbols

Operator	Symbol	Example	English Example
1) Conjunction (AND)	$\wedge$, $\bullet$	A • B	• similar to $\bigcap$ intersection for sets • A and B • A, but B • despite the fact that A, B • even though A, B • although A, B • overlap
2) Disjunction (OR)	$\vee$, $+$	A ∨ B	• similar to $\bigcup$ union for sets • A or B • inclusive or • both combined
3) Negation (NOT)	~, $\bar{A}$	~A	• not A
4) Conditional	$\rightarrow$, $\supset$	A ⊃ B	• if A then B • if A, B • B if A • A implies B • A only if B • B in case that A • A is sufficient for B • B is necessary for A
5) Biconditional	↔, ⟷, **⟷**, ⇔, ⟺	p ⟷ q	• A iff B • A if and only if B • A is necessary and sufficient for B • if A then B, and conversely • if not A then not B, and conversely
(Equivalence)	≡	$\text{expression}_1 \equiv \text{expression}_2$	• Biconditional • is logically equivalent to • the two expressions always have the same truth value
6) Universal Quantifier	(x), $\forall x$	$(x)\ p(x)$	• for all • for any • for each
7) Existential Quantifier	$(\exists x)$	$(\exists x)\ p(x)$	• there exists • there is at least one

"… the structure of all mathematical statements can be understood using these symbols, and all mathematical reasoning can be analyzed in terms of the proper use of these symbols."
Source: "How to Prove It: A Structured Approach", 3rd Edition, p. 75.

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Logical Truth Tables

A	B	AND •	NOT AND ~•	OR ∨	NOT OR ~∨	XOR ⊻, ⊕	NOT XOR ⊙	NOT ~ (~A)	If … Then ⊃	Iff ≡	Taut-ology (True) T	Contra-diction (False) F
F	**F**	F	T	F	T	F	T	T	T	T	T	F
F	**T**	F	T	T	F	T	F	T	T	F	T	F
T	**F**	F	T	T	F	T	F	F	F	F	T	F
T	**T**	T	F	T	F	F	T	F	T	T	T	F

Blank Truth Tables

Inputs				Output		
A	**B**	**C**	**D**	**X**	**Y**	**Z**
F	**F**	**F**	**F**			
F	**F**	**F**	**T**			
F	**F**	**T**	**F**			
F	**F**	**T**	**T**			
F	**T**	**F**	**F**			
F	**T**	**F**	**T**			
F	**T**	**T**	**F**			
F	**T**	**T**	**T**			
T	**F**	**F**	**F**			
T	**F**	**F**	**T**			
T	**F**	**T**	**F**			
T	**F**	**T**	**T**			
T	**T**	**F**	**F**			
T	**T**	**F**	**T**			
T	**T**	**T**	**F**			
T	**T**	**T**	**T**			

Inputs			Output	
A	**B**	**C**	**X**	**Y**
F	**F**	**F**		
F	**F**	**T**		
F	**T**	**F**		
F	**T**	**T**		
T	**F**	**F**		
T	**F**	**T**		
T	**T**	**F**		
T	**T**	**T**		

Inputs		Output
A	**B**	**X**
F	**F**	
F	**T**	
T	**F**	
T	**T**	

Precedence Rules (PEMDAS for Logic) (used in this sheet)

#	Operator	Symbol	Precedence
1	**Parenthesis**	( )	Highest precedence. Used for scope.
2	**Logical NOT**	~	
3	**Quantifiers**	(x), $(\exists x)$	Depends on scope
4	**Logical AND**	•	Applied Left to Right
5	**Logical OR**	∨	Applied Left to Right
6	**Logical Conditional**	⊃	Parenthesize nested conditionals
7	**Logical Biconditional**	≡	Lowest precedence

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Logical Conditional Connective Laws

