COMP 410 Lecture 1

Kyle Dewey

About Me

- I research automated testing techniques and their intersection with CS education
- My dissertation used logic programming extensively
- This is my third time teaching this class

About this Class

- See something wrong? Want something improved? Email me about it! (kyle.dewey@csun.edu)
- I generally operate based on feedback

Bad Feedback

- This guy sucks.
- This class is boring.
- This material is useless.

Good Feedback

- This guy sucks, *I can't read his writing.*
- This class is boring, *it's way too slow.*
- This material is useless, *I don't see how it relates to anything in reality.*

- I can't fix anything if I don't know what's wrong

What is Logic Programming?

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- What, not how

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- What, not how
- No mutable state

What is Logic Programming?

- What, not how
- No mutable state
- Basis in formal logic
  - = means =

What is Logic Programming?

- What, not how
- No mutable state
- Basis in formal logic
  - = means =
- Line between input/output is blurry

What is this Course?

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- Programming, programming, programming

What is this Course?

- Programming, programming, programming
- Thinking in a logic programming way

What is this Course?

- Programming, programming, programming
- Thinking in a logic programming way
- Applying logic programming without a logic programming language

What this course **isn't**

What this course **isn't**

- Artificial intelligence

What this course **isn't**

- Artificial intelligence
- Machine learning

What this course **isn't**

- Artificial intelligence
- Machine learning
- Theoretical

Syllabus

Outline

- Abstract Syntax Trees and evaluation
- SAT and Semantic Tableau

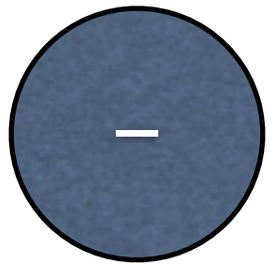
Abstract Syntax Trees and Evaluation

Abstract Syntax Tree

- Abbreviation: AST
- Unambiguous tree-based representation of a sentence in a language
- Very commonly used in compilers, interpreters, and related software

$$(1 + 2) - 3 * 4$$

(1 + 2) − 3 * 4



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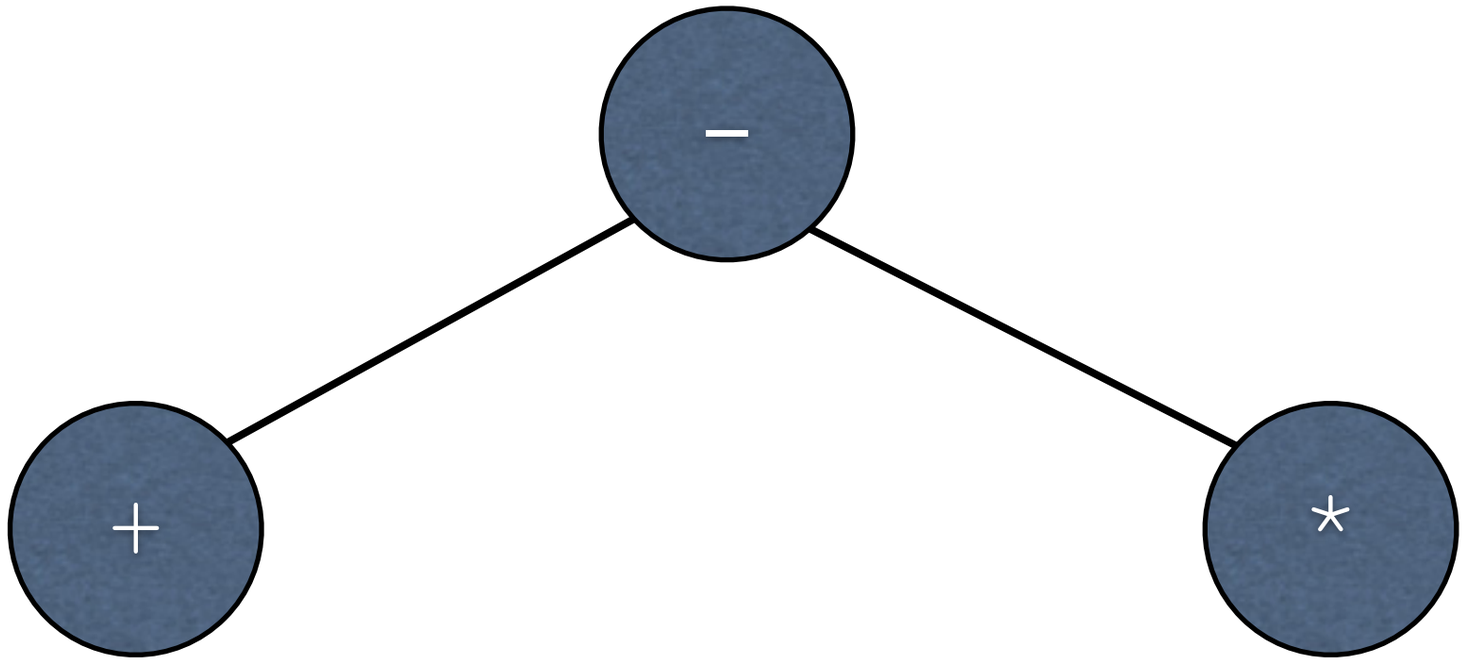

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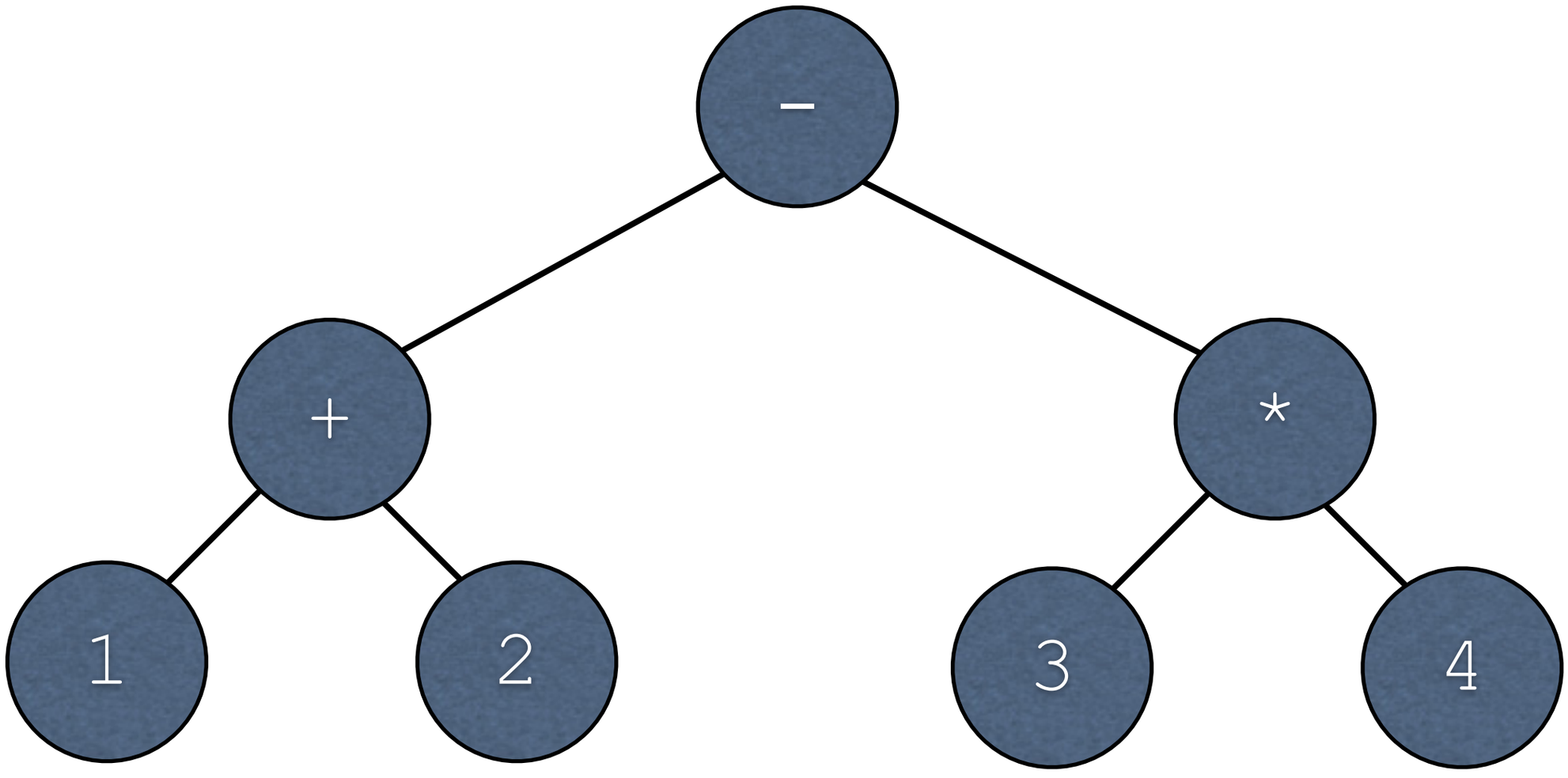
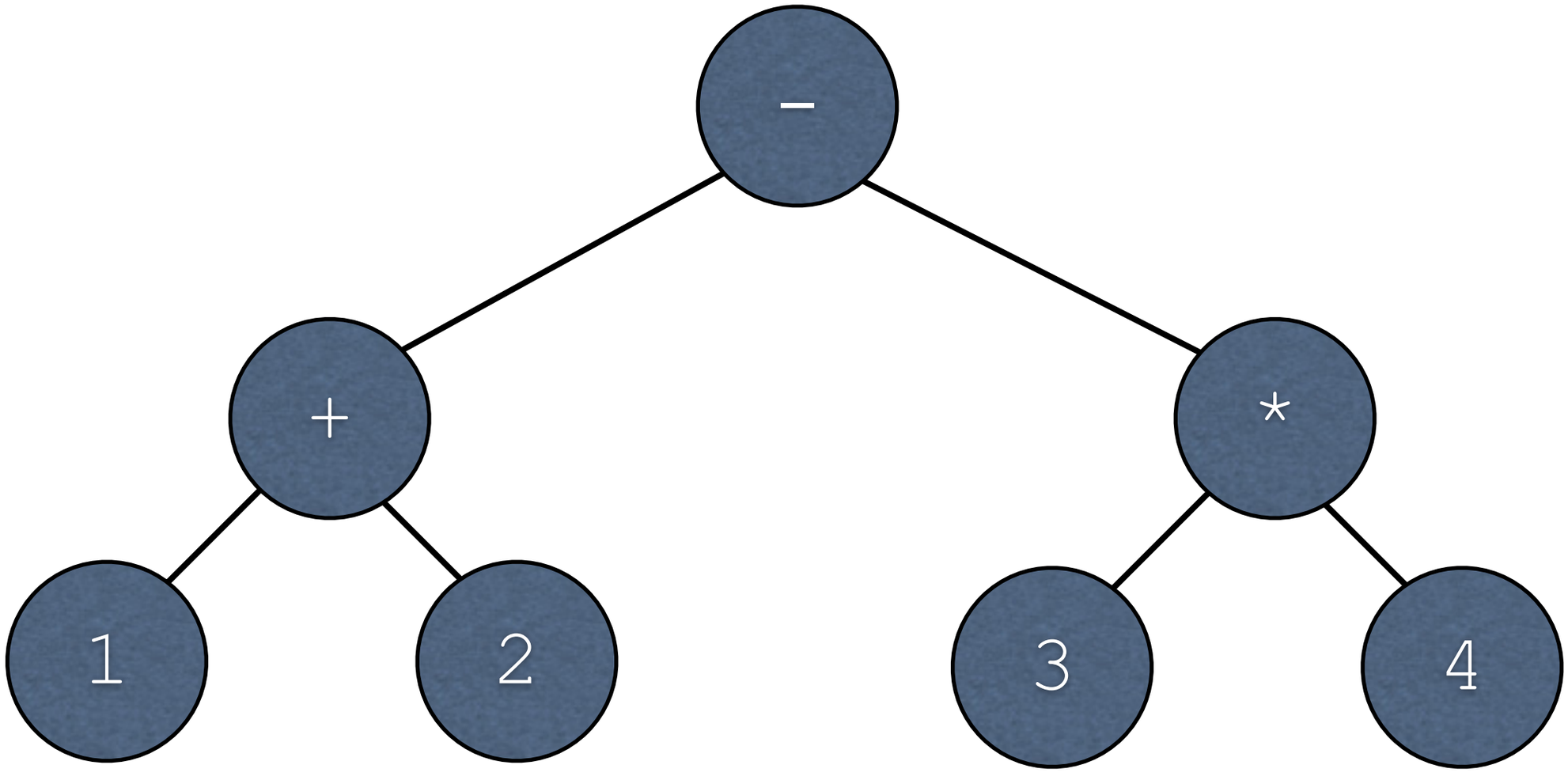


Exercise: First Side of AST/Evaluation Sheet

Evaluation



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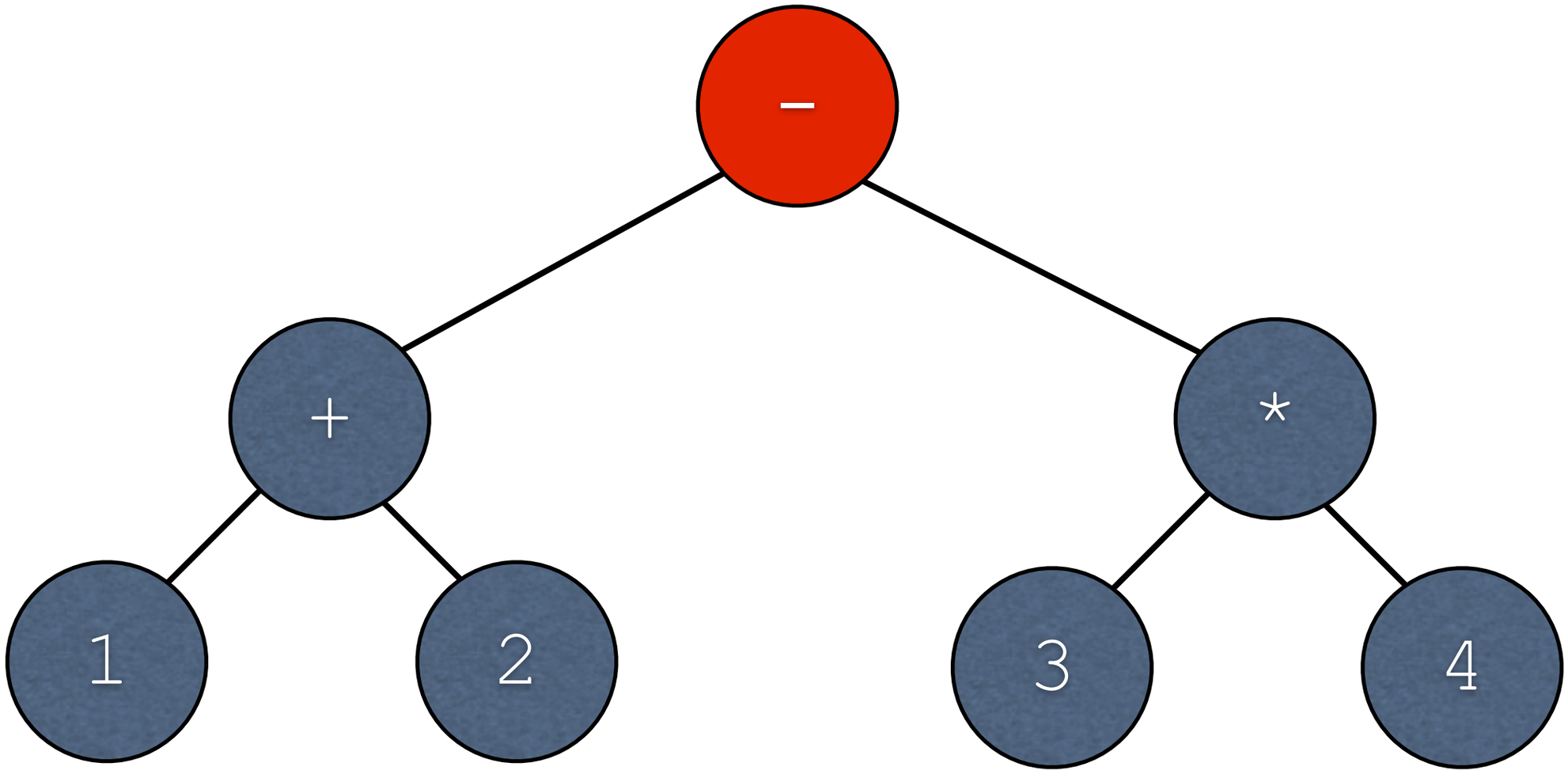

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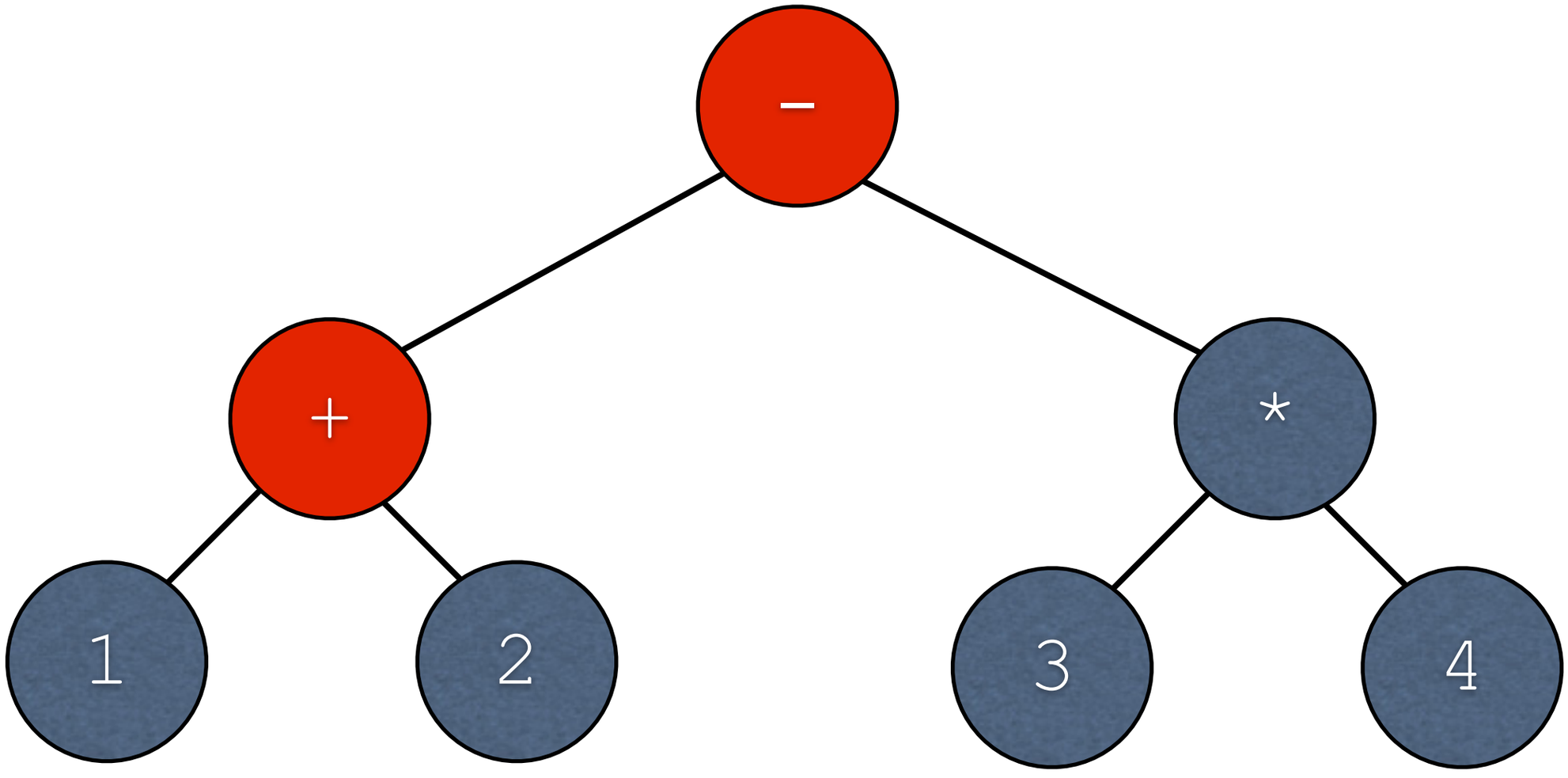

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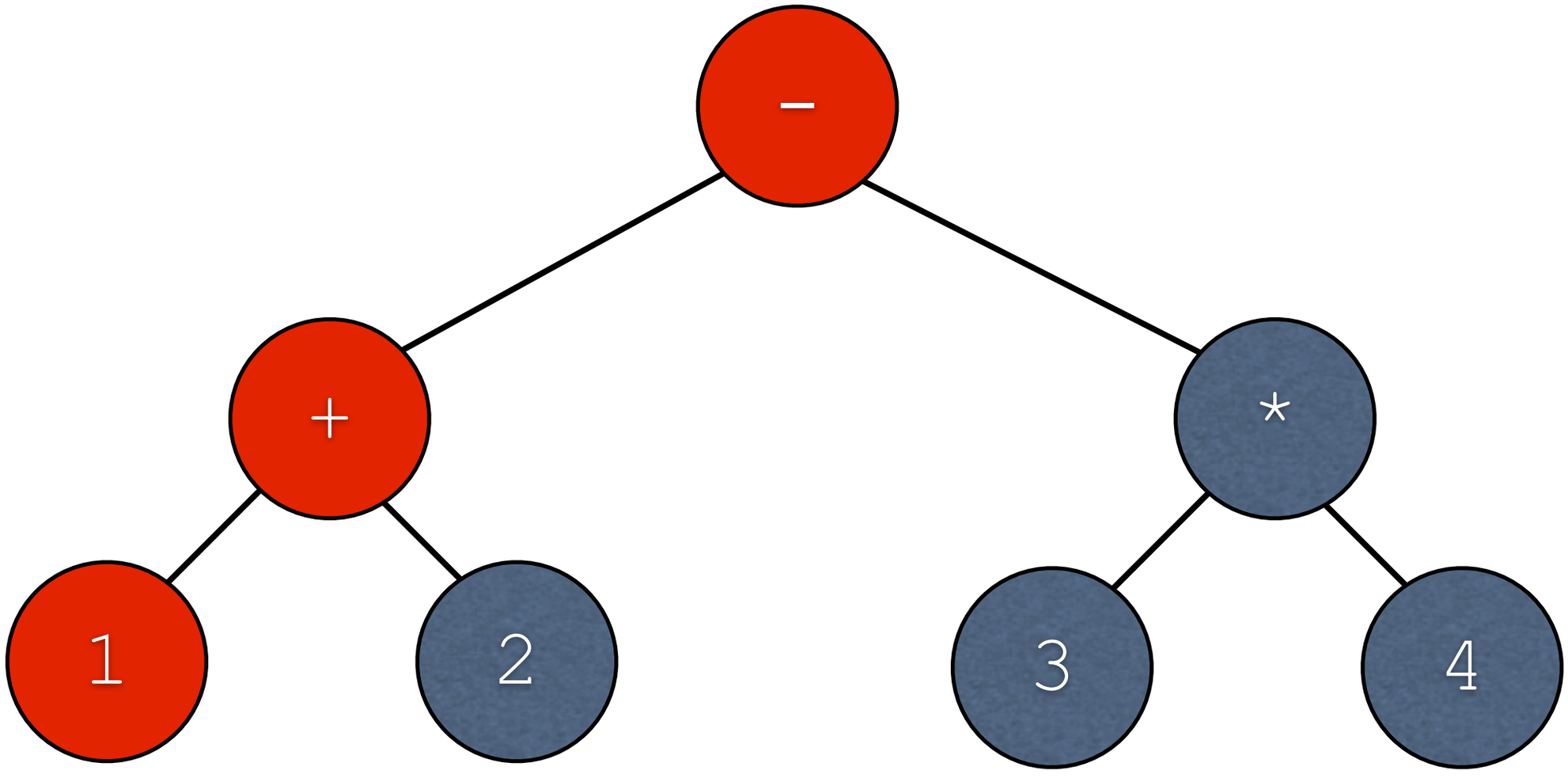