Law or Statement	Logical Expression	Is Equivalent To (≡)		Description
Antecedent / Consequent	If <Antecedent>, then <Consequent> . <Consequent> if <Antecedent> .			The Antecedent immediately follows the "if" statement. a.k.a. <Hypothesis> / <Conclusion>
Conditional Laws	$p \supset q$	≡	$\sim p \vee q$ $\sim(p \bullet \sim q)$ Logical Equivalences: $p \vee q \equiv \sim p \supset q$ $p \bullet q \equiv \sim(p \supset \sim q)$ $\sim(p \supset q) \equiv p \bullet \sim q$ $(p \supset q) \bullet (p \supset r) \equiv p \supset (q \bullet r)$ $(p \supset q) \vee (p \supset r) \equiv p \supset (q \vee r)$ $(p \supset r) \bullet (q \supset r) \equiv (p \vee q) \supset r$ $(p \supset r) \vee (q \supset r) \equiv (p \bullet q) \supset r$	Conditional, If ... Then, Implication
Biconditional Laws	$p \equiv q$ $p \leftrightarrow q$	≡	$(p \supset q) \bullet (q \supset p)$ $(p \supset q) \bullet (\sim p \supset \sim q)$ $(p \bullet q) \vee (\sim p \bullet \sim q)$ $\sim p \leftrightarrow \sim q$ Logical Equivalences: $\sim (p \leftrightarrow q) \equiv p \leftrightarrow \sim q$	Bi-conditional, If and only If, iff, XNOR Is equivalent to
(Equivalence)	$p \leftrightarrow q$ (can be true for one assignment)		$p \equiv q$ (must be true for every assignment)	Is logically equivalent to $(p \equiv \neg \neg p)$ Is equivalent to $p \equiv q$ exactly when $p \leftrightarrow q$ is a tautology
Converse*	$p \supset q$	≢	$q \supset p$	Not logically equivalent in general.
Inverse*		≢	$\sim p \supset \sim q$	

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Rules of Implication
(Inference with Propositions)

Rule Name	Rule Logic	English Example
Hypothesis	Givens. First lines of a proof.	It is raining today. You live in McKinney, Texas.
Therefore	$\therefore$	Therefore. In conclusion.
1) Modus Ponens (MP)	p $p \supset q$ $\therefore q$	It is raining today. If it is raining today, I will not ride my bike to school. Therefore, I will not ride my bike to school.
2) Modus Tollens (MT)	$\sim q$ $p \supset q$ $\therefore \sim p$	If Sam studied for his test, then Sam passed his test. Sam did not pass his test. Therefore, Sam did not study for his test.
3) Hypothetical Syllogism (HS) (Transitivity)	$p \supset q$ $q \supset r$ $\therefore p \supset r$	If you are mad, then you will yell. If you yell, then you will wake the baby. Therefore, if you are mad, then you will wake the baby.
4) Disjunctive Syllogism (DS) (Elimination)	$p \vee q$ $\sim p$ $\therefore q$	Sam studied for his test or Sam took a nap. Sam did not study for his test. Therefore, Sam took a nap.
5) Constructive Dilemma (CD)	$p \vee q$ $(p \supset r) \bullet (q \supset s)$ $\therefore r \vee s$	Oscar is either a dog or a cat. If Oscar is a dog, then you'll have fleas, and if Oscar is a cat, then you'll have fur balls. Therefore, you'll have either fleas or fur balls.
6) Simplification (Simp) (Specialization)	$p \bullet q$ $\therefore p$	It is rainy today, and it is windy today. Therefore, it is rainy today.
7) Conjunction (Conj)	p q $\therefore p \bullet q$	Sam studied for his test. Sam passed his test. Sam studied for his test and passed his test.
8) Addition (Add) (Generalization)	p $\therefore p \vee q$	It is raining today. Therefore, it is either raining today, snowing today, or both.
Resolution	$p \vee q$ $\sim p \vee r$ $\therefore q \vee r$	Your shirt is red, or your pants are blue. Your shirt is not red, or your shoes are white. Therefore, your pants are blue, or your shoes are white.