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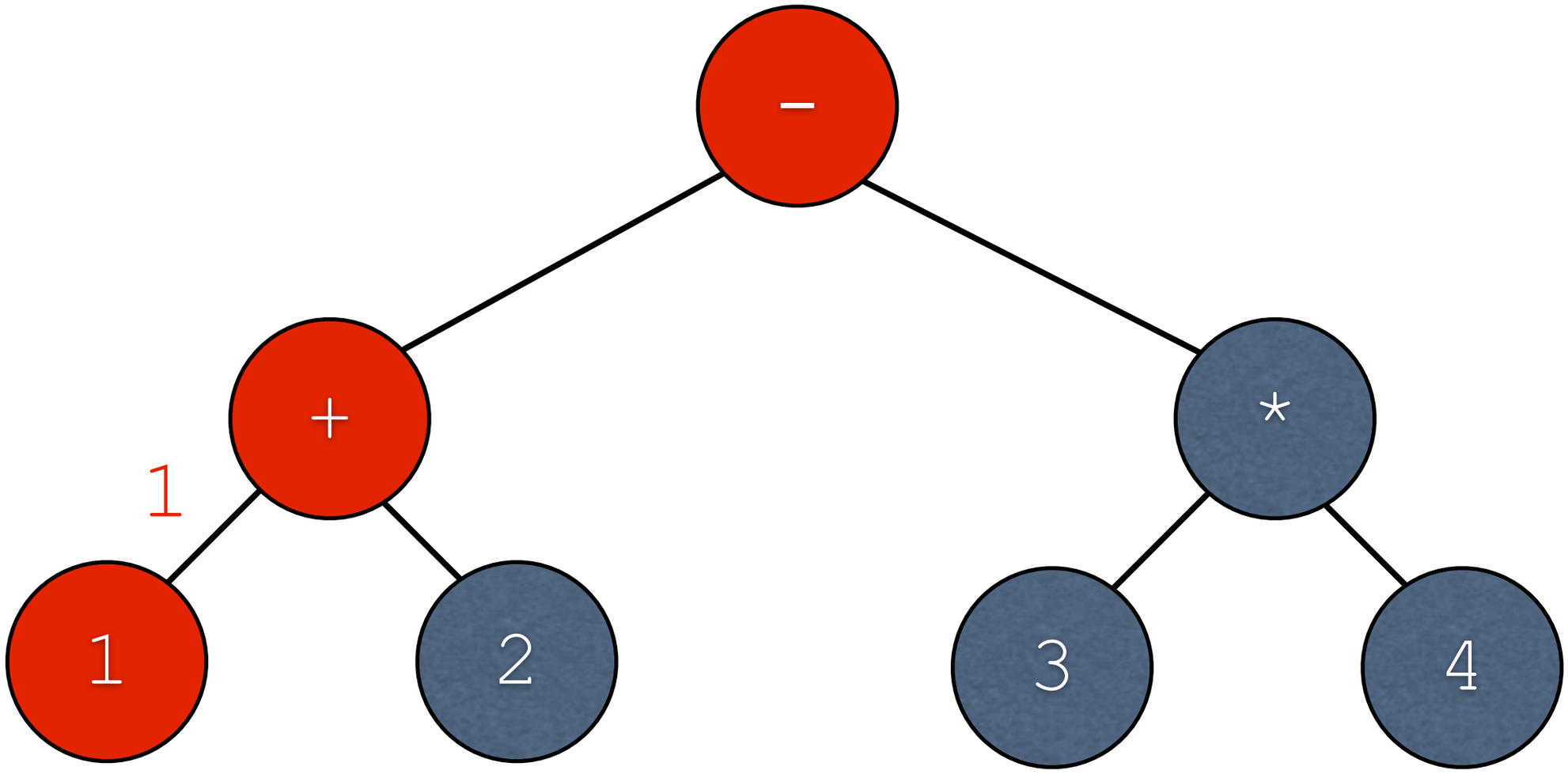

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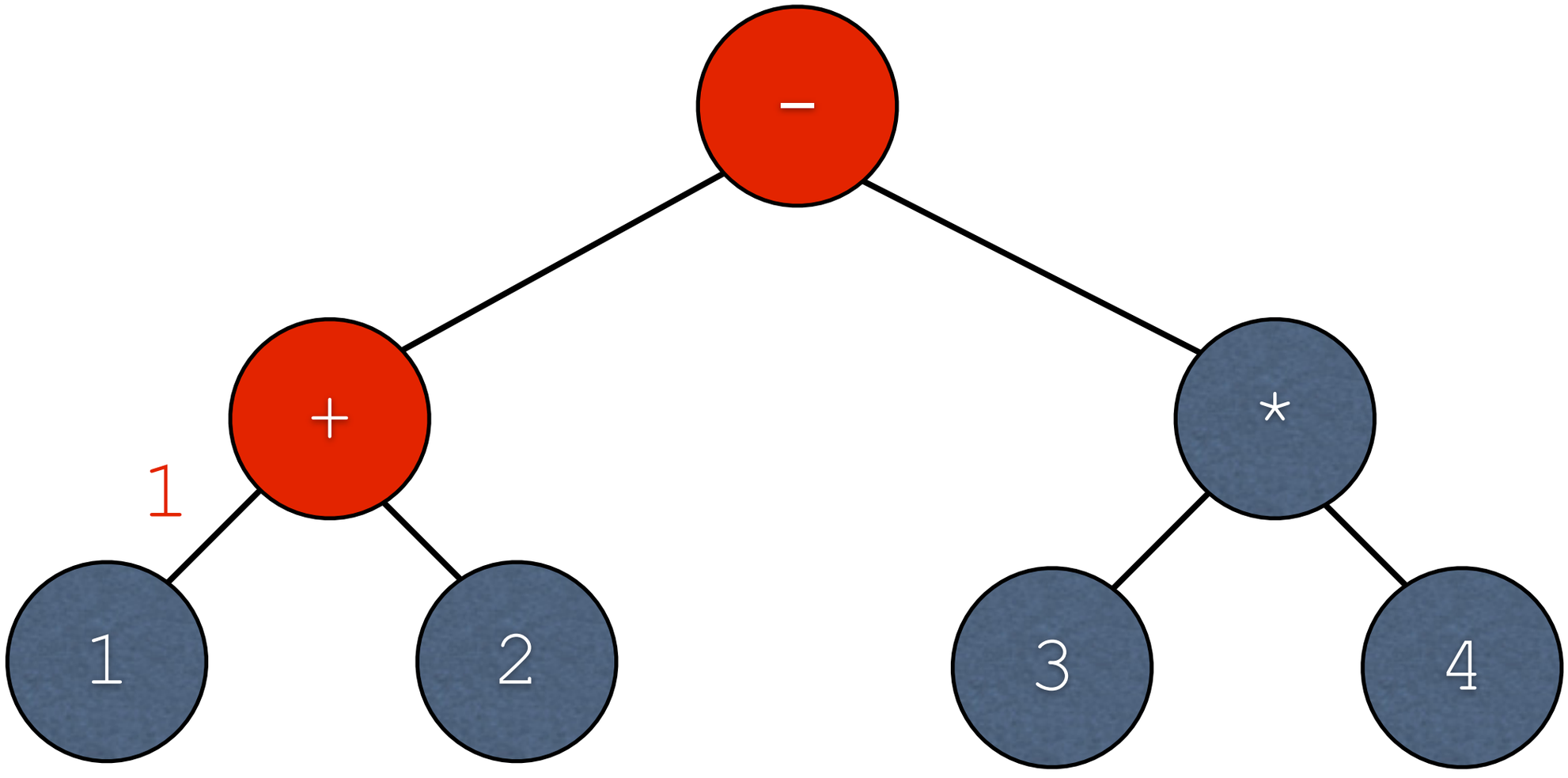

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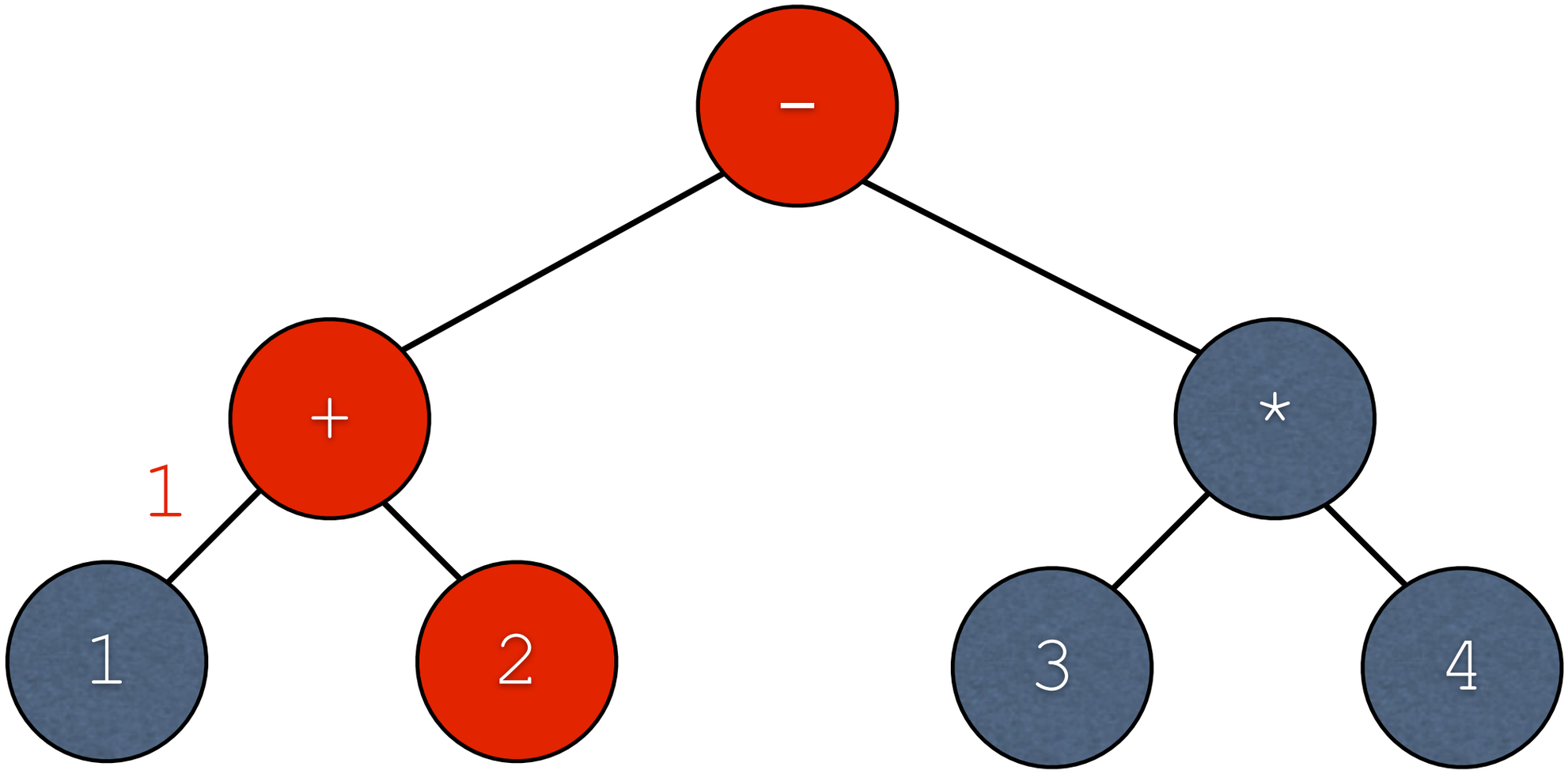

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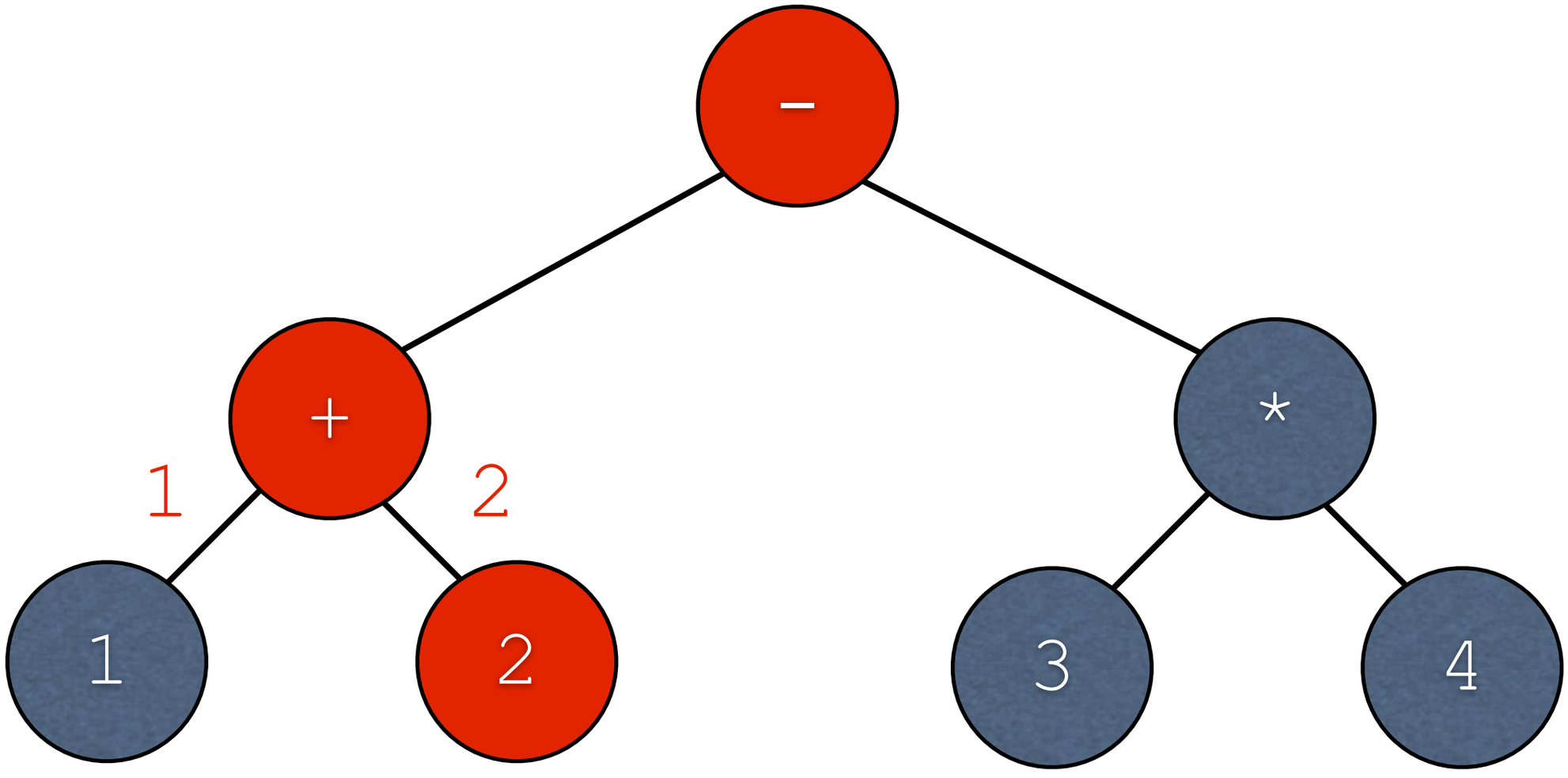

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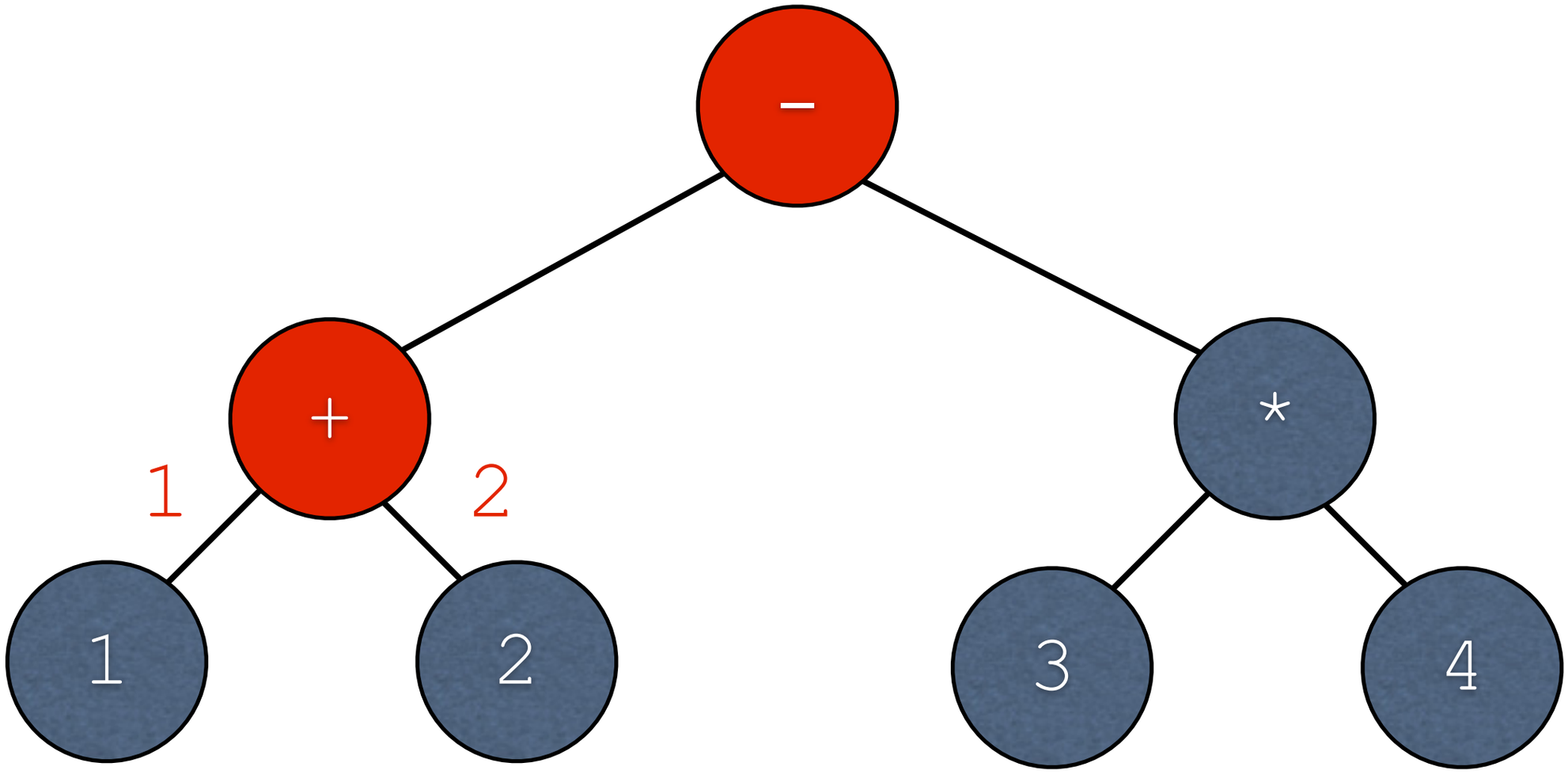

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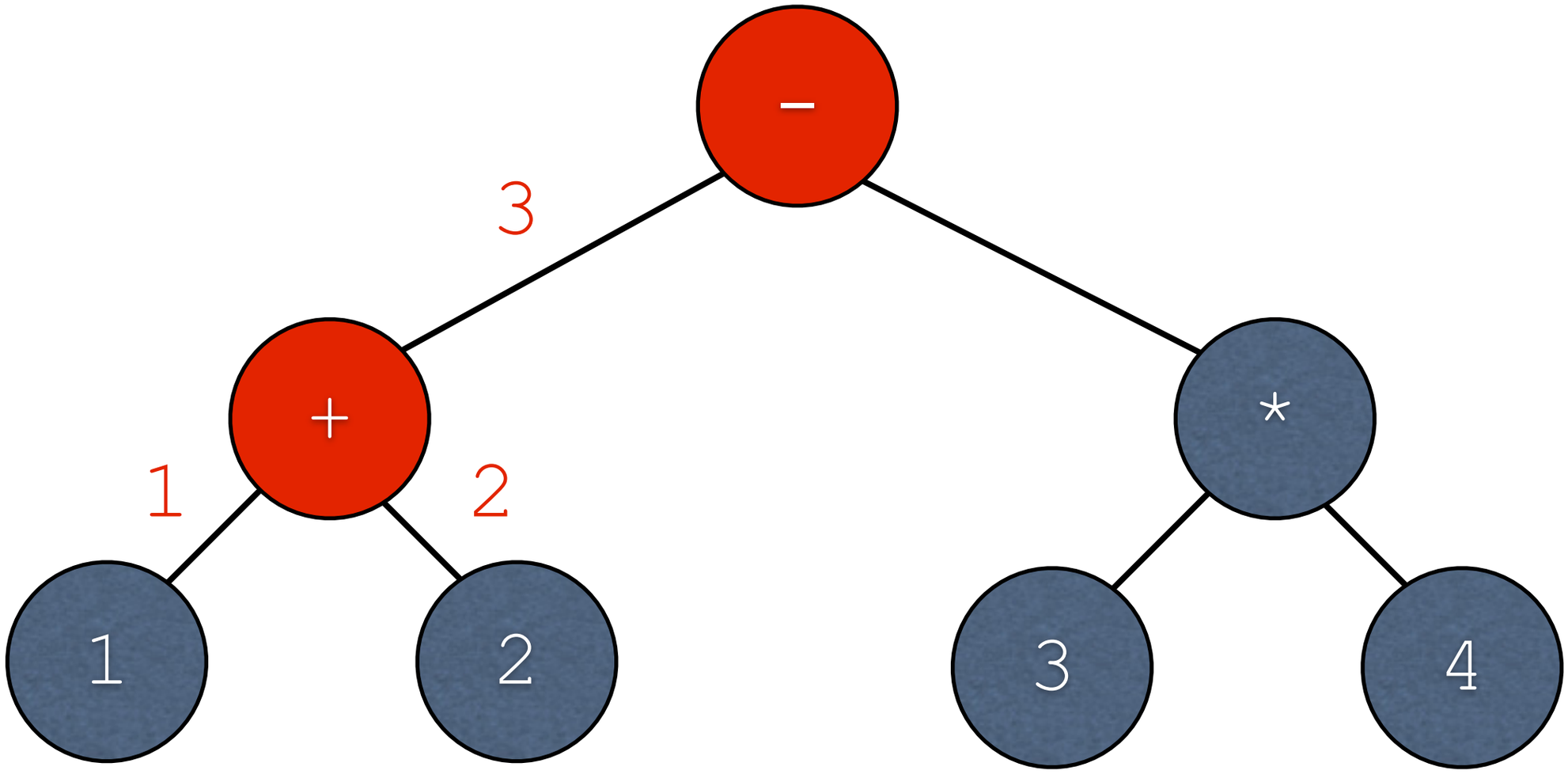

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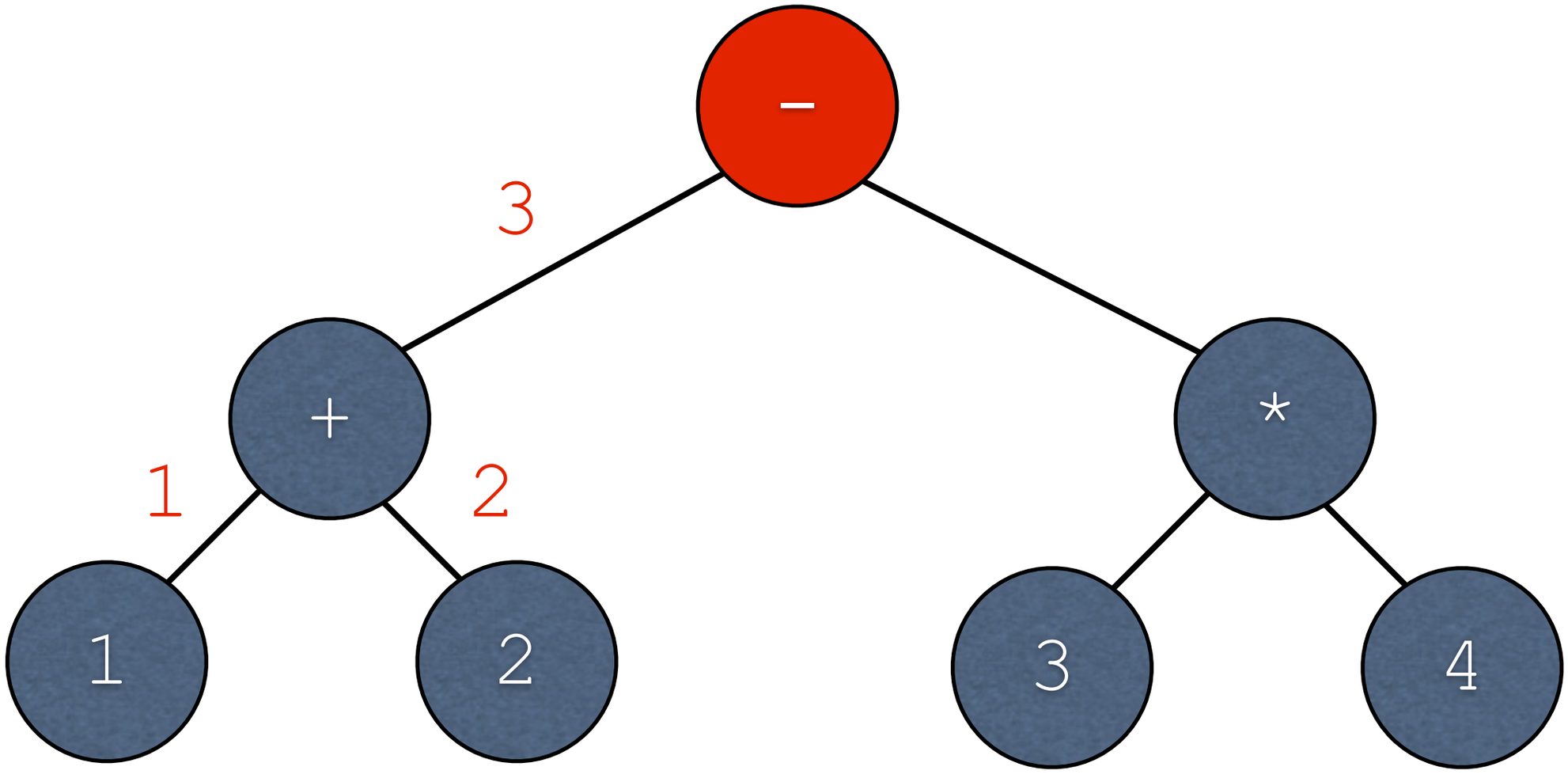

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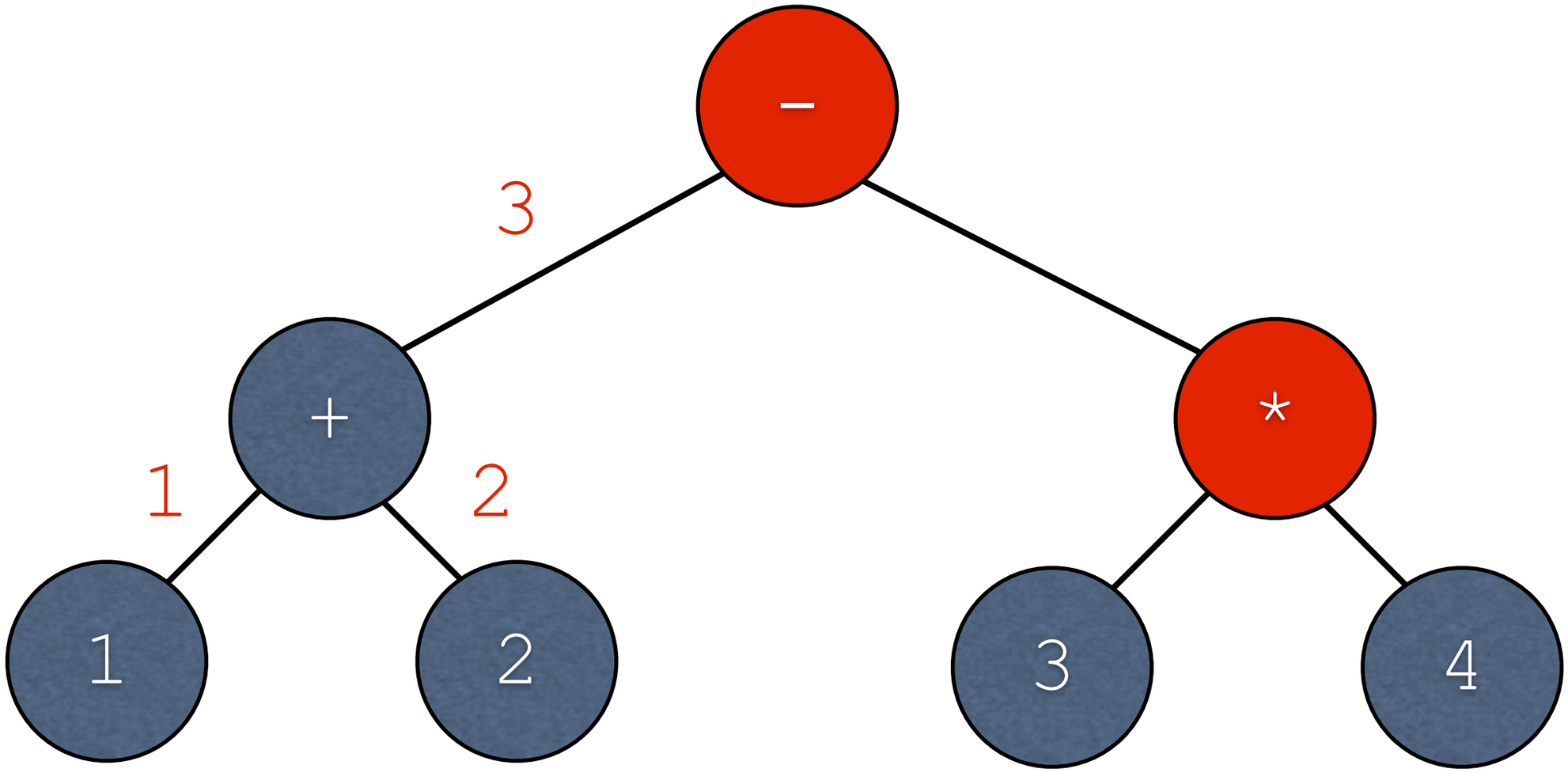

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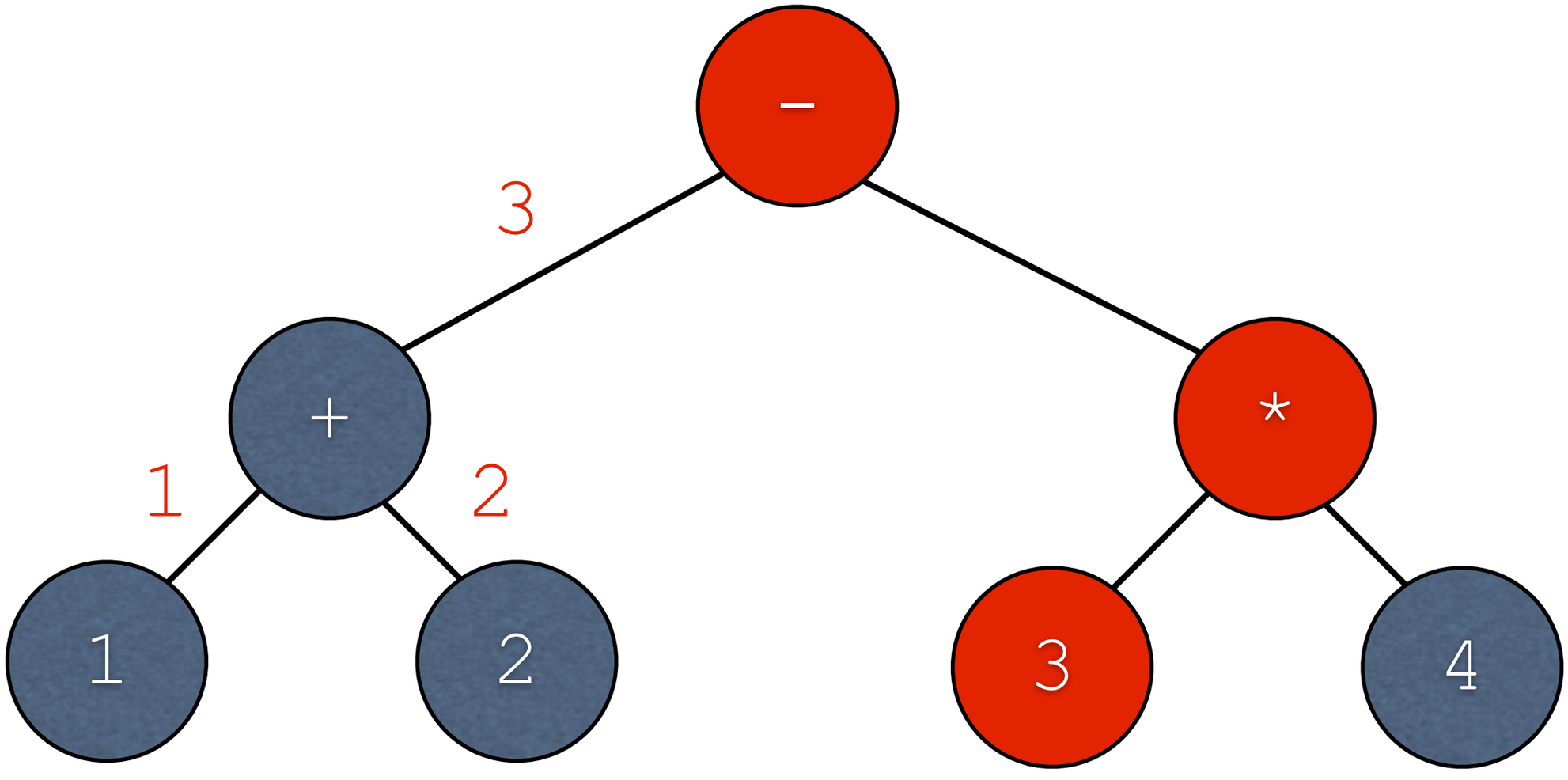

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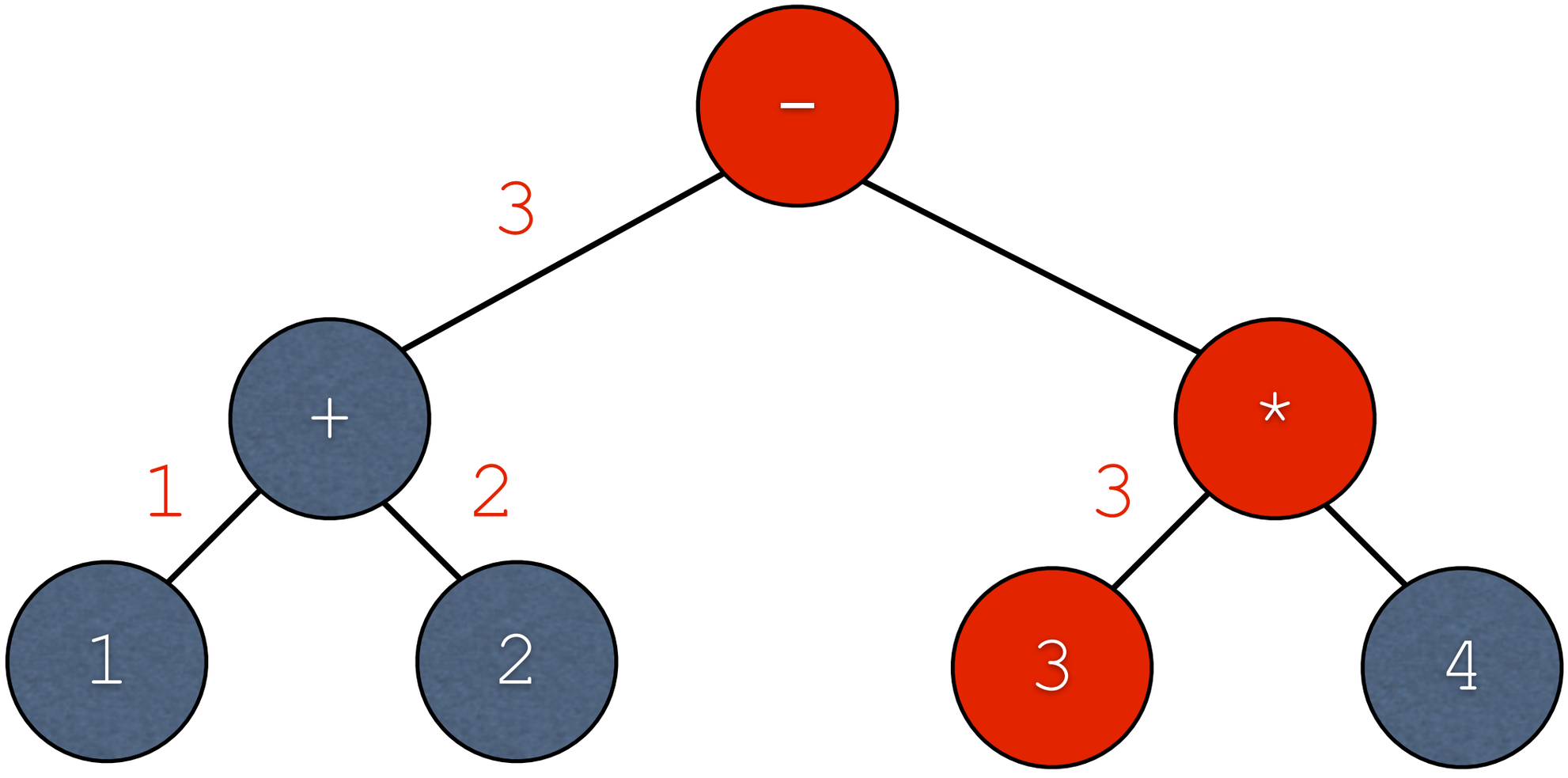

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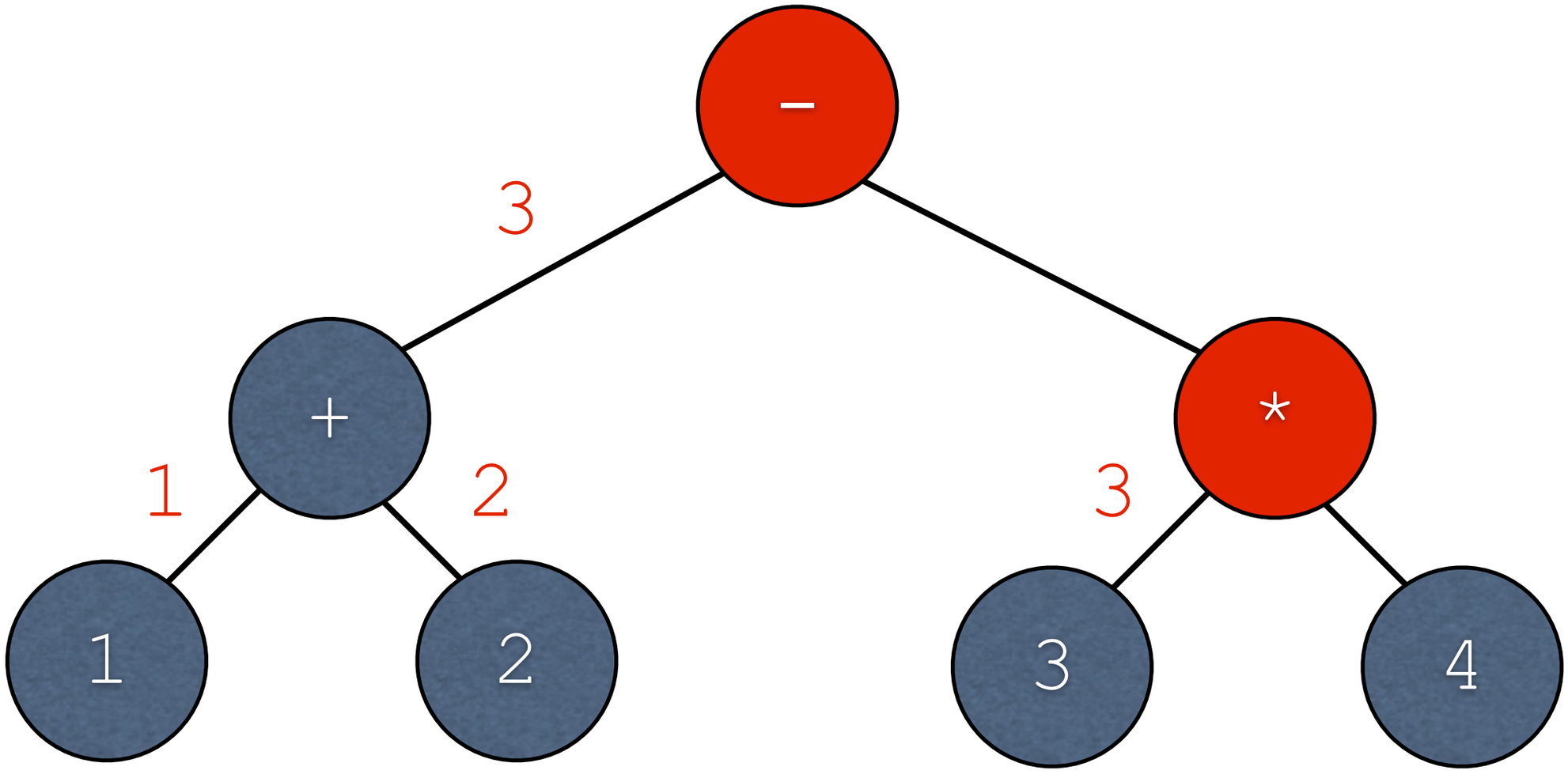

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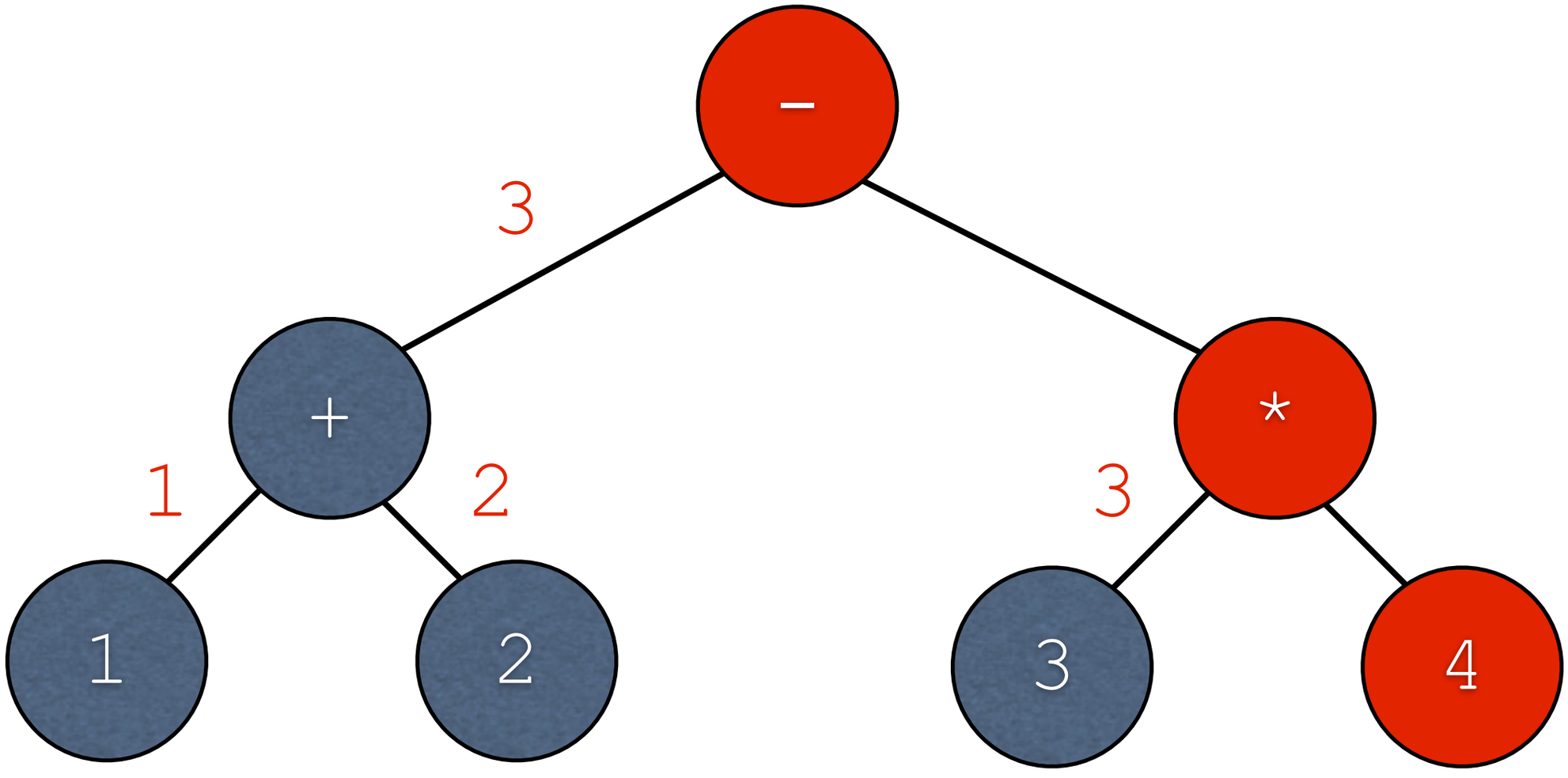

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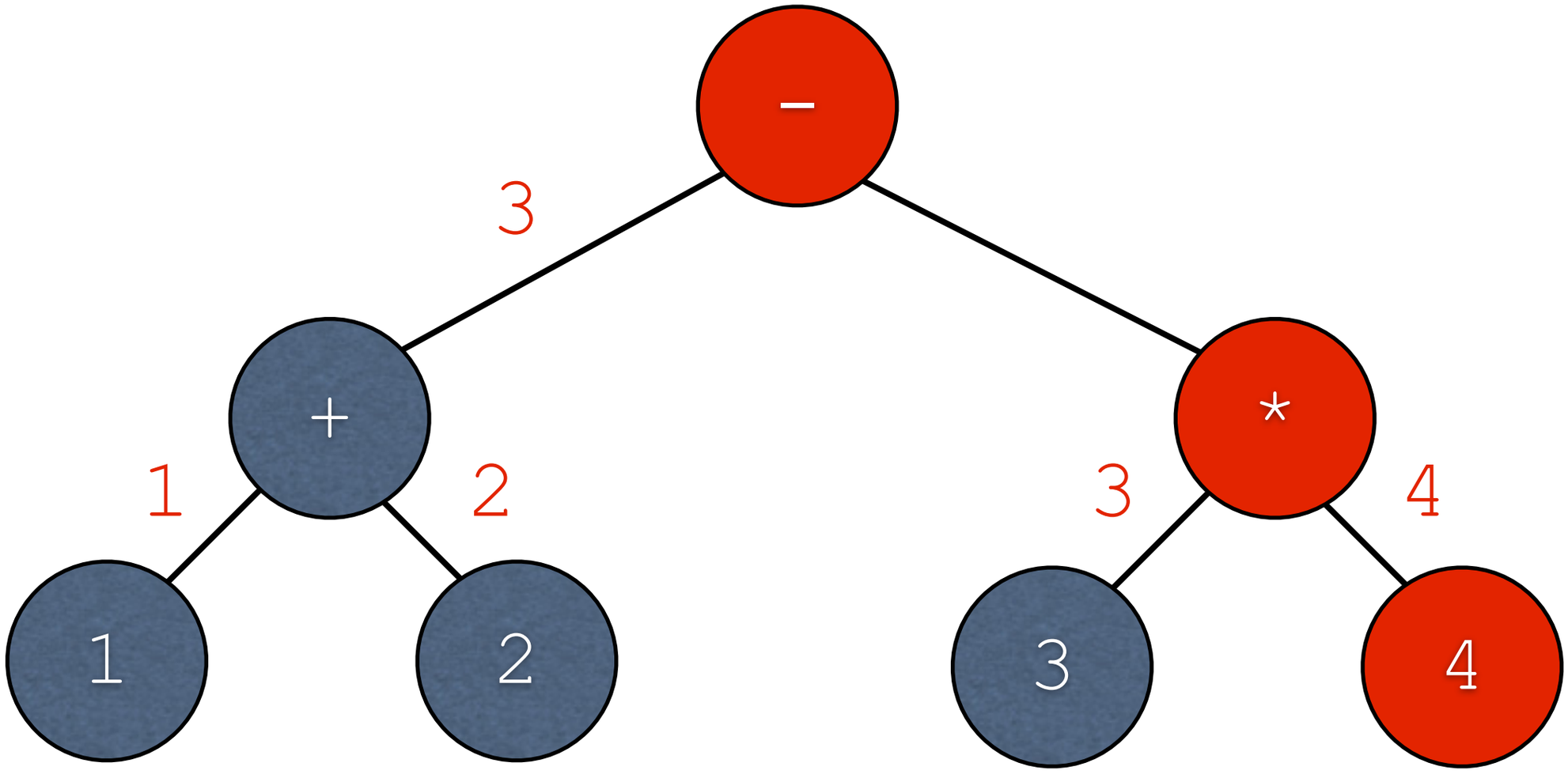