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Proof by Division into Cases	$\begin{array}{l} p \vee q \\ p \supset r \\ q \supset r \\ \hline \therefore r \end{array}$	It is raining, or it is Monday. It is raining, so it is wet. It is Monday, so it is wet. It is wet.
Contradiction Rule	$\begin{array}{l} \sim p \supset F \\ \hline \therefore p \end{array}$	If "it is not raining" is false, then it is raining.

Rules of Replacement

(Logical Connective Laws / Equivalences / Inference)

Law	"Or" Example	"And" Example
9) De Morgan's rule (DM) (Propositional Logic)	p ∨ q ≡ ~(~p • ~q) ~(p ∨ q) ≡ ~p • ~q (p ∨ ~q) ⊃ r ≡ ~r ⊃ (~p • q)	p • q ≡ ~ (~p ∨ ~q) ~(p • q) ≡ ~p ∨ ~q (p • ~q) ⊃ r ≡ ~r ⊃ (~p ∨ q)
10) Commutative (Com)	p ∨ q ≡ q ∨ p	p • q ≡ q • p
11) Associative (Assoc)	(p ∨ q) ∨ r ≡ p ∨ (q ∨ r)	(p • q) • r ≡ p • (q • r)
12) Distributive (Dist)	p • (q ∨ r) ≡ (p • q) ∨ (p • r)	p ∨ (q • r) ≡ (p ∨ q) • (p ∨ r)
13) Double Negations (DN) (Involution Law)	~ ~p ≡ p	
14) Transposition (Trans) (Contrapositive)	(p ⊃ q) ≡ (~q ⊃ ~p)	
15) Material Implication (Impl)	(p ⊃ q) ≡ (~p ∨ q)	
16) Material Equivalence (Equiv)	(p ≡ q) ≡ [(p • q) ∨ (~p • ~q)]	(p ≡ q) ≡ [(p ⊃ q) • (q ⊃ p)]
17) Exportation (Exp)		[(p • q) ⊃ r] ≡ [p ⊃ (q ⊃ r)]
18) Tautology (Taut) (Idempotent)	p ≡ (p ∨ p)	p ≡ (p • p)
Identity	p ∨ F ≡ p	p • T ≡ p
Domination or Null (Universal Bound Laws)	p ∨ T ≡ T	p • F ≡ F
Negation or Complement (Complementary Laws)	p ∨ ~p ≡ T ~F ≡ T	p • ~p ≡ F ~T ≡ F
Uniting	(p • q) ∨ (p • ~q) ≡ p	(p ∨ q) • (p ∨ ~q) ≡ p
Absorption	p ∨ (p • q) ≡ p	p • (p ∨ q) ≡ p
Multiplication and Factoring Laws	(p ∨ q) • (~p ∨ r) ≡ (p • r) ∨ (~p • q)	(p • q) ∨ (~p • r) ≡ (p ∨ r) • (~p ∨ q)
Consensus	(p • q) ∨ (q • r) ∨ (~p • r) ≡ (p • q) ∨ (~p • r)	(p ∨ q) • (q ∨ r) • (~p ∨ r) ≡ (p ∨ q) • (~p ∨ r)
Exclusive Or (⊕)	p ⊕ q ≡ [(p ∨ q) • ~(p • q)]	p ⊕ q ≡ [(~p • q) ∨ (p • ~q)]