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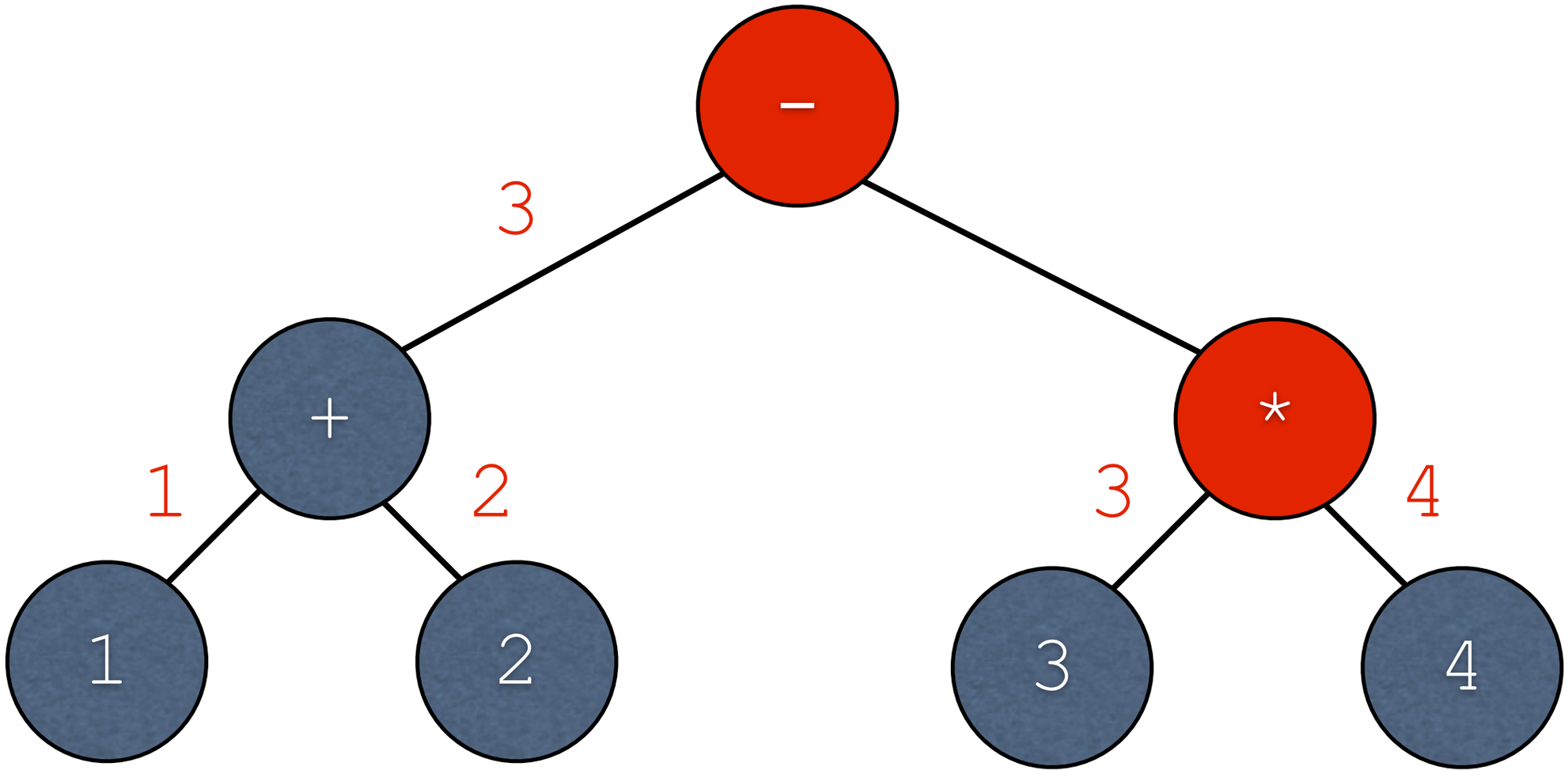

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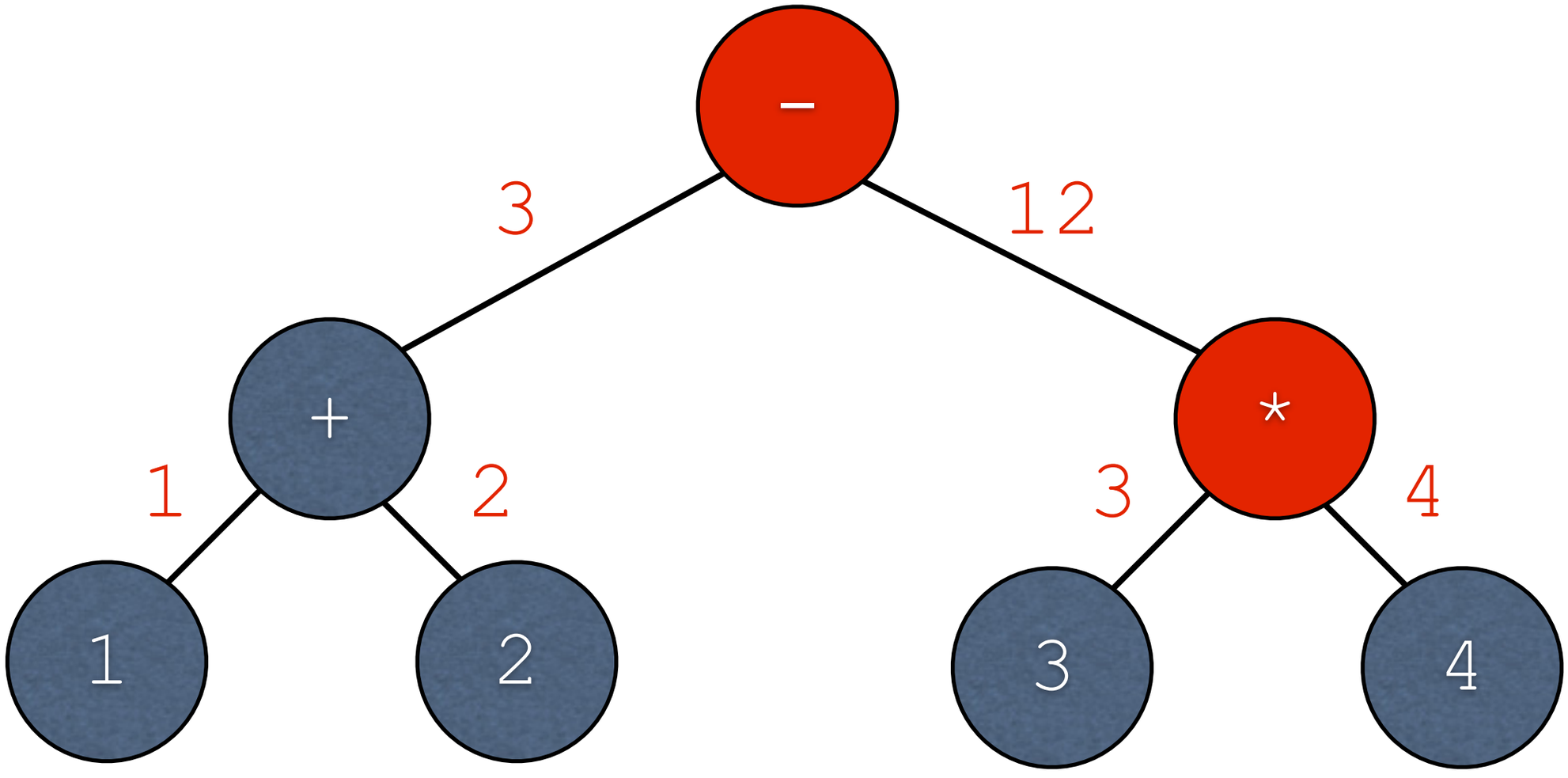

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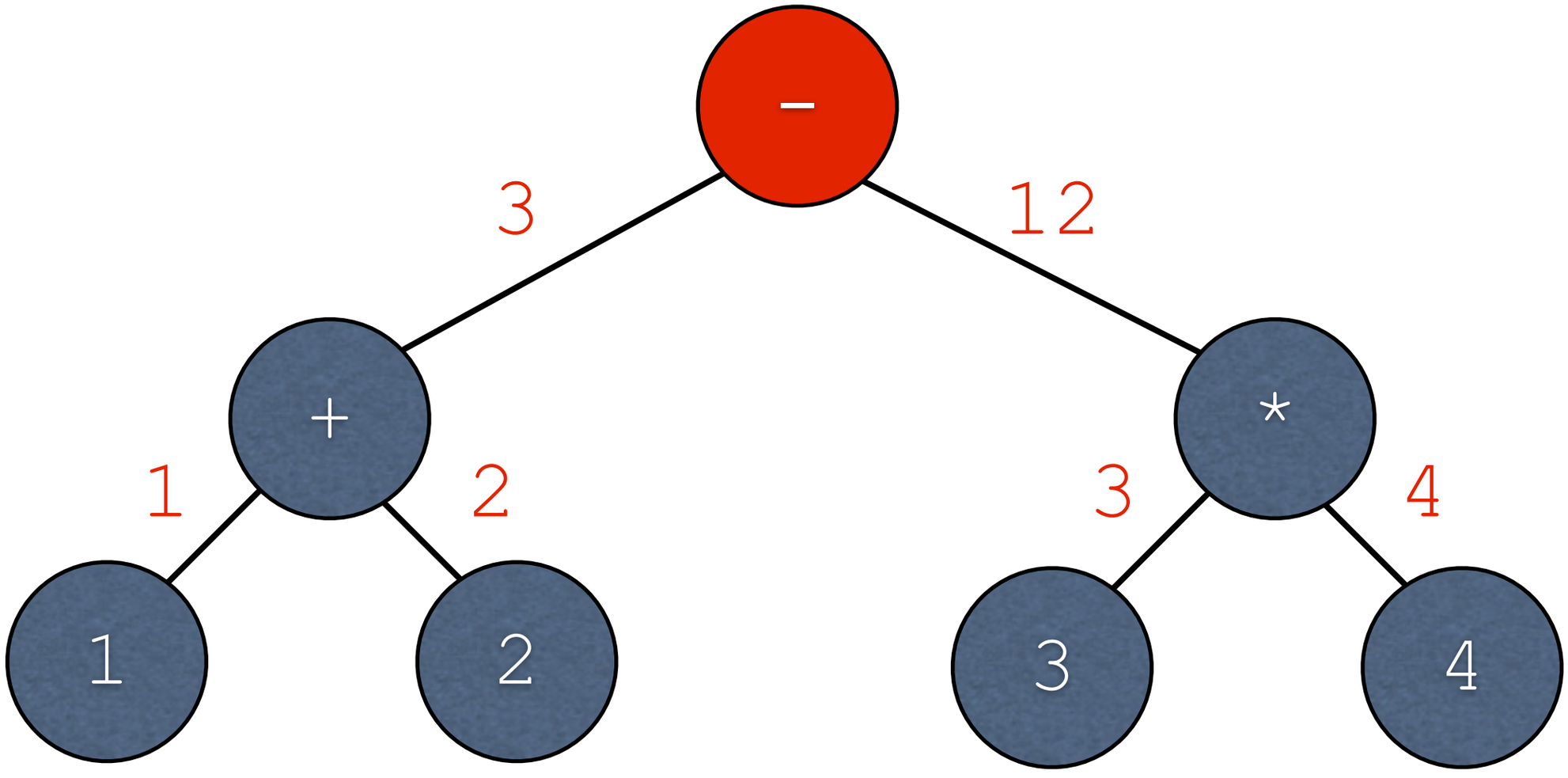

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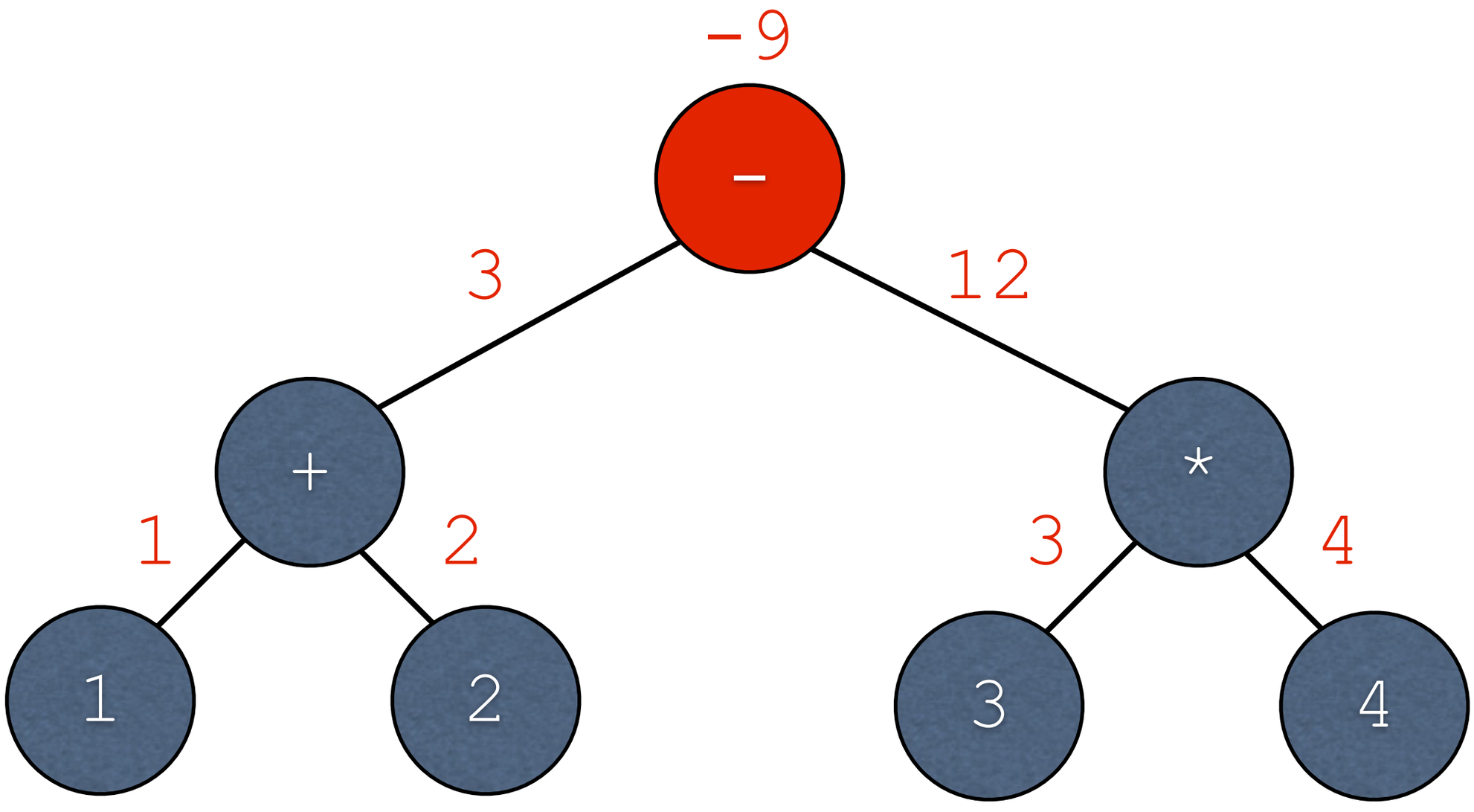

Exercise: Second Side of AST/Evaluation Sheet

Evaluator Example:

arithmetic_evaluator.py

SAT and Semantic Tableau

SAT Background

SAT

- Short for the Boolean satisfiability problem
- Given a Boolean formula with variables, is there an assignment of true/false to the variables which makes the formula true?

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$(x \land \neg x)$

No

Relevance

Widespread usage in hardware and software verification

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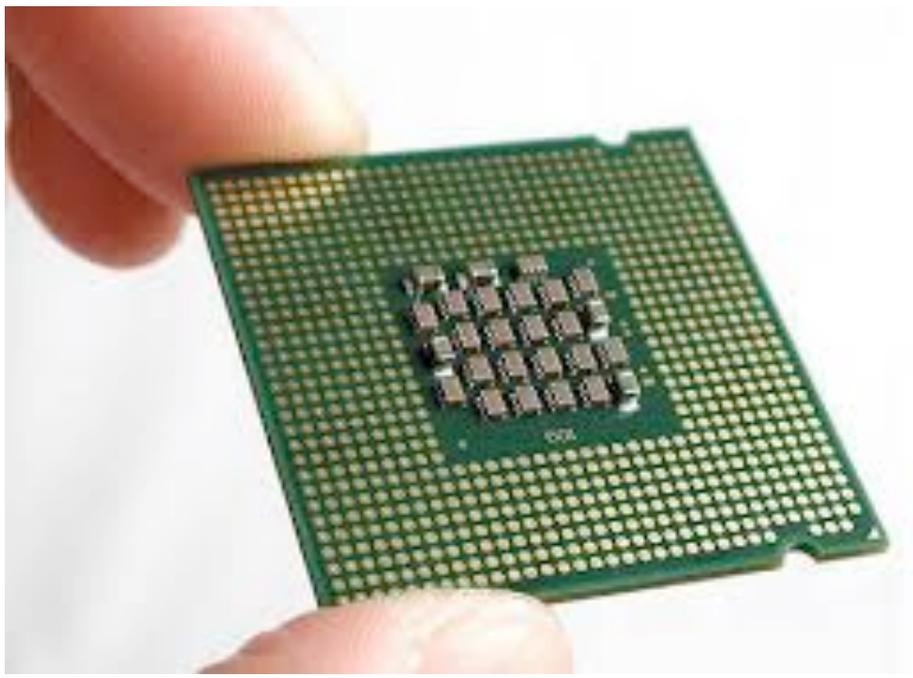

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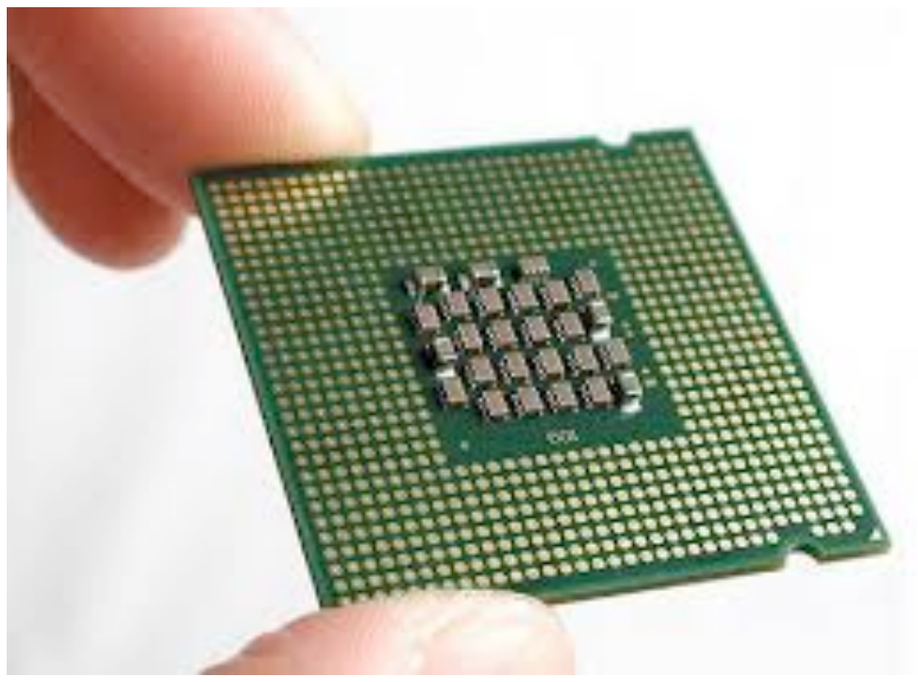

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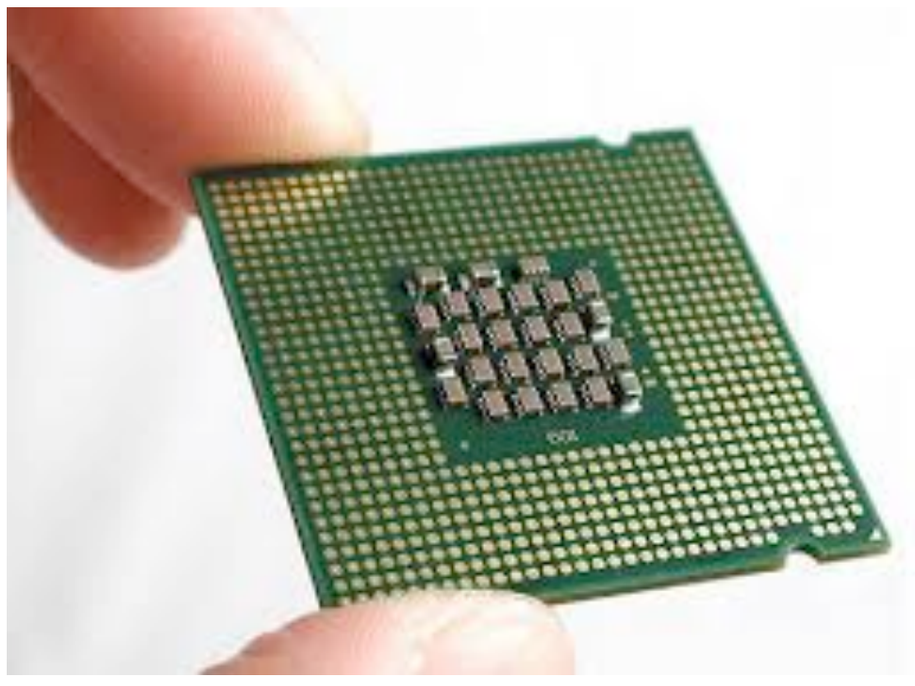


Relevance to Logic Programming

- Methods for solving SAT can be used to execute logic programs
- Logic programming can be phrased as SAT with some additional stuff

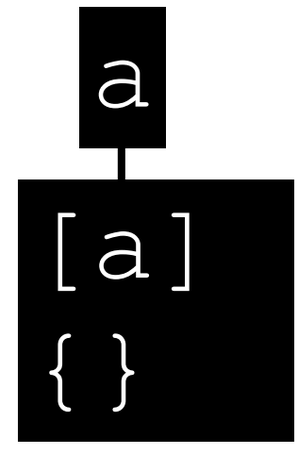
Semantic Tableau

- One method for solving SAT instances
- Basic idea: iterate over the formula
  - Maintain subformulas that must be true
  - Learn which variables must be true/false
  - Stop at conflicts (unsatisfiable), or when no subformulas remain (have solution)

Positive Literals

a

Positive Literals



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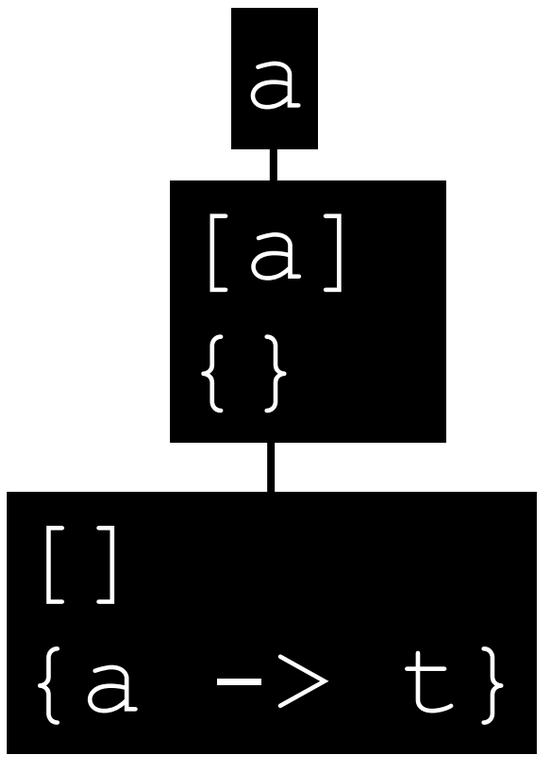

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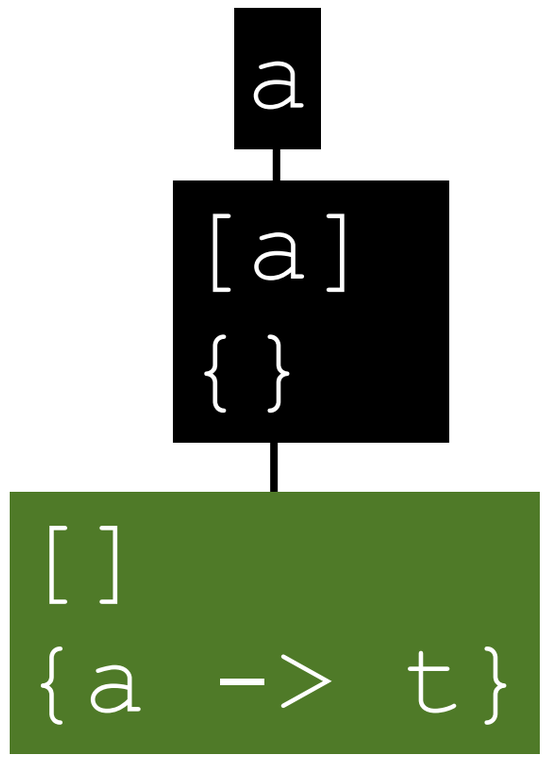
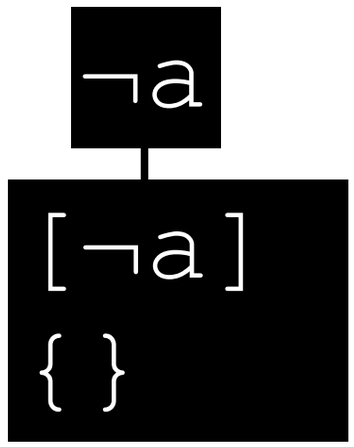