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Proof Methods

Method	Definition
Direct (DP)	• Assume the hypothesis (antecedent) is true, then use logical steps to arrive at the conclusion (consequent). • Assume p is true, then conclude q.
Indirect (IP) (Contradiction)	• Assume the opposite of what you want to prove, then show this leads to a contradiction. • To prove p, assume ~p and derive a contradiction, such as ~q • q. • If some statement is assumed true, and a logical contradiction occurs, then the statement must be false. • Technique: Assume ~(p ⊃ q), which is equivalent to p • ~q. • Assumption for Indirect Proof (AIP)
Conditional (CP)	• Assume a hypothesis (antecedent) is temporarily true to derive a conclusion (consequent). • After discharging an assumption, statements that depend on it cannot be used outside that subproof. • Assume p, derive q; conclude p ⊃ q. • The goal is not to prove p is true in reality, but to prove that **if** p were true, then q would necessarily follow. • Assumption for Conditional Proof (ACP)
Contrapositive	• Similar to Modus Tollens. • To prove p ⊃ q, assume ~q, derive ~p, and discharge the assumption to obtain ~q ⊃ ~p; then use Transposition.
Construction (Example)	• The construction of a concrete example with a property to show that something having that property exists. • AKA proof by example.
Exhaustion / By Cases	• The conclusion is established by dividing it into a finite number of cases and proving each one separately.
Induction	• A single "base case" is proved, and an "induction rule" is proved that establishes that any arbitrary case implies the next case. • Prove $P(n_0)$. Then prove $P(k) \rightarrow P(k+1)$ for an arbitrary integer $k \geq n_0$. Conclude $P(n)$ for every integer $n \geq n_0$.

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Proof Examples with Solutions

Indirect Proof	Logical Solution Steps	Rules
Given: 1. $(N \vee O) \supset (C \bullet D)$ 2. $(D \vee K) \supset (P \vee \sim C)$ 3. $(P \vee G) \supset \sim(N \bullet D)$ **Prove:** $\sim N$	1. $(N \vee O) \supset (C \bullet D)$ 2. $(D \vee K) \supset (P \vee \sim C)$ 3. $(P \vee G) \supset \sim(N \bullet D)$ 4. N 5. $N \vee O$ 6. $C \bullet D$ 7. $D \bullet C$ 8. D 9. $D \vee K$ 10. $P \vee \sim C$ 11. C 12. $\sim C \vee P$ 13. $\sim\sim C$ 14. P 15. $P \vee G$ 16. $\sim(N \bullet D)$ 17. $\sim N \vee \sim D$ 18. $\sim\sim N$ 19. $\sim D$ 20. $D \bullet \sim D$ 21. $\sim N$	Given Given Given AIP 4, Add 1, 5, MP 6, Com 7, Simp 8, Add 2, 9, MP 6, Simp 10, Com 11, DN 12, 13, DS 14, Add 3, 15, MP 16, DM 4, DN 17, 18, DS 8, 19, Conj 4-20, IP

Conditional Proof	Logical Solution Steps	Rules
Given: 1. $Q \supset (R \supset S)$ 2. $Q \supset (T \supset \sim U)$ 3. $U \supset (R \vee T)$ **Prove:** $Q \supset (U \supset S)$	1. $Q \supset (R \supset S)$ 2. $Q \supset (T \supset \sim U)$ 3. $U \supset (R \vee T)$ 4. Q 5. U 6. $R \supset S$ 7. $T \supset \sim U$ 8. $\sim\sim U$ 9. $\sim T$ 10. $R \vee T$ 11. $T \vee R$ 12. R 13. S 14. $U \supset S$ 15. $Q \supset (U \supset S)$	Given Given Given ACP ACP 1, 4 MP 2, 4, MP 5, DN 7, 8, MT 3, 5, MP 10, Com 9, 11, DS 6, 12, MP 5-13, CP 4-14, CP