Negative Literals

$\neg a$

Negative Literals



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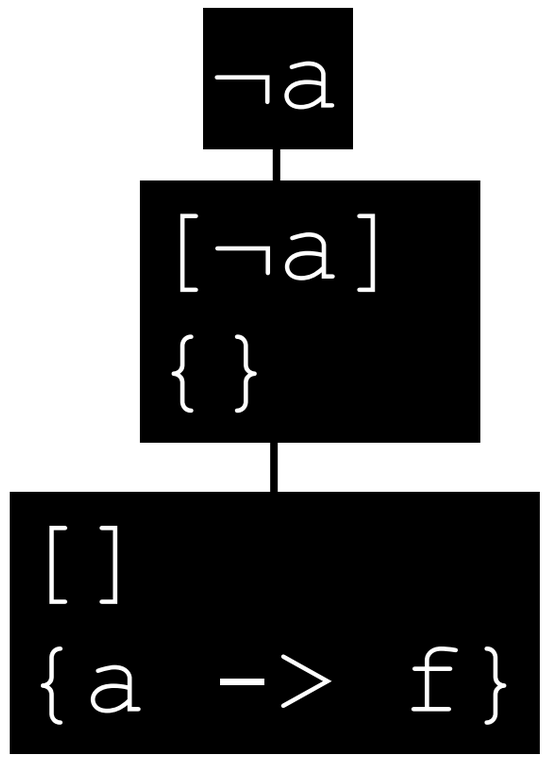

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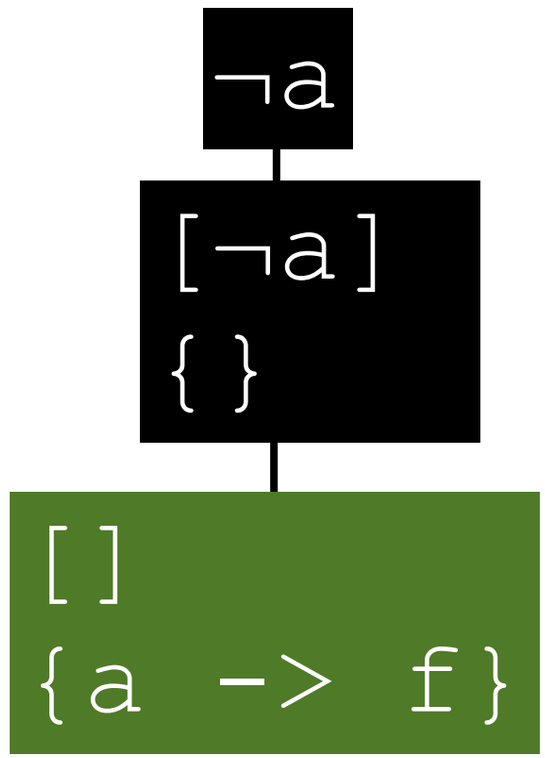
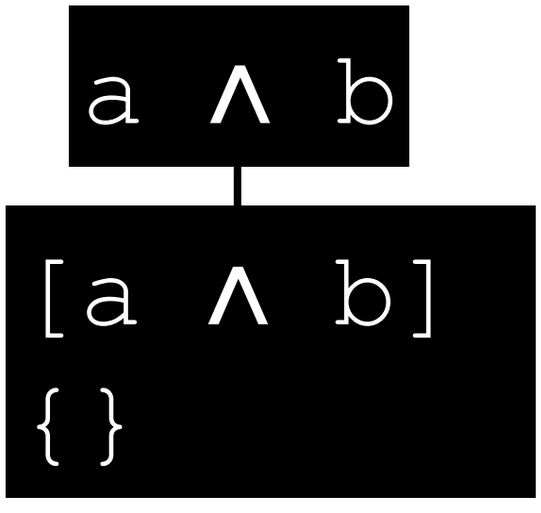


Logical And

$$a \wedge b$$

Logical And



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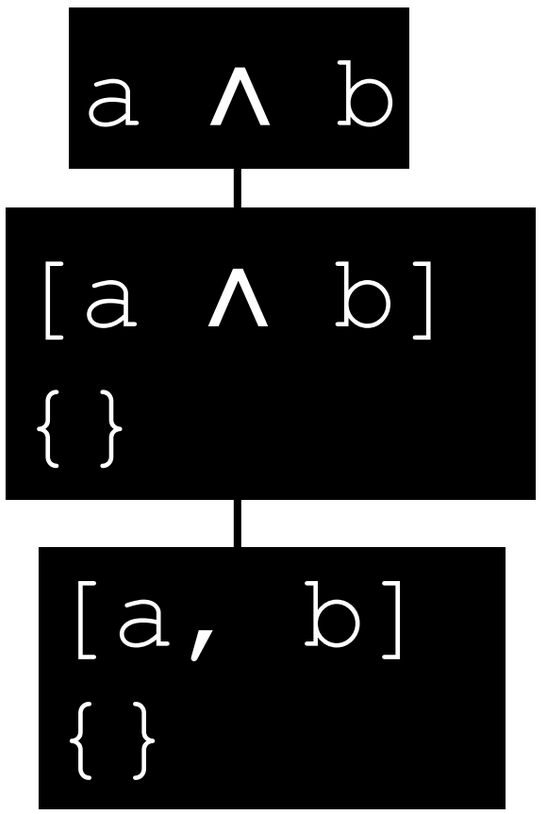

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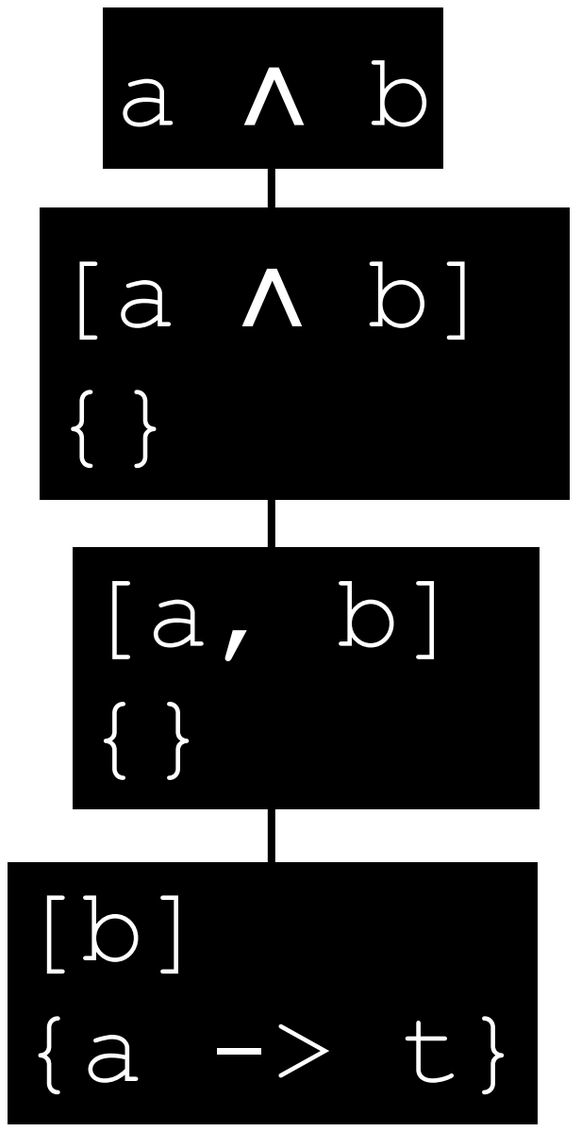

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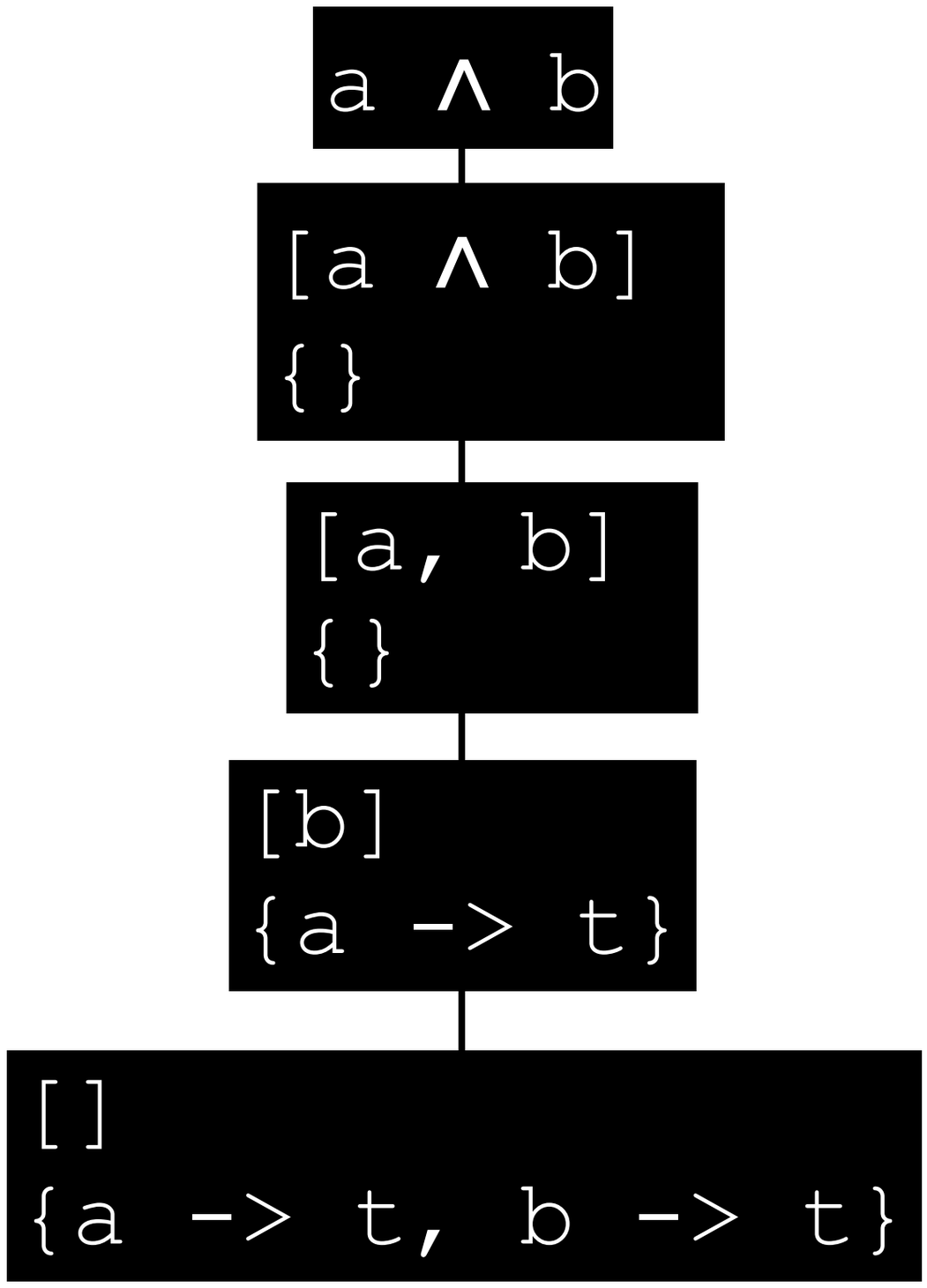

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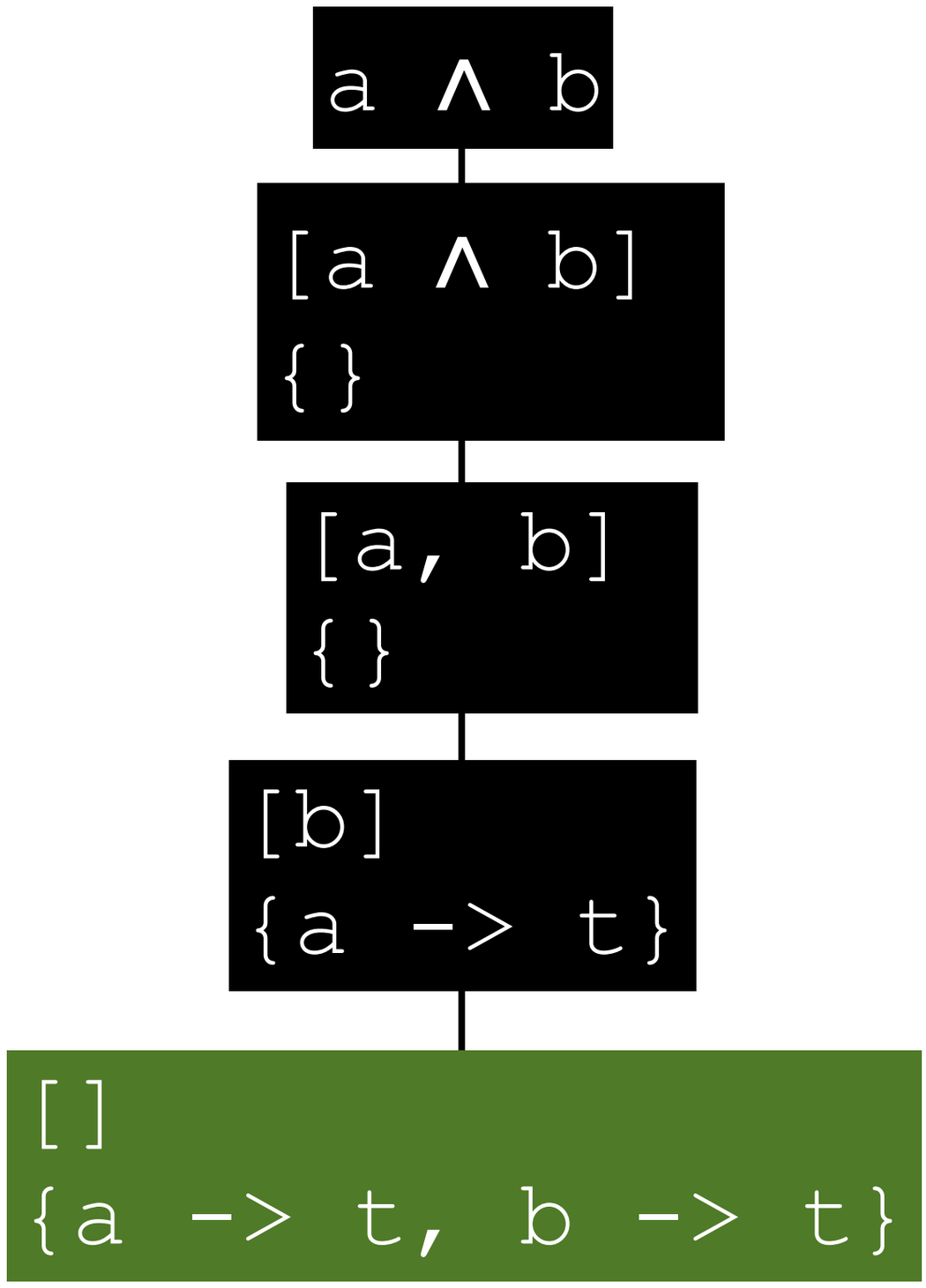

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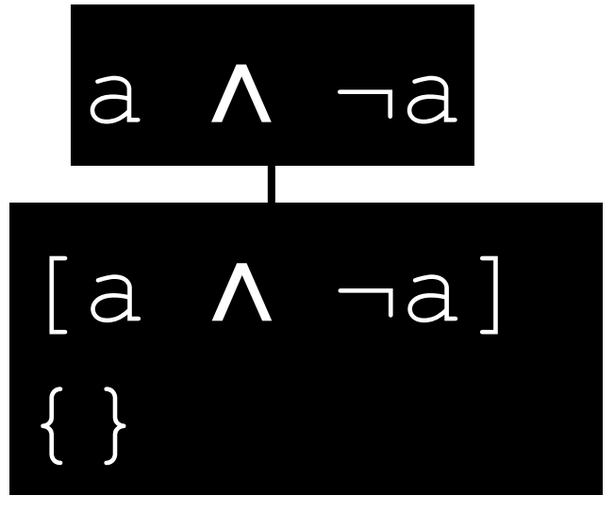

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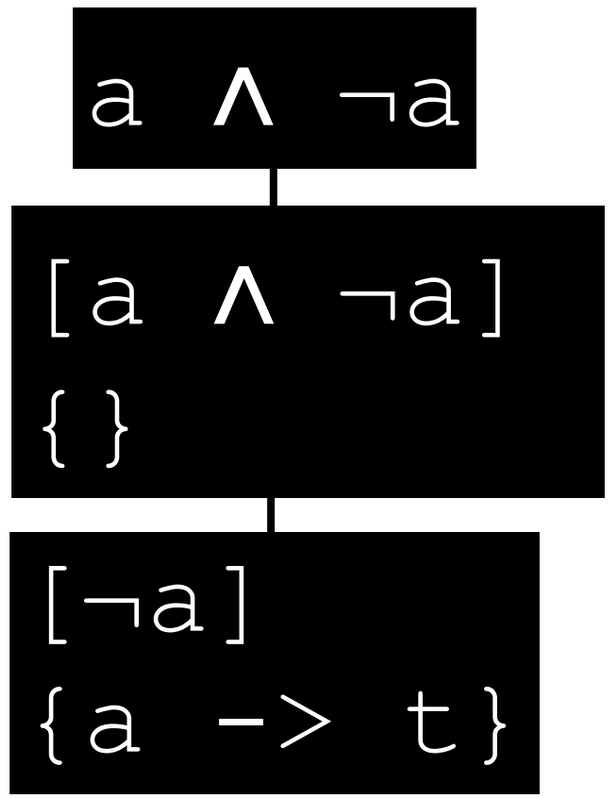

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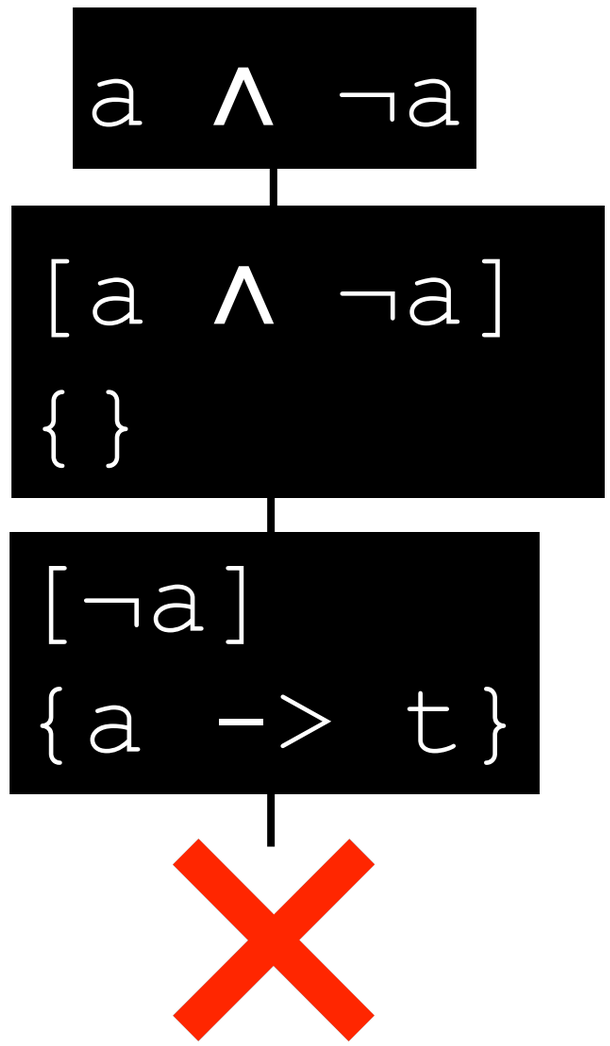
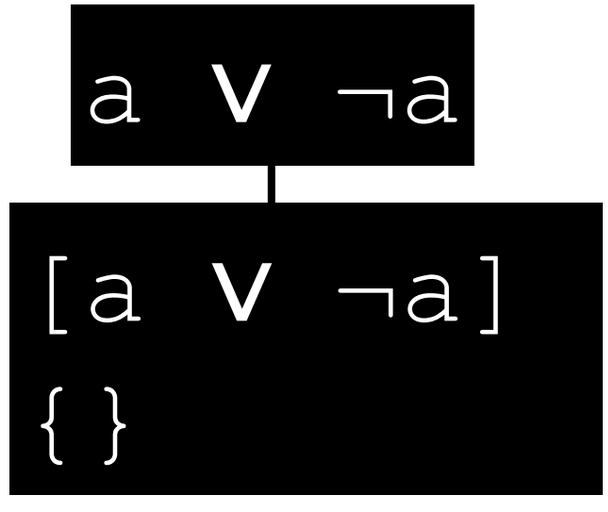


Exercise: First Side of SAT Sheet

Logical Or

$$a \vee \neg a$$

Logical Or



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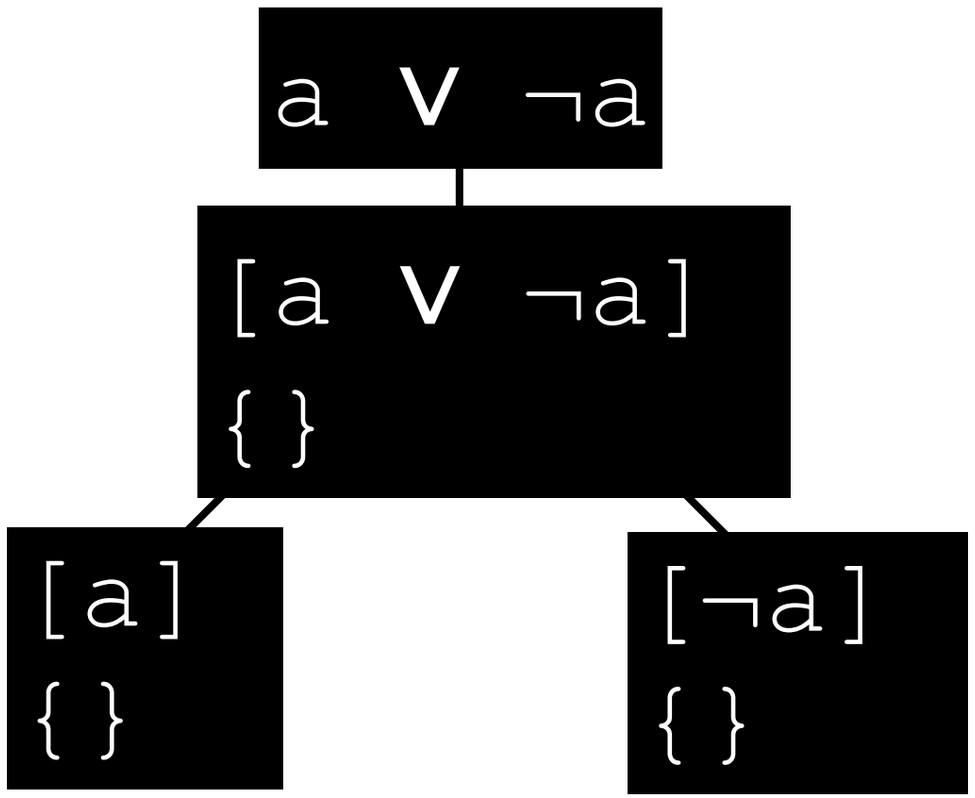