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Logical Quantifiers

Definition	Logical Expression	Is Equivalent To (≡)	English Example
Universal Quantifier (*x*)	$(x)\ Px$ *(x), if x is in* $\mathbb{D}$ *then* Px	"For all *x* in the domain, P*x* is true" $(x)\ (x \in \mathbb{D} \supset Px)$ For the finite set domain of discourse $\{a_1, a_2, \ldots, a_k\}$, $(x)\ Px \equiv Pa_1 \bullet Pa_2 \bullet \ldots \bullet Pa_k$	• for all • all elements • for each member • any • anyone • anything • every • everyone • everybody • everything • *x* could be anything at all • whoever • none but • only <plural noun>[1] • the only (pronoun>[1] • no … except <plural noun>[1]
Existential Quantifier (∃*x*)	$(\exists x)\ Px$	"There exists *x* in the domain such that P*x* is true" For the finite set domain of discourse $\{a_1, a_2, \ldots, a_k\}$, $(\exists x)\ Px \equiv Pa_1 \vee Pa_2 \vee \ldots \vee Pa_k$ $(\exists x)\ (x \in \mathbb{D} \bullet Px)$ $\{x \in \mathbb{D}: Px\} \neq \emptyset$	• there exists an *x* • there is • some • someone • somebody • something • at least one value of *x* • there is at least one *x* • the truth set is not equal to ∅
Uniqueness Quantifier (∃!)	$\exists!x\ Px$	"Exactly one *x* in the domain satisfying P*x*" $(\exists x)\ [Px \bullet \sim(\exists y)\ (Py \bullet y \neq x)]$ $(\exists x)\ [Px \bullet (y)\ (Py \supset y = x)]$ $(\exists x)\ (y)\ (Py \equiv y = x)$ $(\exists x)\ Px \bullet (y)\ (z)\ ((Py \bullet Pz) \supset y = z)$	• unique • there is a unique *x* • there exists exactly one • there is exactly one *x* in the domain for which *P(x)* is true
Negated Quantifiers	$\sim(\exists x)\ Px$	$(x)\ \sim Px$	• nobody • no one • not one • there does not exist
	$\sim(x)\ Px$	$(\exists x)\ \sim Px$	• not everyone

[1]Requires attention to the direction of the conditional.

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Quantifier Logic Examples

Quantifier	Symbolic Translations	English Example
Everyone	$(x)\ Px$	• Everyone is <something>.
	$(x)\ (y)\ Pxy$ NOTE: includes $(x = y)$	• Everyone <did something> to everyone.
Everyone Else	$(x)\ (x \neq a \supset Px) \bullet \sim Pa$	• Everyone except <someone> is <something>.
	$(x)\ (y)\ ((x \neq y) \supset Pxy)$ NOTE: excludes $(x = y)$	• Everyone <did something> to everyone else.
Not Every	$\sim(x)\ (Ax \supset Bx)$	• It is not the case that every <something> <did something>.
	$(\exists x) \sim Px$	• Not every <something> <did something>.
Someone Else	$(\exists x)\ (x \neq a \bullet Px)$	• Someone other than <someone> is <something>.
	$(x)\ (\exists y)\ ((x \neq y) \bullet Pxy)$ NOTE: excludes $(x = y)$	• Everyone <did something> to <someone> else.
Exactly One	$\exists !x\ Px$	• Exactly one person <did something>.
	$(\exists x)\ [Px \bullet (y)\ ((x \neq y) \supset \sim Py)]$	
No One	$\sim(\exists x)\ Px$	• No one <did something>.
	$(x)\ \sim Px$	

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Rules of Inference with Quantifiers

Rule Name	Rule Logic	Necessary Qualification	English Example
Variables	***x***: Quantified variable		The domain is the set of all integers.
Elements	***c, d***: Elements of the domain, arbitrary or particular		*c* is a particular integer. Element definition.
Universal Instantiation (UI)	*c* is an element (arbitrary or particular) (*x*) P*x* ∴ P*c*	Substitute consistently for the variable's free occurrences within the quantified formula. Avoid variable capture.	Sam is a student in the class. Every student in the class completed the assignment. Therefore, Sam completed his assignment.
Universal Generalization (UG)	*c* is an arbitrary element P*c* ∴ (*x*) P*x*	The instance must concern an arbitrary individual. Its derivation must not depend on a premise or undischarged assumption that singles out that individual.	All psychiatrists are doctors. All doctors are college graduates. Therefore, all psychiatrists are college graduates. 1. (*x*) (P*x* ⊃ D*x*) Given 2. (*x*) (D*x* ⊃ C*x*) Given 3. P*x* ⊃ D*x* 1, UI 4. D*x* ⊃ C*x* 2, UI 5. … 6. P*x* ⊃ C*x* 7. ∴ (*x*) (P*x* ⊃ C*x*) 6, UG
Existential Instantiation (EI)	(∃*x*) P*x* ∴ P*c* (*c* is a fresh witness name or a particular element)	Introduce a fresh witness name. Use a previously unused name. Do not assume the witness is identical to—or distinct from—any named individual without justification.	All attorneys are college graduates. Some attorneys are golfers. Therefore, some golfers are college graduates. i.e., If an object is known to exist, then that object can be given a name.
Existential Generalization (EG)	*c* is an element (arbitrary or particular) P*c* ∴ (∃*x*) P*x*	Generalize from a legitimate instance, avoiding variable capture.	All tenors are singers. Andrea Bocelli is a tenor. Therefore, there is at least one singer. 1. (*x*) (T*x* ⊃ S*x*) Given 2. T*a* Given 3. T*a* ⊃ S*a* 1, UI 4. S*a* 2,3, MP 5. ∴ (∃*x*) S*x* 4, EG

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Quantifier Translation Hints

Statement Form	Symbolic Translation	English Example
A B	$Ax \bullet Bx$	Pretty girl.
Either A or B	$Ax \vee Bx$	Rachel is a journalist or a newscaster.
	$(Ax \bullet \sim Bx) \vee (\sim Ax \bullet Bx)$	Rachel is either a journalist or a newscaster, but not both. (XOR)
Neither A nor B	$\sim Ax \bullet \sim Bx$	Neither Wordsworth nor Shelley was Irish. $\sim I(w) \bullet \sim I(s)$
A is B	Se	Eli is a student.
Anything is A	$(x)\ Ax$	Anything is conceivable.
All A are B	$(x)\ (Ax \supset Bx)$	All maples are trees. Sea lions are mammals.
Some A are B	$(\exists x)\ (Ax \bullet Bx)$	Some grapes are sour.
Some A are not B	$(\exists x)\ (Ax \bullet \sim Bx)$	Some grapes are not sour.
A exist	$(\exists x)\ Ax$	Tigers exist.
A do not exist	$\sim(\exists x)\ Ax$ $(x)\ \sim Ax$	Unicorns do not exist.
No A are B	$(x)\ (Ax \supset \sim Bx)$ $\sim(\exists x)\ (Ax \bullet Bx)$	No novels are biographies.
Not a single A did B	$(x)\ (Ax \supset \sim Bx)$ $\sim(\exists x)\ (Ax \bullet Bx)$	Not a single psychologist attended the convention.
Whoever is A is B	$(x)\ (Ax \supset Bx)$	Whoever is a socialite is vain.
Some A B iff C	$(\exists x)\ (Ax \bullet (Bx \leftrightarrow Cx))$	Some dogs bite if and only if they are teased.
Some A B are C	$(\exists x)\ [(Ax \bullet Bx) \bullet Cx]$	Some French restaurants are exclusive.
A B are C	$(x)\ [(Ax \bullet Bx) \supset Cx]$	Ripe apples are delicious.
A and B are C D	$(x)\ [(Ax \vee Bx) \supset (Cx \bullet Dx)]$	Violins and cellos are stringed instruments.
Only i is F.	$Fi \bullet (x)\ [Fx \supset (x = i)]$	Only Sally is running.
The only F that is G is i.	$Fi \bullet Gi \bullet (x)\ [(Fx \bullet Gx) \supset (x = i)]$	The only student who is running is Sally.
No F except i is G.		No student except Sally is running.
All F except i are G.	$Fi \bullet \sim Gi \bullet (x)\ [(Fx \bullet (x \neq i)) \supset Gx]$	All students except Billy are on time.
i is the F that is most/more so-and-so.	$Fi \bullet (x)\ [(Fx \bullet (x \neq i)) \supset i$ is more so-and-so than $x]$	Rex is the dog that is more loved than the rest.
There is at most one F.	$(x)\ (y)\ [(Fx \bullet Fy) \supset (x = y)]$	There is at most one moon.
There are at least two F's.	$(\exists x)\ (\exists y)\ [Fx \bullet Fy \bullet (x \neq y)]$	There are at least two moons.
There are exactly two F's.	$(\exists x)\ (\exists y)\ \{ Fx \bullet Fy \bullet (x \neq y) \bullet (z)\ [Fz \supset ((z = x) \vee (z = y))] \}$	There are exactly two moons.
The F is G.	$(\exists x)\ [Fx \bullet (y)\ (Fy \supset (y = x)) \bullet Gx]$	The moon is bright.