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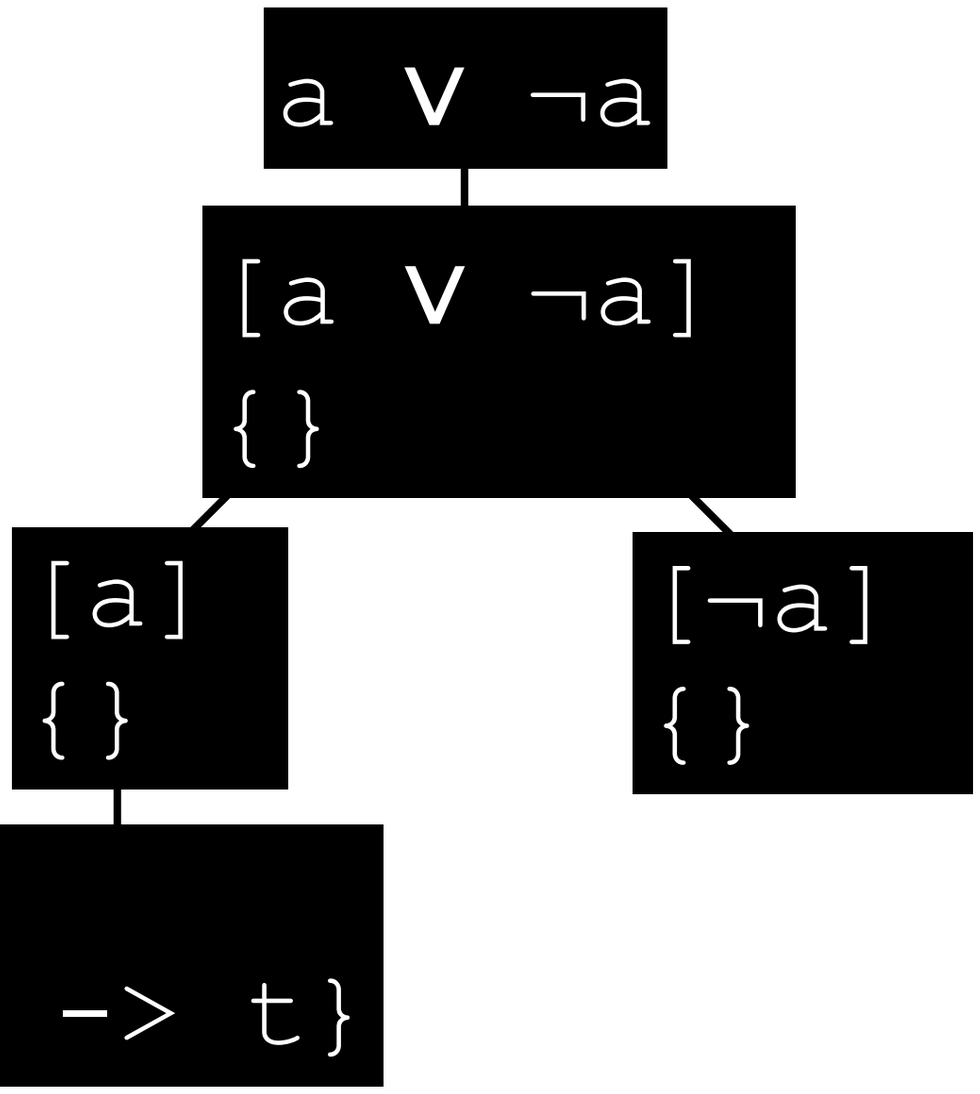

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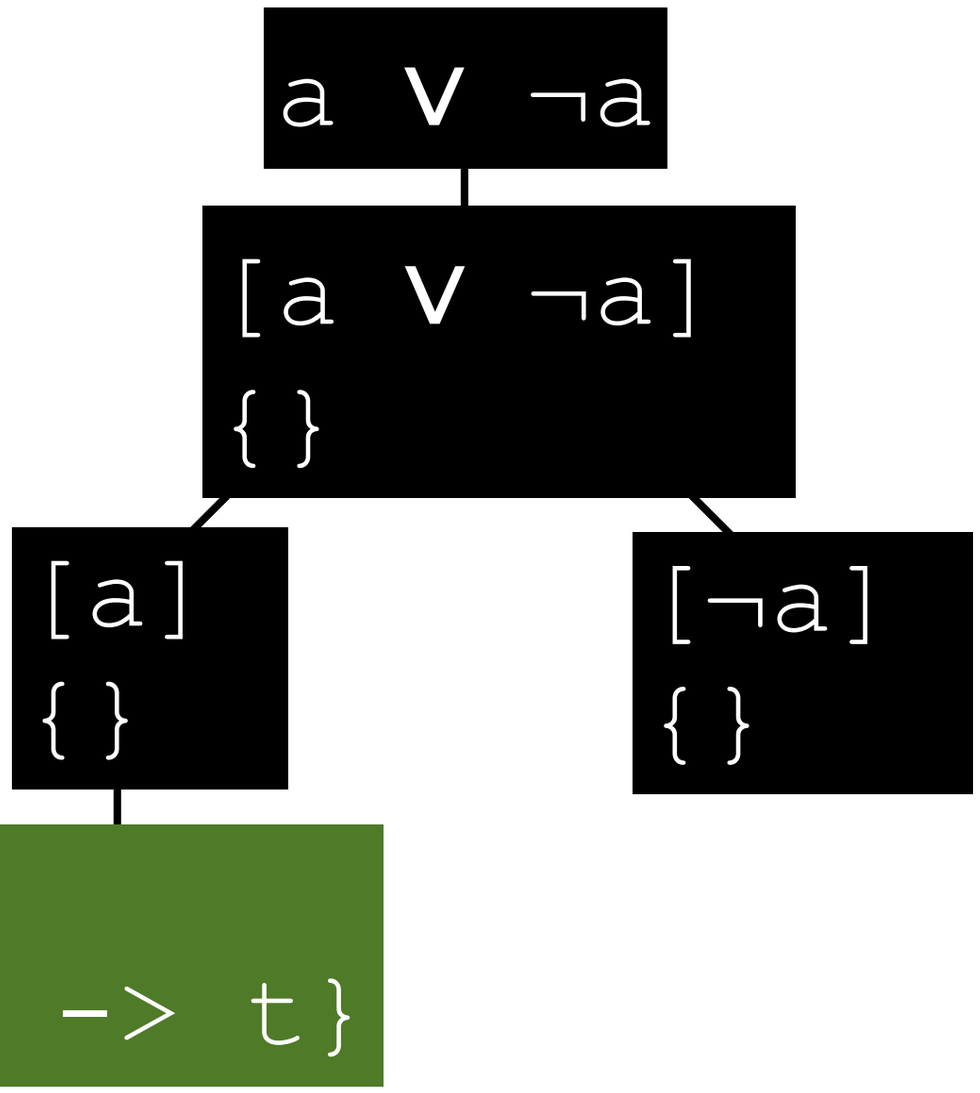

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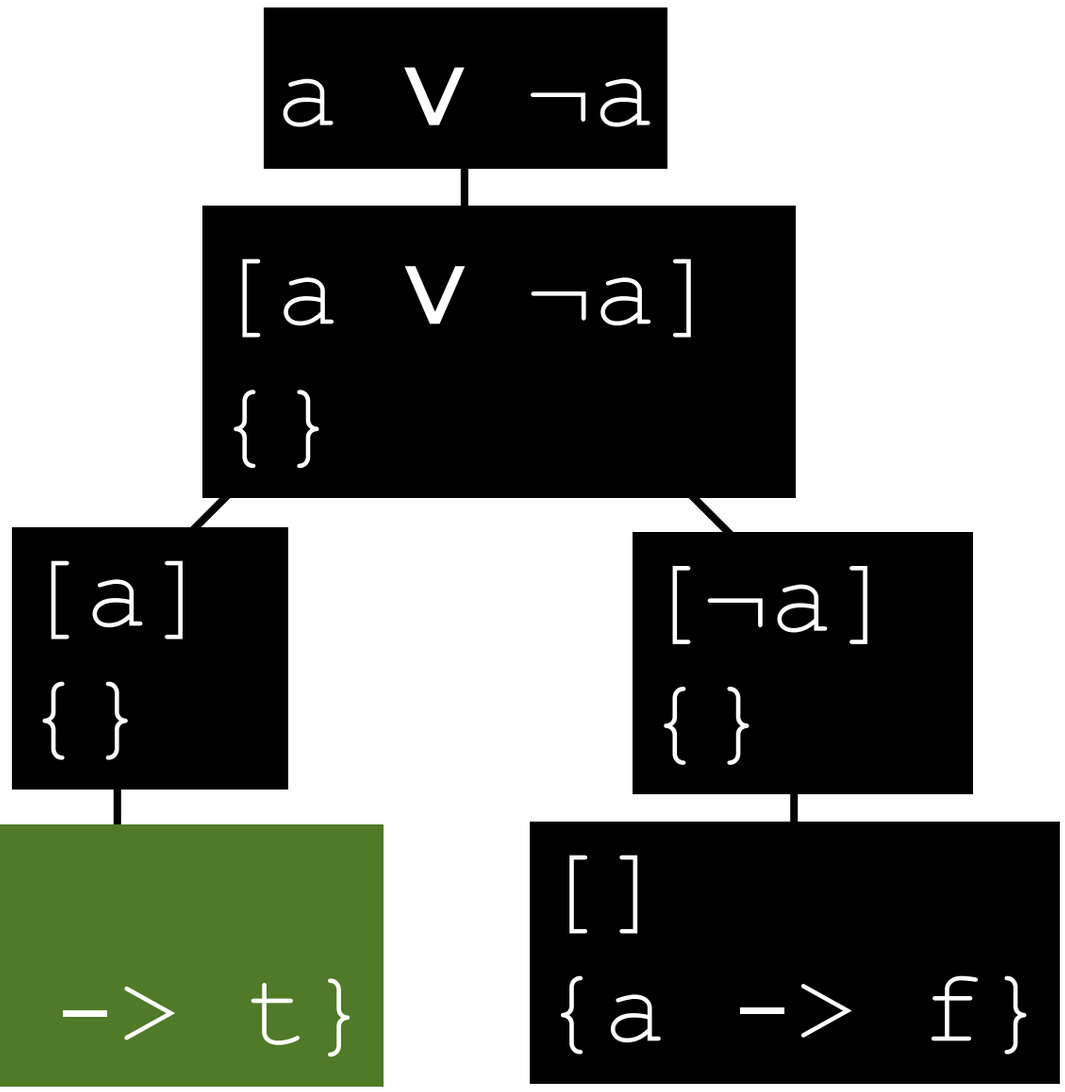

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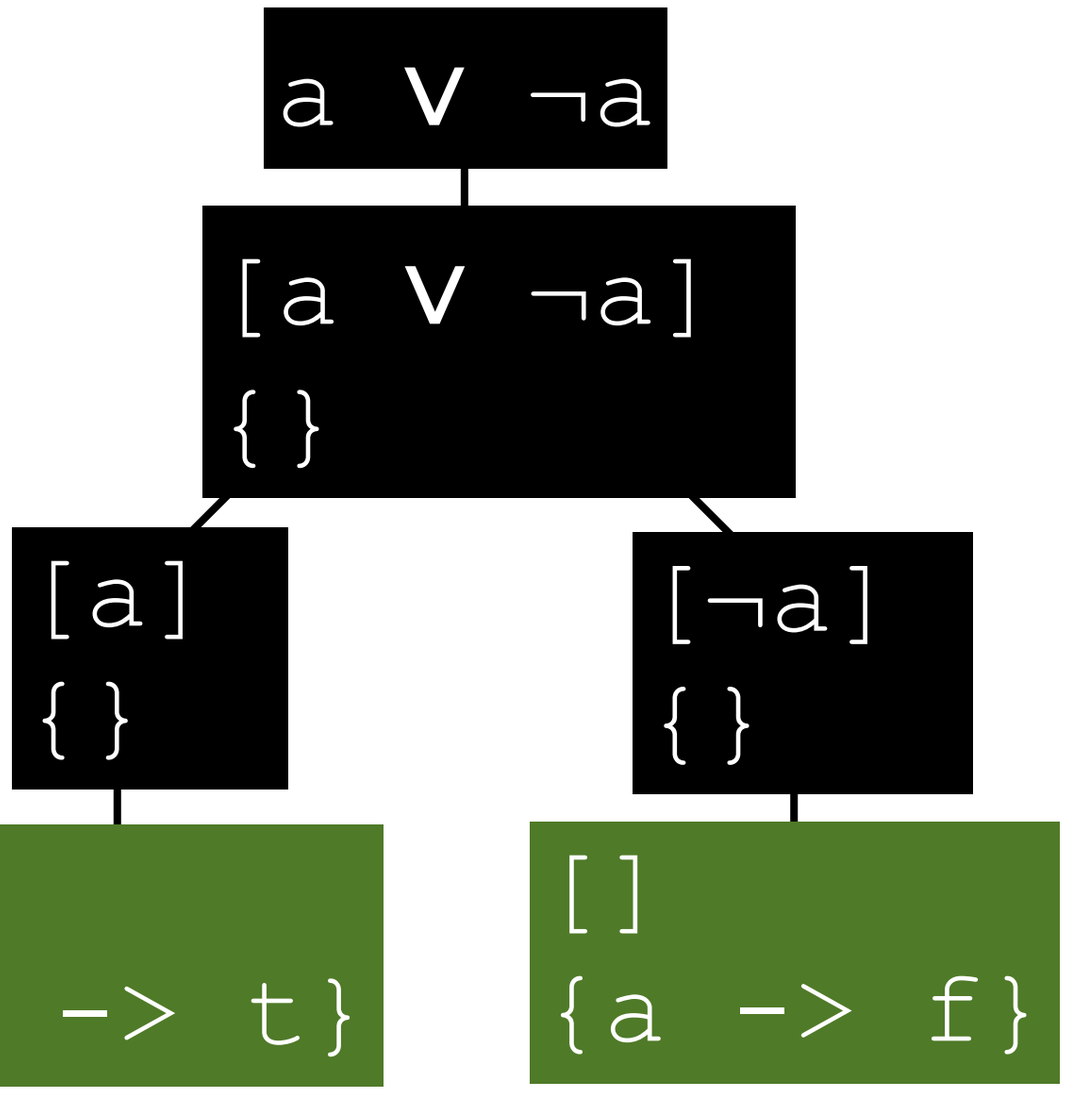
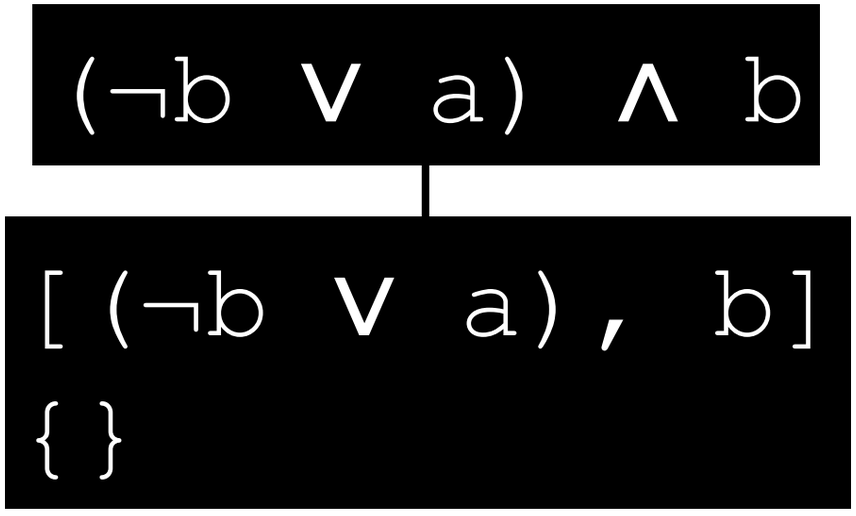


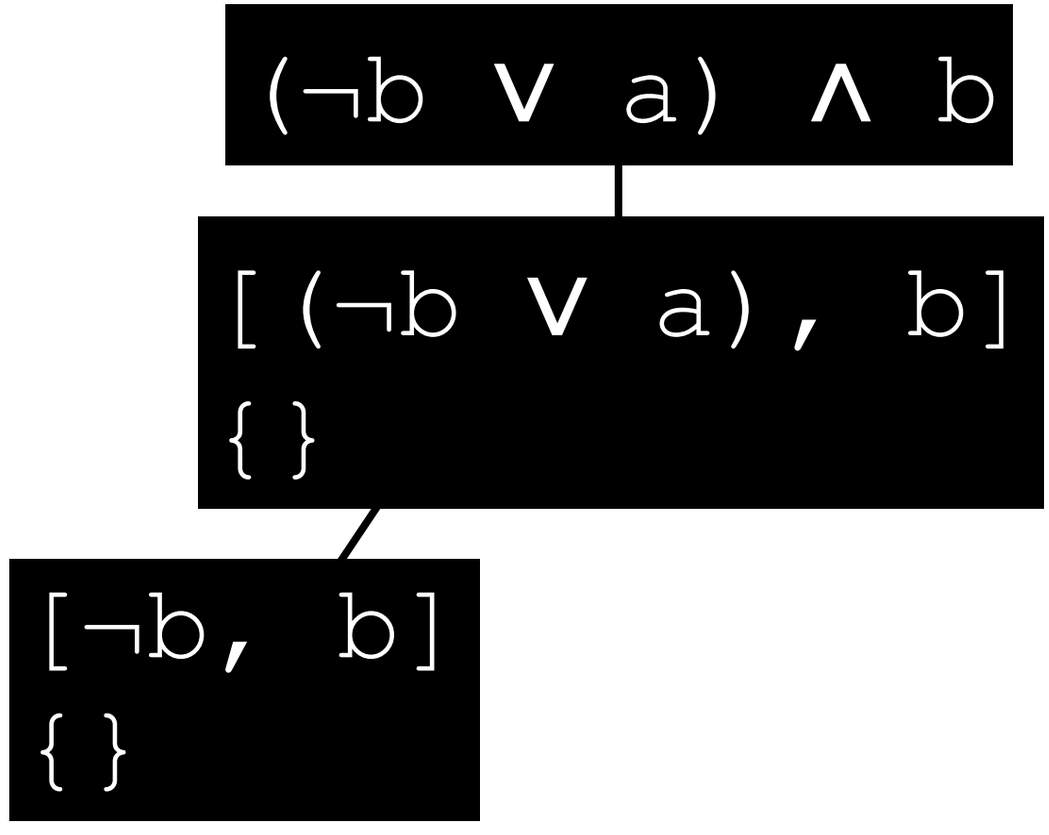
Examples

Example 1:

$(\neg b \lor a) \land b$

$$(\neg b \lor a) \land b$$


(¬b ∨ a) ∧ b
[(¬b ∨ a), b]
{}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{}
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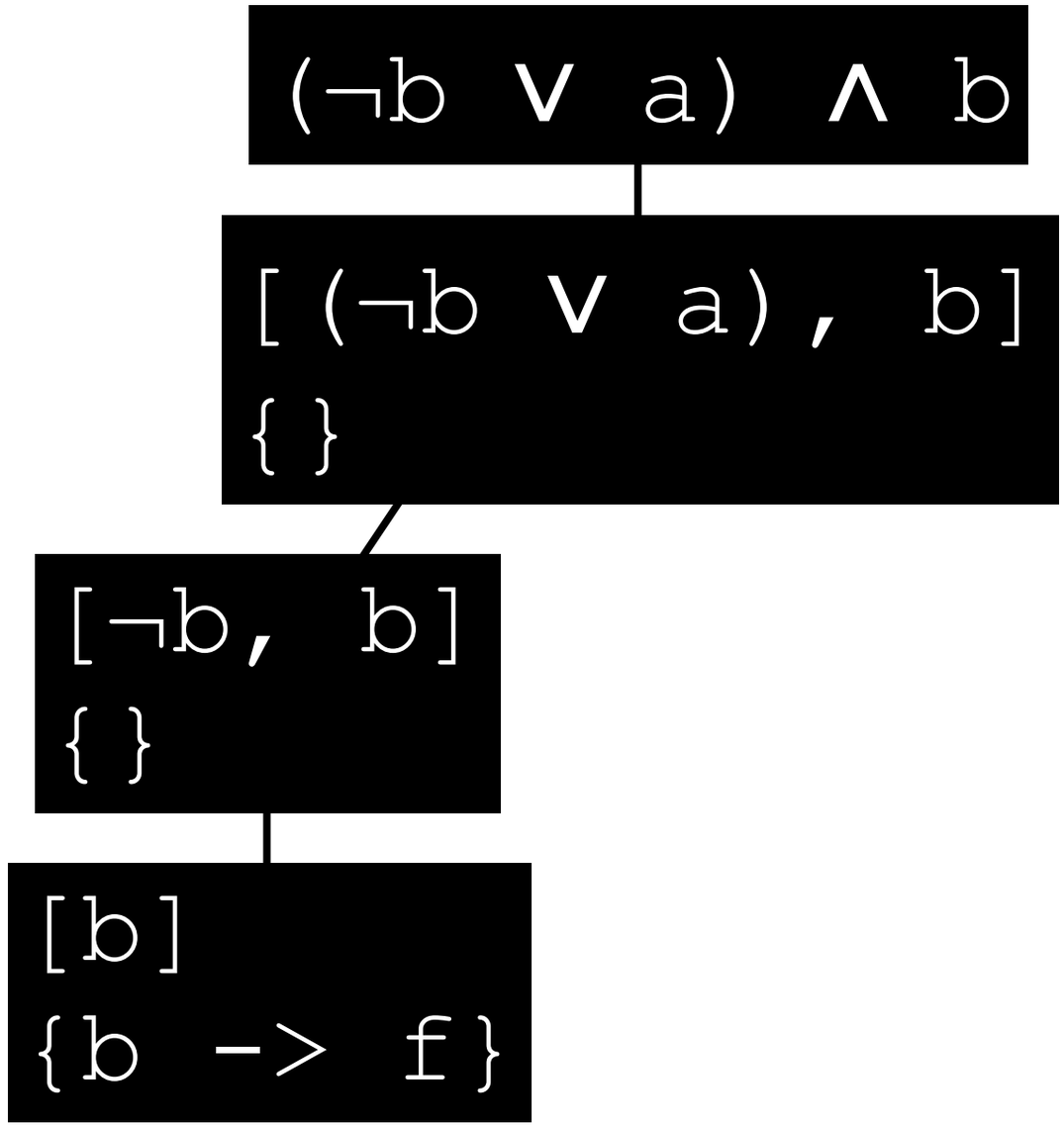
{}