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Quantifier Laws

Definition	Logical Expression	Is Equivalent To (≡)		English Example
Abbreviation	$(x)\ (x \in A \supset Px)$	≡	$((x) \in A)\ Px$	Simplification
	$(\exists x)\ (x \in A \bullet \sim Px)$	≡	$(\exists x \in A)\ \sim Px$	
Expanding Abbreviation	$(x) \in A\ Px$	≡	$(x)\ (x \in A \supset Px)$	Complication
1) Quantifier Negation Laws (QN)	$(x)\ Px$	≡	$\sim(\exists x)\ \sim Px$	• Everyone is perfect. • No one is imperfect.
	$(\exists x)\ Px$	≡	$\sim(x)\ \sim Px$	• Somebody is perfect. • Not everyone is imperfect.
	$\sim(x)\ Px$	≡	$(\exists x)\ \sim Px$	• Not everyone is perfect. • Someone is imperfect.
	$\sim(\exists x)\ Px$	≡	$(x)\ \sim Px$	• No one is perfect. • Everybody is imperfect.
2) Conditional Law (like ACP)	$x \in A \supset Px$	≡	$x \notin A \vee Px$	$p \supset q \equiv \sim p \vee q$
3) Membership Negation (Subset Negation Law)	$x \in A$ $x \subseteq A$	≡	$\sim(x \notin A)$ $\sim(x \not\subseteq A)$	Negate, then swap ∈ with ∉, or vice versa. Negate, then swap ⊆ with ⊈, or vice versa.
4) De Morgan's Law (Quantifier Negation)	$\sim(x)\ Px$	≡	$(\exists x)\ \sim Px$	De Morgan's Law for a single quantifier
	$\sim(\exists x)\ Px$	≡	$(x)\ \sim Px$	
	$\sim(x)\ (y)\ Pxy$	≡	$(\exists x)\ (\exists y)\ \sim Pxy$	De Morgan's Law for nested quantifiers
	$\sim(x)\ (\exists y)\ Pxy$	≡	$(\exists x)\ (y)\ \sim Pxy$	
	$\sim(\exists x)\ (y)\ Pxy$	≡	$(x)\ (\exists y)\ \sim Pxy$	
	$\sim(\exists x)\ (\exists y)\ Pxy$	≡	$(x)\ (y)\ \sim Pxy$	
5) Nested / Multiple-Quantified Statements	$(x)\ (y)\ Pxy$	≡	$(y)\ (x)\ Pxy$	• for all objects x and y, …
	$(\exists x)\ (\exists y)\ Pxy$	≡	$(\exists y)\ (\exists x)\ Pxy$	• there are objects x and y such that …
	$(x)\ (\exists y)\ Pxy$	≢	$(\exists x)\ (y)\ Pxy$	Not equivalent in general. Counterexample for $x, y \in \mathbb{Z}$: $(x)\ (\exists y)\ (x + y = 0) \equiv$ True $(\exists x)\ (y)\ (x + y = 0) \equiv$ False
	$\sim((x)\ (\exists y)\ Pxy)$	≡	$(\exists x)\ (y)\ \sim Pxy$	Negation of multiple quantified statements
	$\sim((\exists x)\ (y)\ Pxy)$	≡	$(x)\ (\exists y)\ \sim Pxy$	
6) Moving Quantifiers	$(x)\ (Px \supset (\exists y)\ Qxy)$	≡	$(x)\ (\exists y)\ (Px \supset Qxy)$	You can move a quantifier left subject to the condition stated below.

Note: Moving a quantifier requires the variable not to occur **free** in the crossed formula and must avoid variable capture.

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Valid Quantifier Formulas

A	Direction	B
$(x)\ (Px \bullet Qx)$	≡	$(x)\ Px \bullet (x)\ Qx$
$(\exists x)\ (Px \bullet Qx)$	→	$(\exists x)\ Px \bullet (\exists x)\ Qx$
$(x)\ (Px \vee Qx)$	←	$(x)\ Px \vee (x)\ Qx$
$(\exists x)\ (Px \vee Qx)$	≡	$(\exists x)\ Px \vee (\exists x)\ Qx$
$(x)\ (Px \supset Qx)$	←	$(\exists x)\ Px \supset (x)\ Qx$
$(\exists x)\ (Px \supset Qx)$	≡	$(x)\ Px \supset (\exists x)\ Qx$
$(x)\ {\sim}Px$	≡	${\sim}(\exists x)\ Px$
$(\exists x)\ {\sim}Px$	≡	${\sim}(x)\ Px$
$(x)\ (\exists y)\ Txy$	←	$(\exists y)\ (x)\ Txy$
$(y)\ (\exists x)\ Txy$	←	$(\exists x)\ (y)\ Txy$
$(x)\ (y)\ Txy$	≡	$(y)\ (x)\ Txy$
$(\exists x)\ (\exists y)\ Txy$	≡	$(\exists y)\ (\exists x)\ Txy$
$(x)\ (Px \vee R)$	≡	$(x)\ Px \vee R$
$(\exists x)\ (Px \bullet R)$	≡	$(\exists x)\ Px \bullet R$
$(x)\ (Px \supset R)$	≡	$(\exists x)\ Px \supset R$
$(\exists x)\ (Px \supset R)$	→	$(x)\ Px \supset R$
$(x)\ (R \supset Qx)$	≡	$R \supset (x)\ Qx$
$(\exists x)\ (R \supset Qx)$	→	$R \supset (\exists x)\ Qx$
$(x)\ R$	←	R
$(\exists x)\ R$	→	R

Note: The above formulas are valid in classical first-order logic, assuming that *x* does not occur free in *R*. The arrows → and ← are the directions of the displayed valid implications.

Invalid Quantifier Formulas

A	Direction	B	Counterexample
$(\exists x)\ (Px \bullet Qx)$	←	$(\exists x)\ Px \bullet (\exists x)\ Qx$	D = {a, b}, M = {Pa, Qb}
$(x)\ (Px \vee Qx)$	→	$(x)\ Px \vee (x)\ Qx$	D = {a, b}, M = {Pa, Qb}
$(x)\ (Px \supset Qx)$	→	$(\exists x)\ Px \supset (x)\ Qx$	D = {a, b}, M = {Pa, Qa}
$(x)\ (\exists y)\ Txy$	→	$(\exists y)\ (x)\ Txy$	D = {a, b}, M = {Tab, Tba}
$(\exists x)\ (Px \supset R)$	←	$(x)\ Px \supset R$	D = Ø, M = {R}
$(\exists x)\ (R \supset Qx)$	←	$R \supset (\exists x)\ Qx$	D = Ø, M = Ø
$(x)\ R$	→	R	D = Ø, M = Ø
$(\exists x)\ R$	←	R	D = Ø, M = {R}

Notes:

- M lists the true atomic statements; unlisted atomic statements are false.
- The first four implication domains are nonempty.
- The last four implications fail only when empty domains are allowed. They are valid when the domain is nonempty.

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Sources

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See Also

- Harold's Logic (Mathematics) Cheat Sheet
- Harold's Logic (Philosophy) Cheat Sheet
- Harold's Boolean Algebra Cheat Sheet
- Harold's Proofs Cheat Sheet
- Harold's Sets Cheat Sheet

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