(¬b ∨ a) ∧ b
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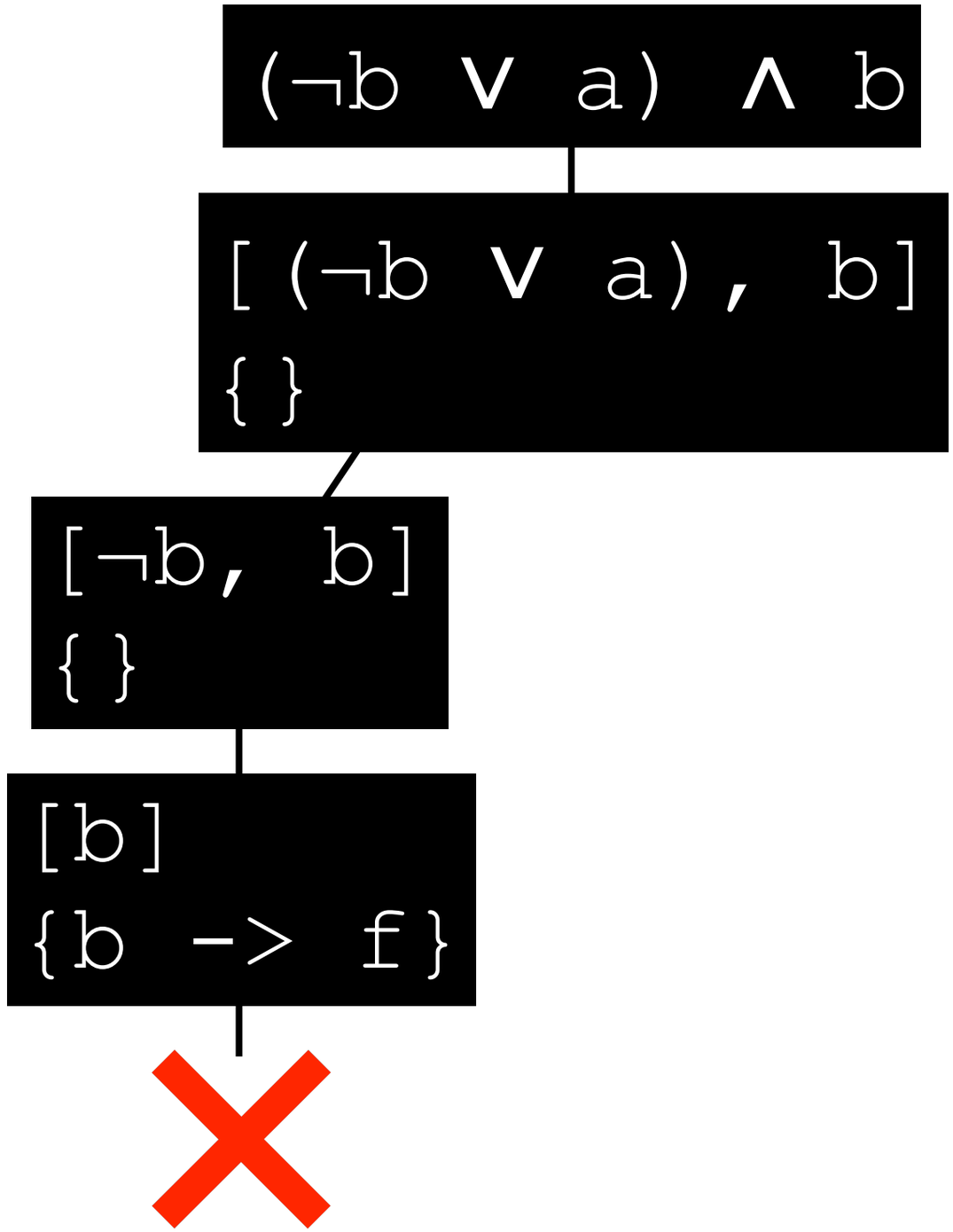
[¬b, b]
{}
[b]
{b -> f}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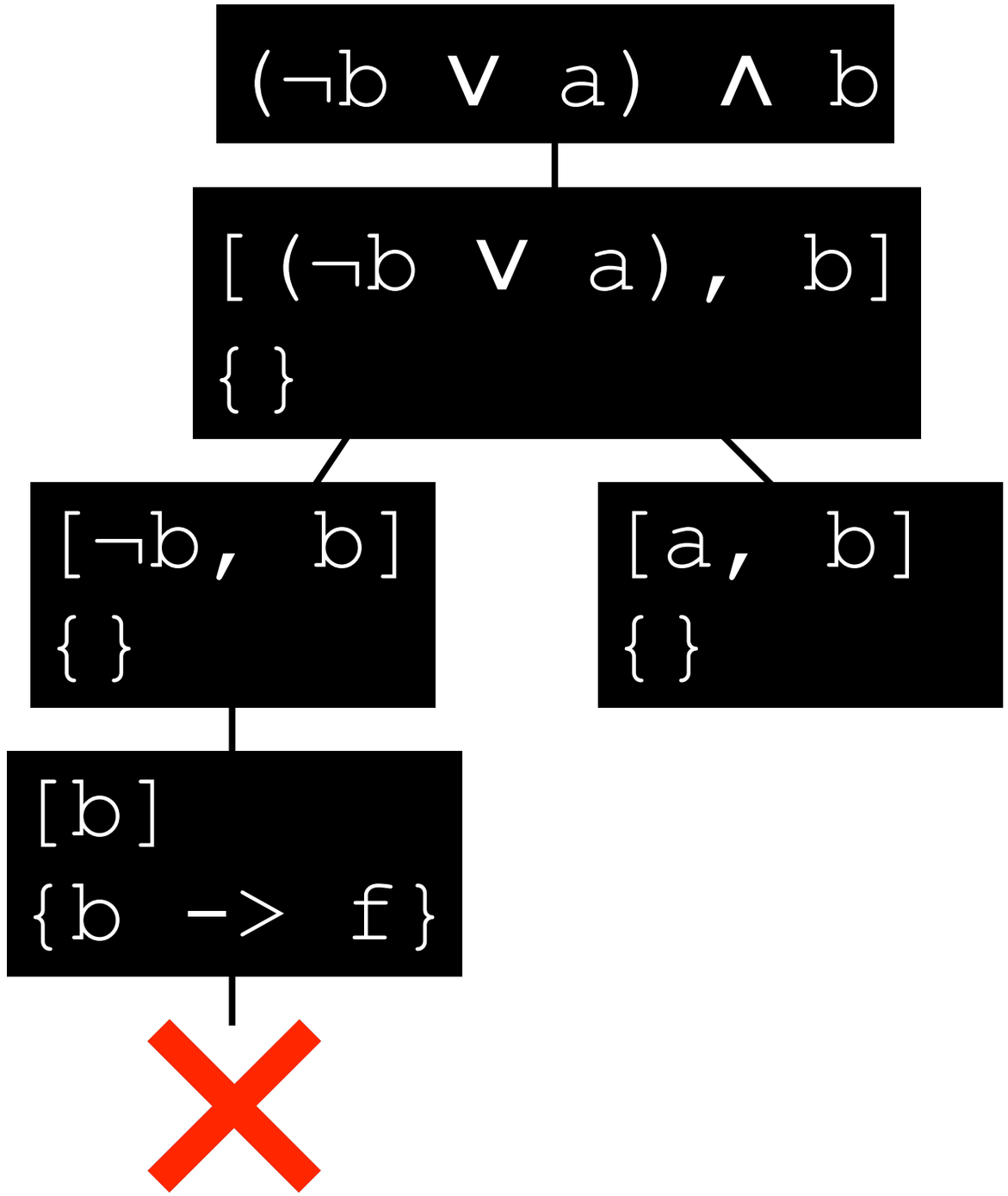
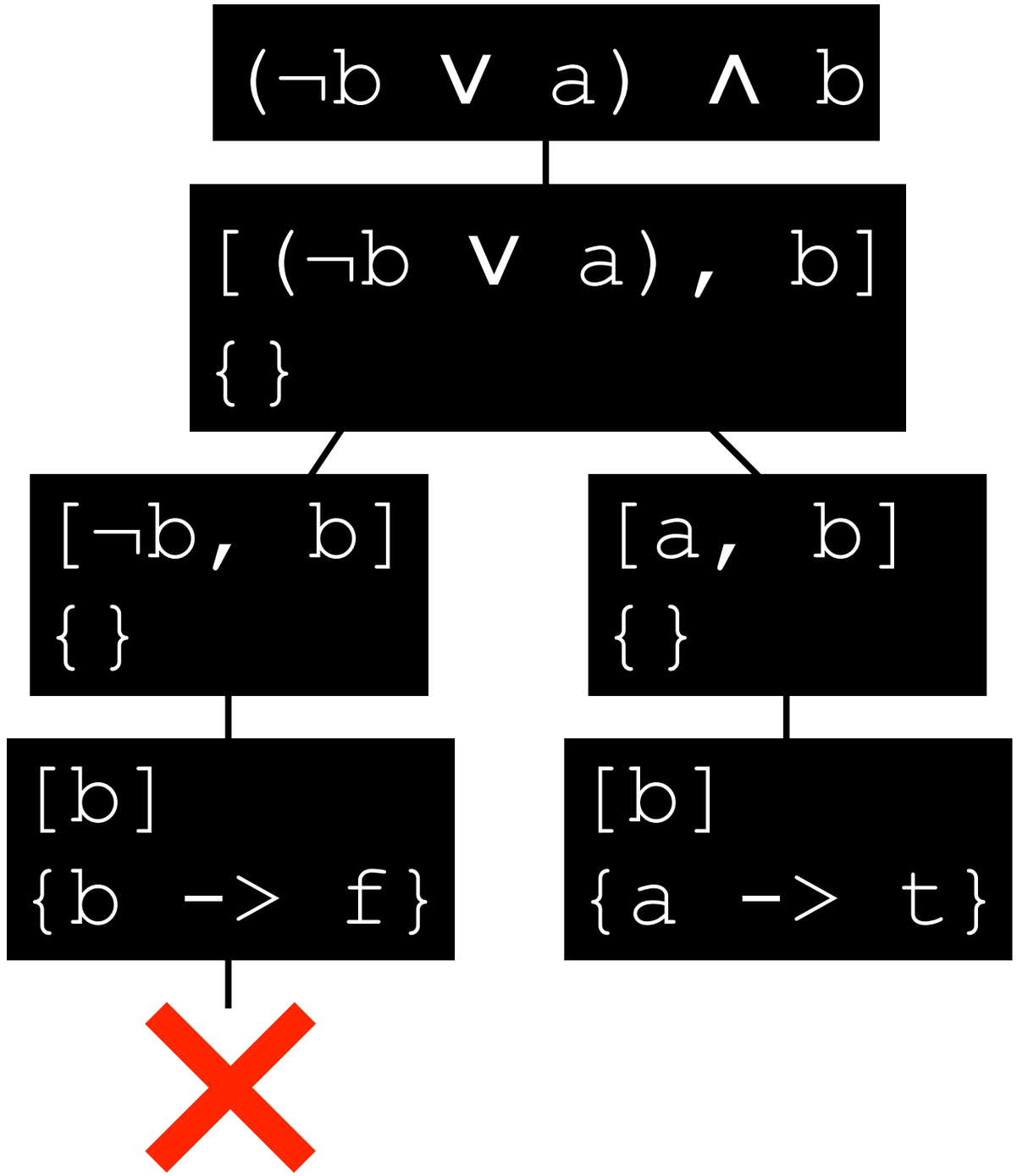
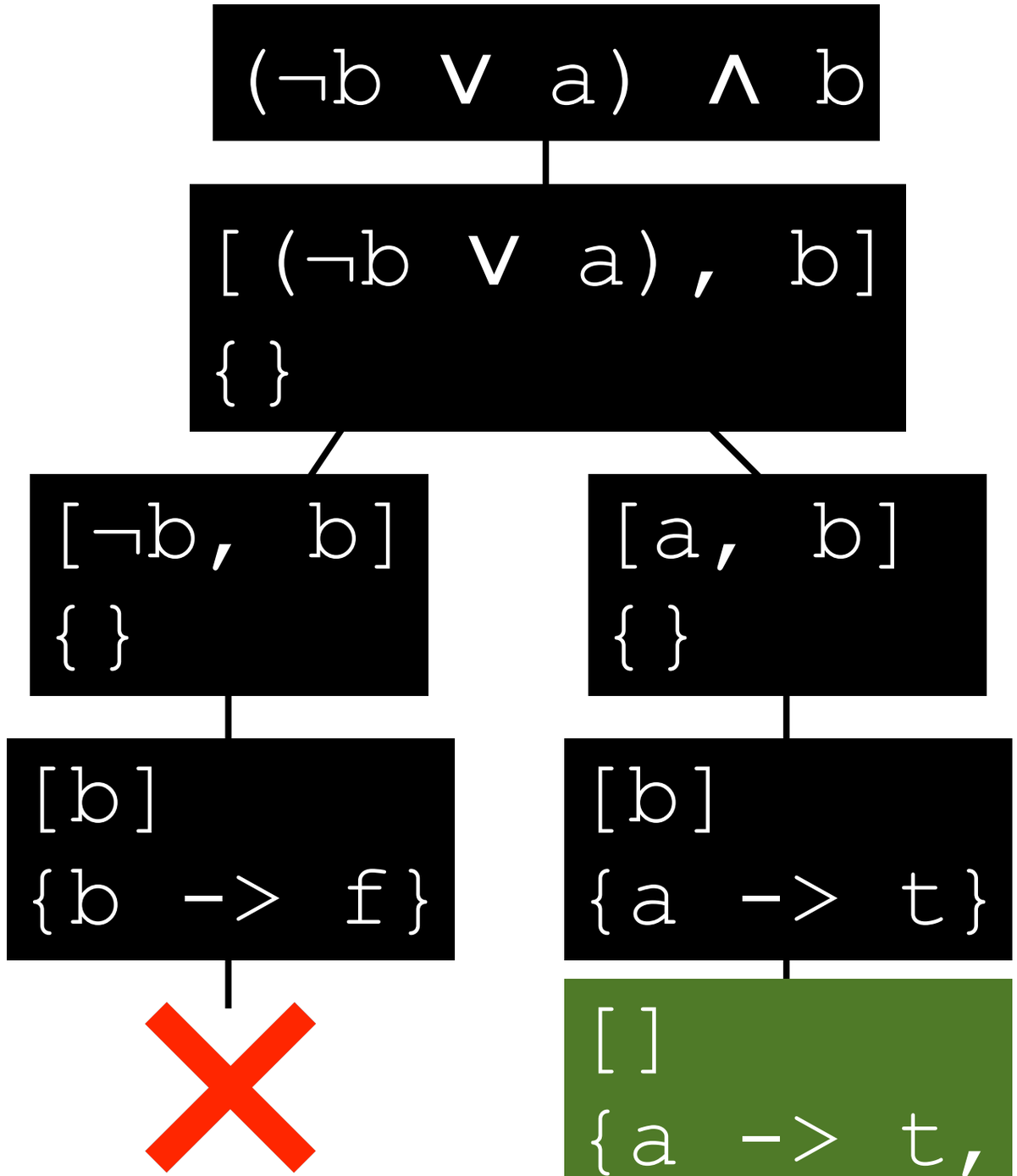
[b]
{b -> f}


(¬b ∨ a) ∧ b
[(¬b ∨ a), b]
{}
[¬b, b]
{}
[a, b]
{}
[b]
{b -> f}

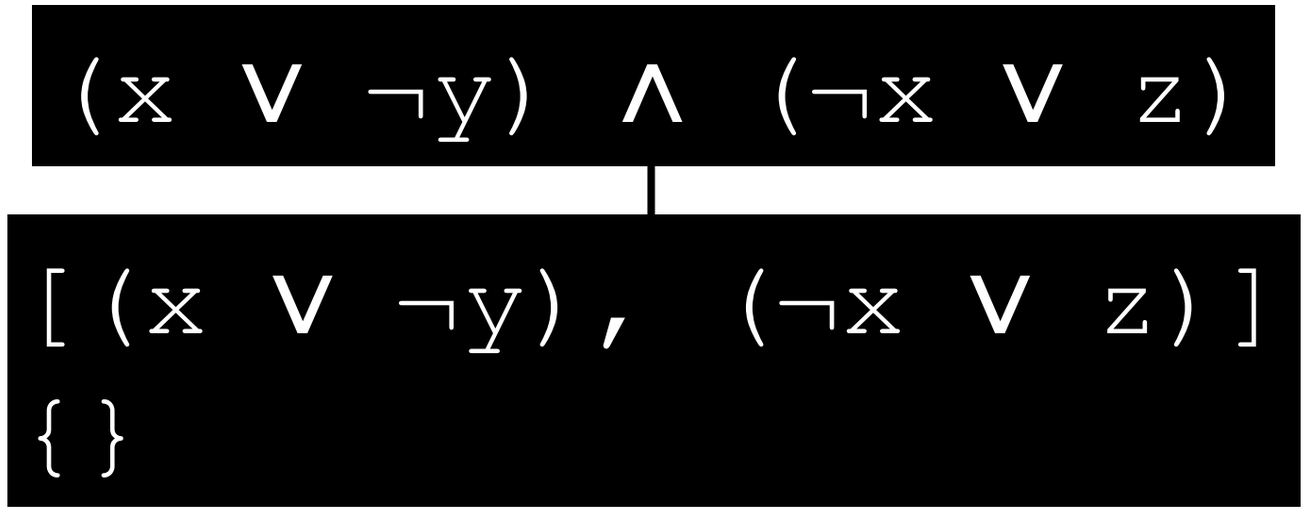

(¬b ∨ a) ∧ b
[(¬b ∨ a), b]
{}
[¬b, b]
{}
[a, b]
{}
[b]
{b -> f}
[b]
{a -> t}

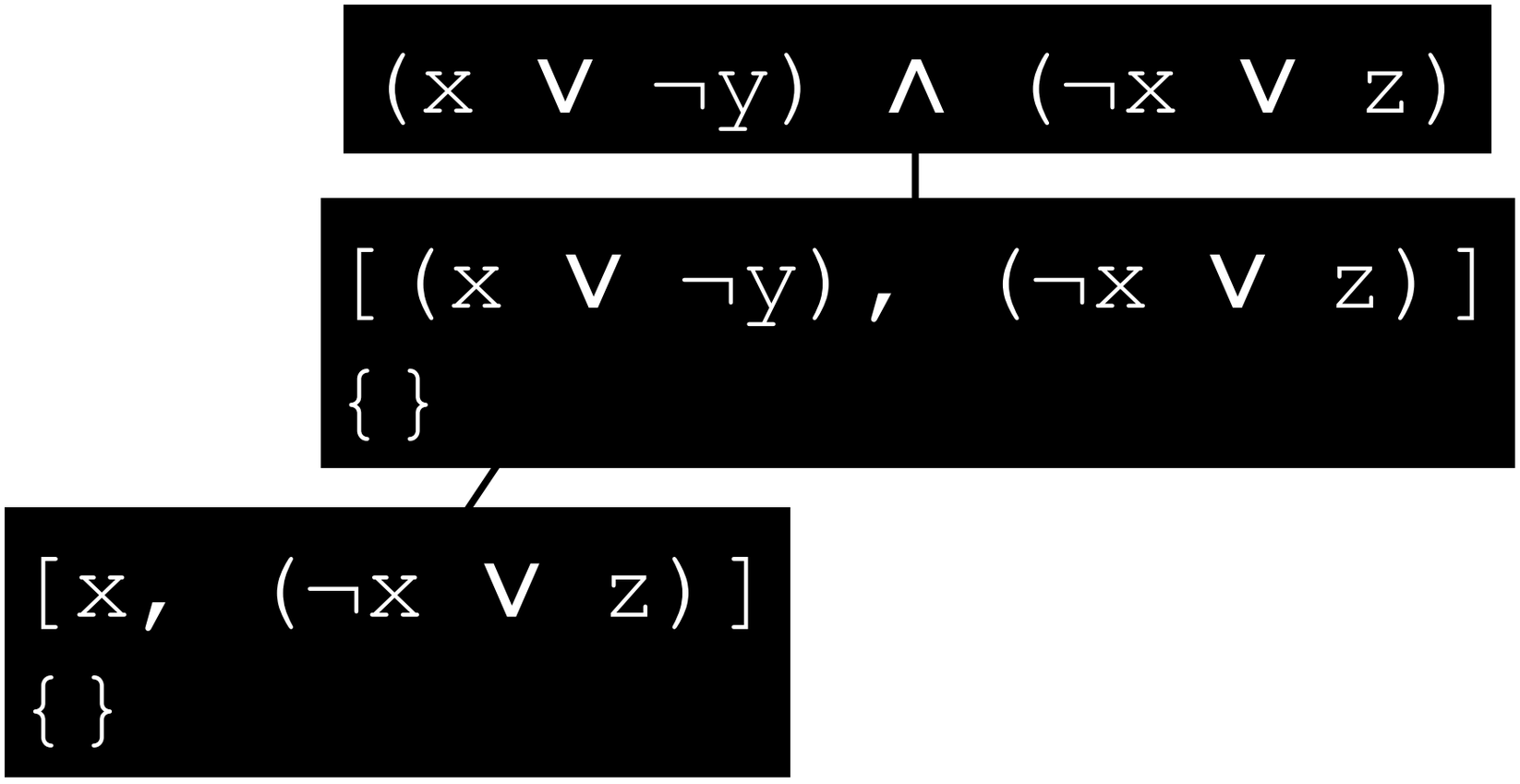

(¬b ∨ a) ∧ b
[(¬b ∨ a), b]
{}
[¬b, b]
{}
[a, b]
{}
[b]
{b -> f}
[b]
{a -> t}
[]
{a -> t,
b -> t}

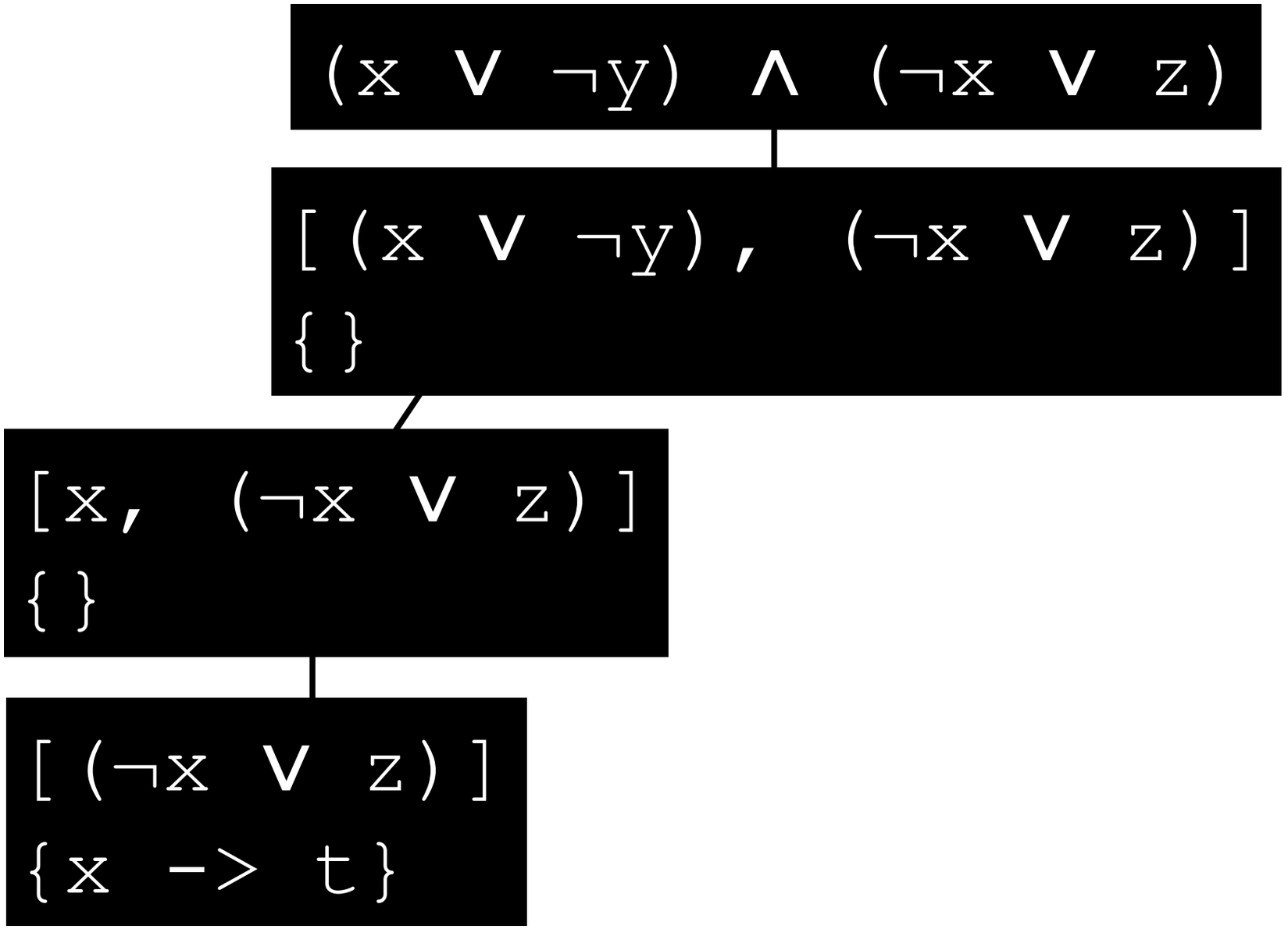
Example 2:

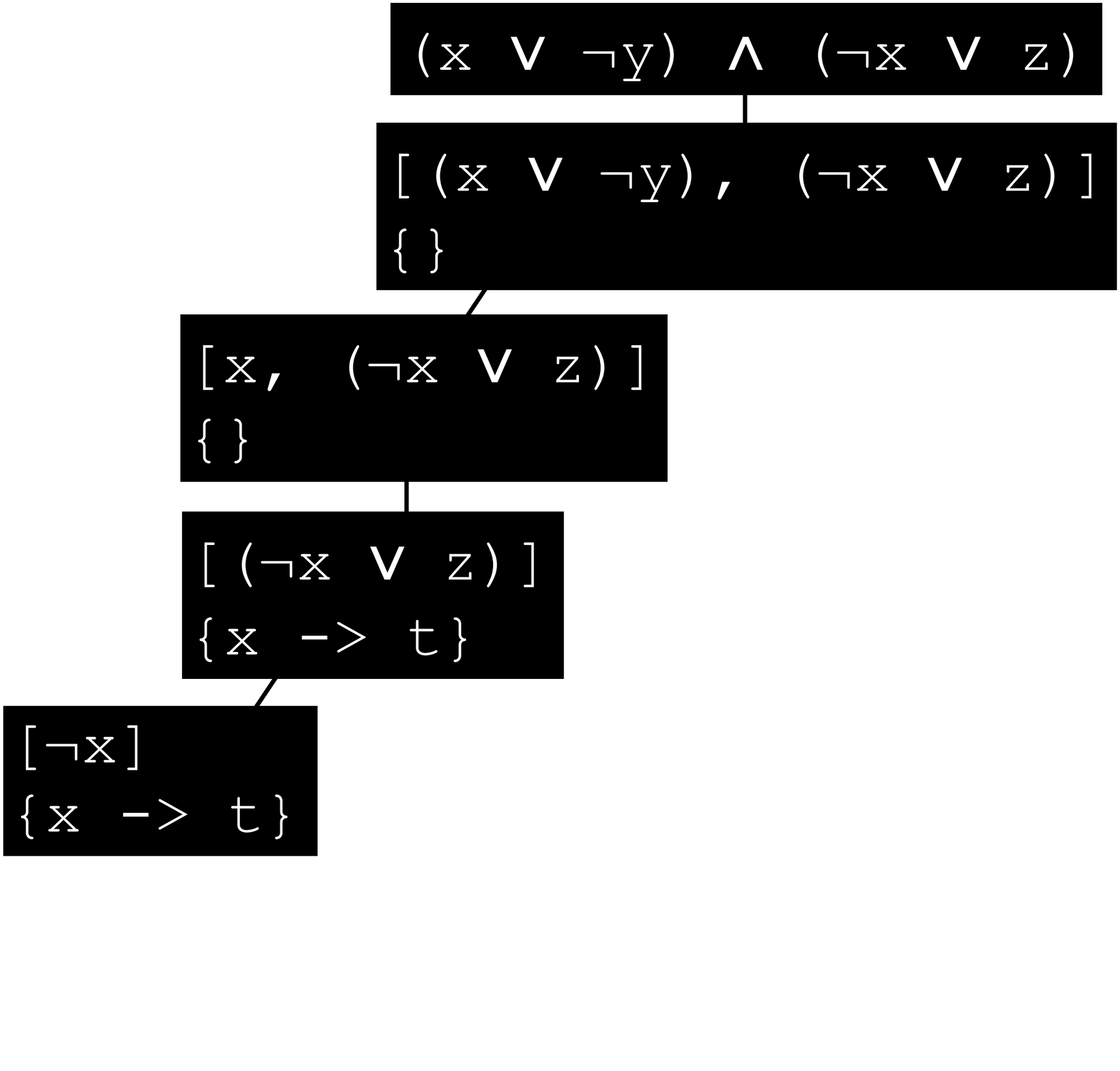
$$(x \lor \neg y) \land (\neg x \lor z)$$

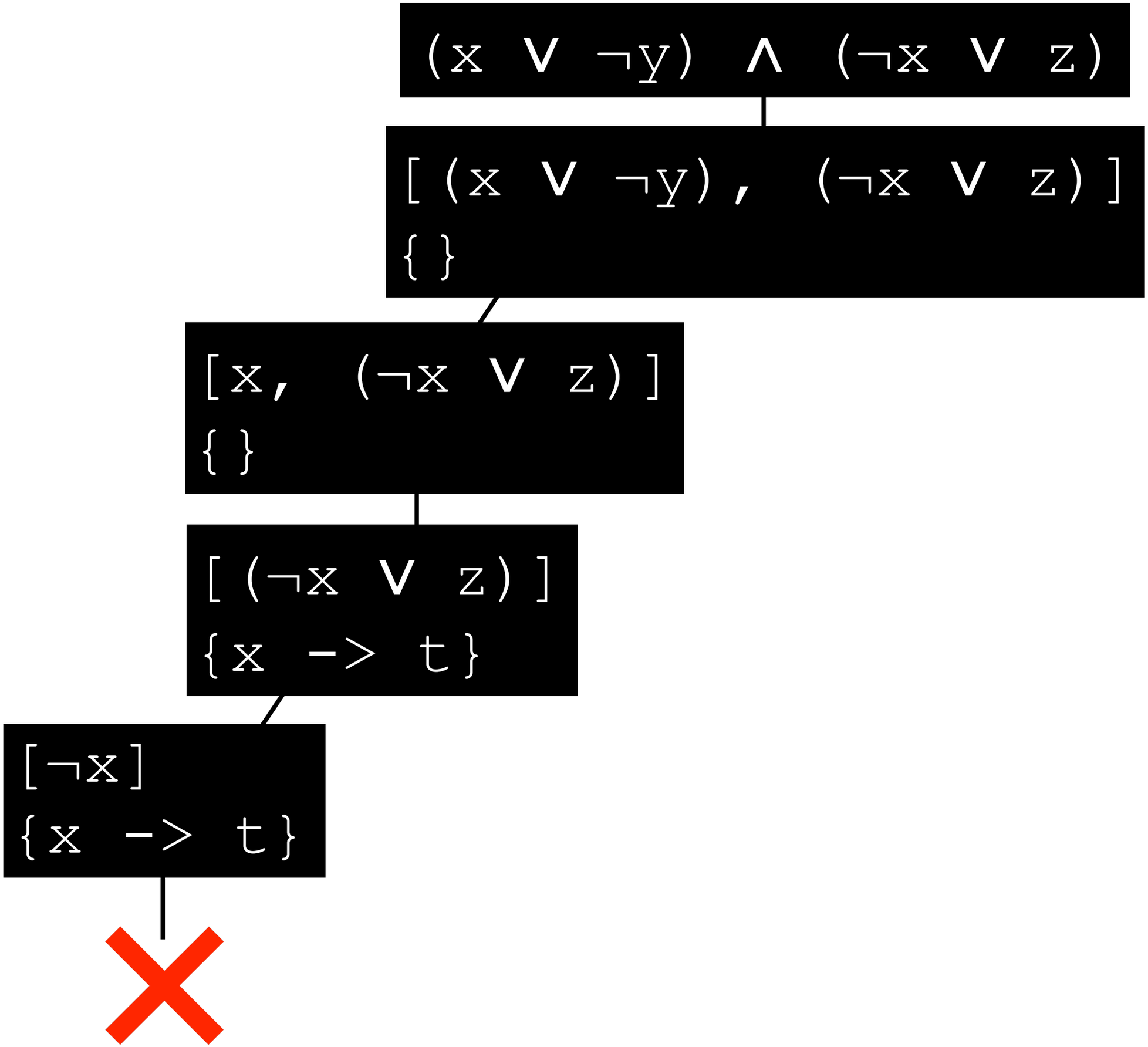
$$(x \lor \neg y) \land (\neg x \lor z)$$

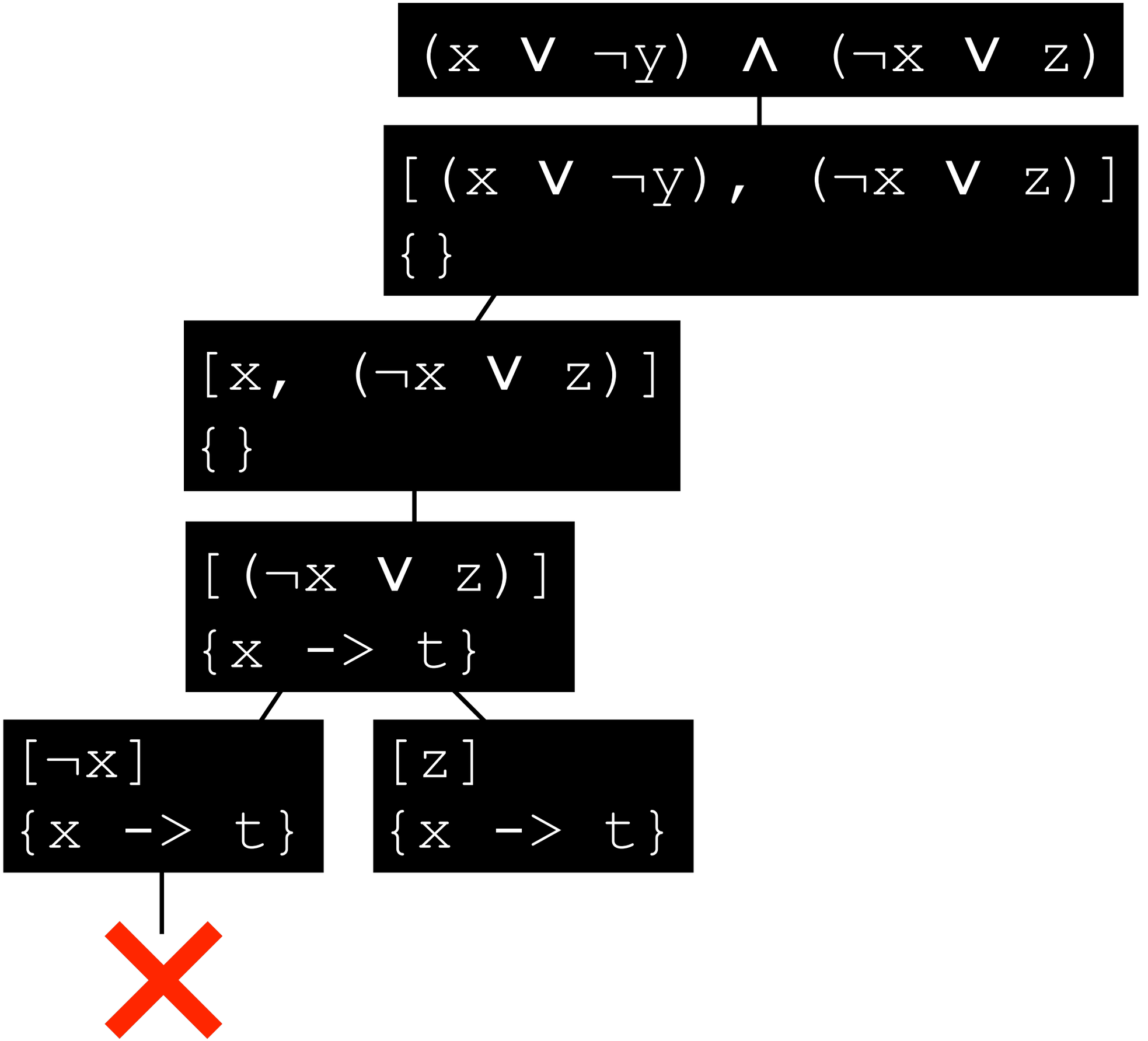

(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}

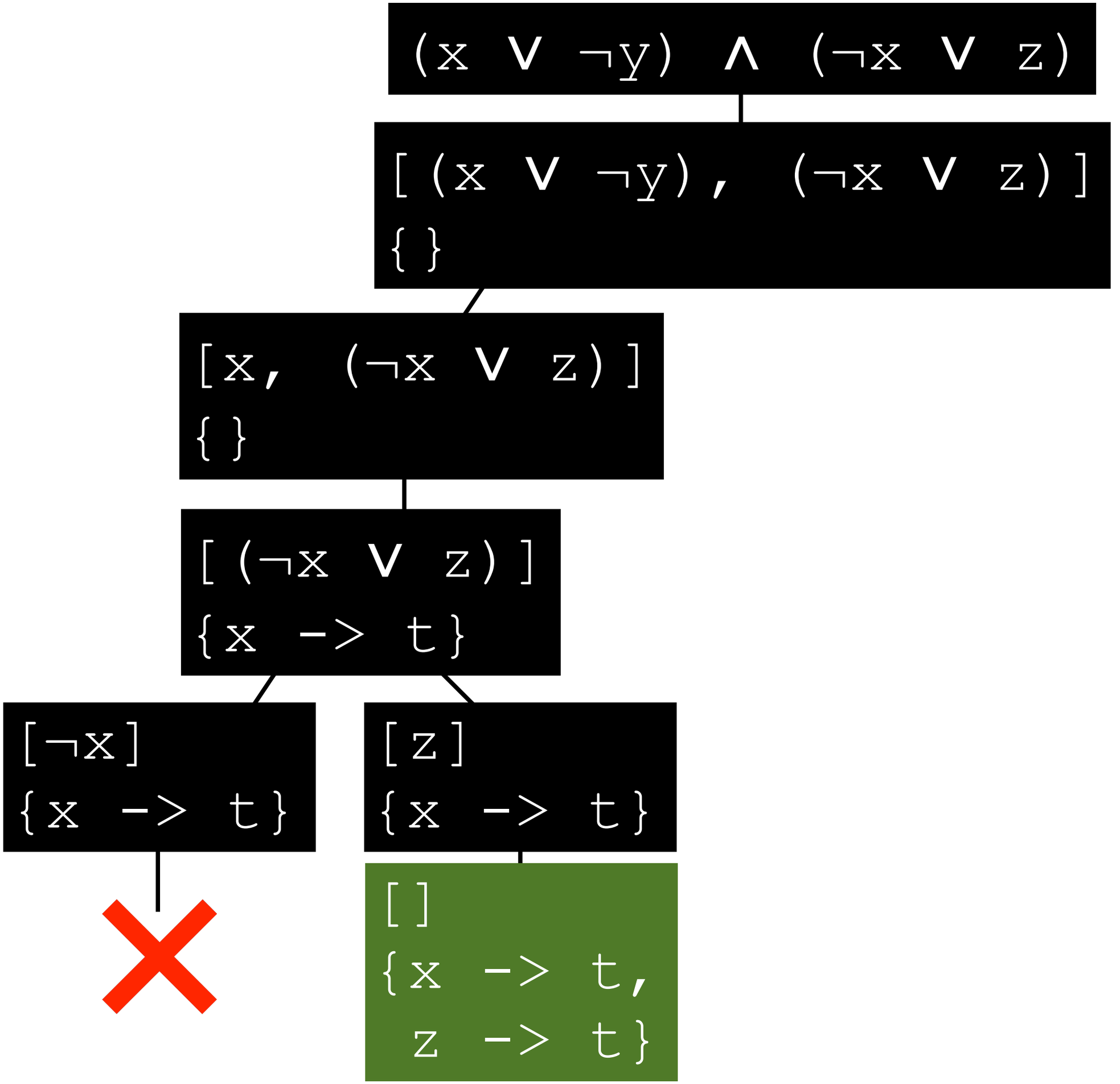

(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}

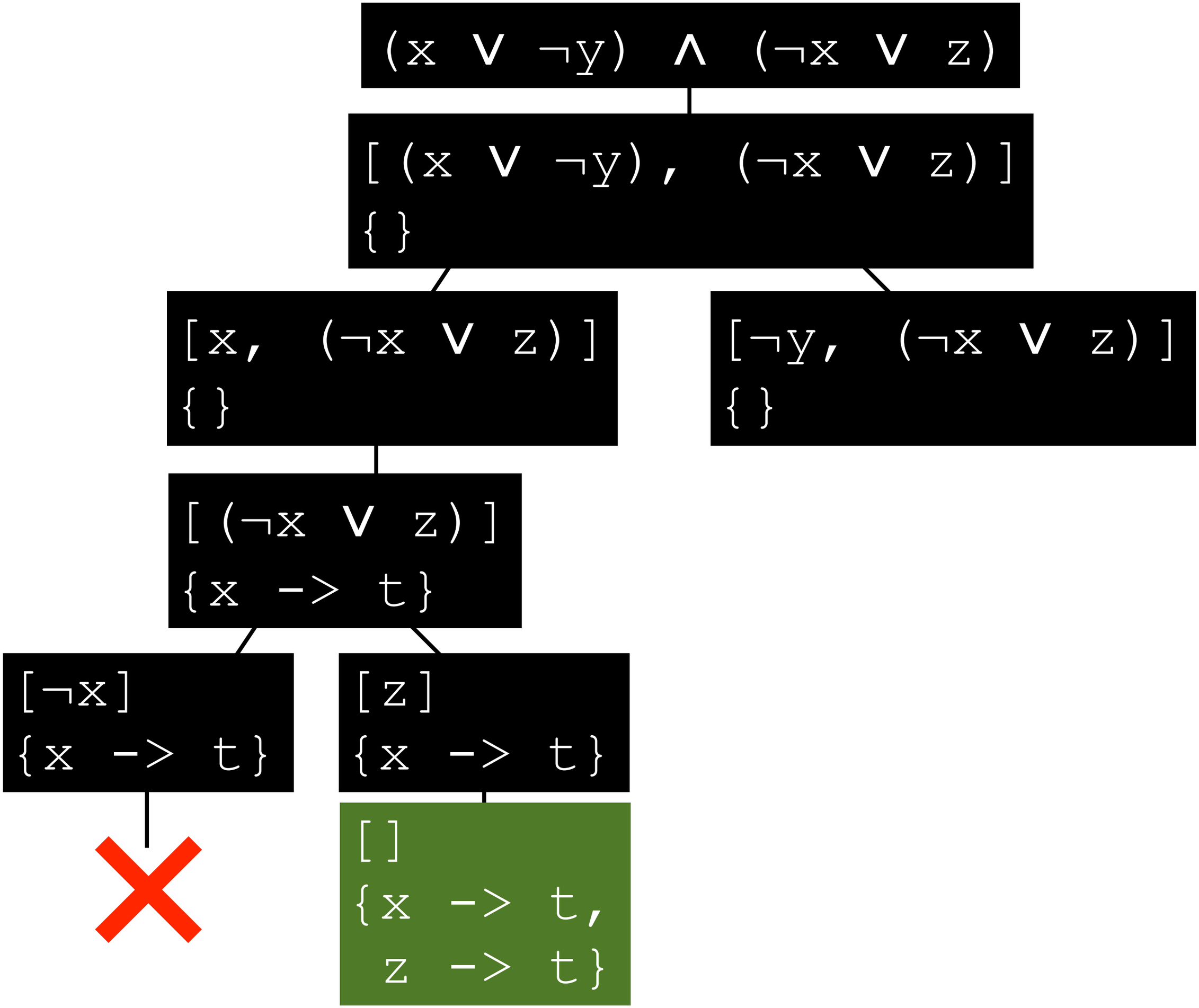

(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}

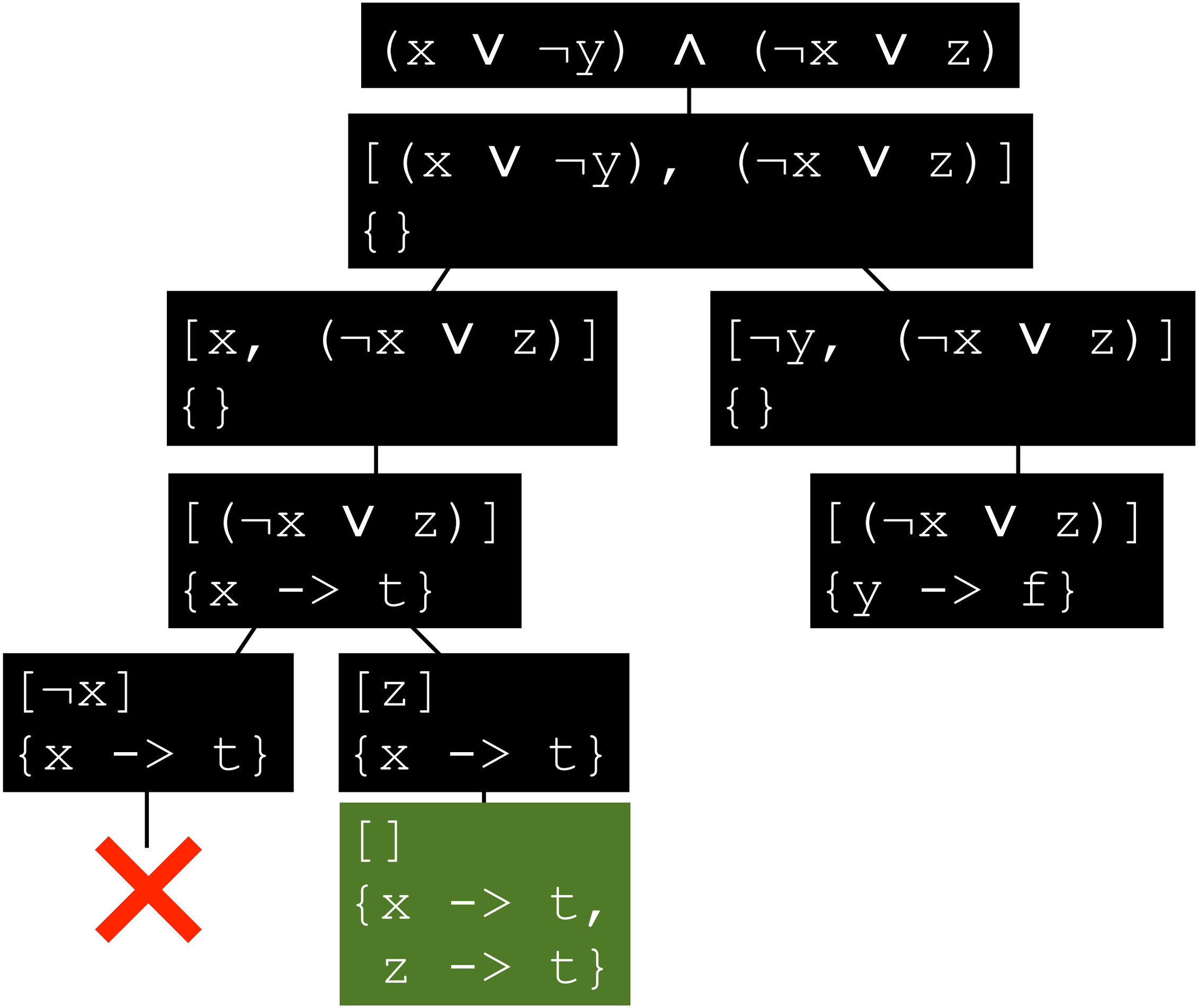

(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[¬x]
{x -> t}

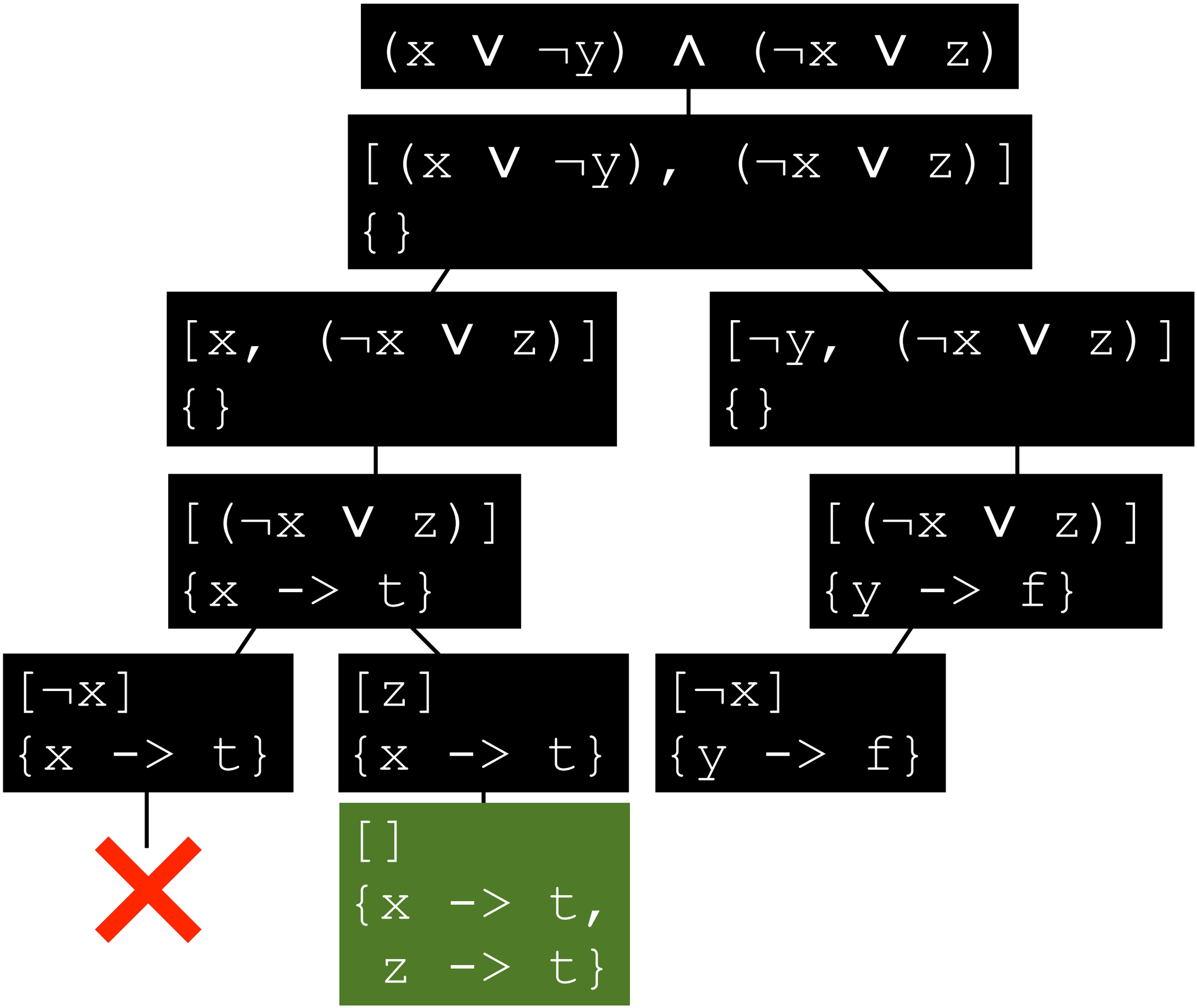

(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[¬x]
{x -> t}

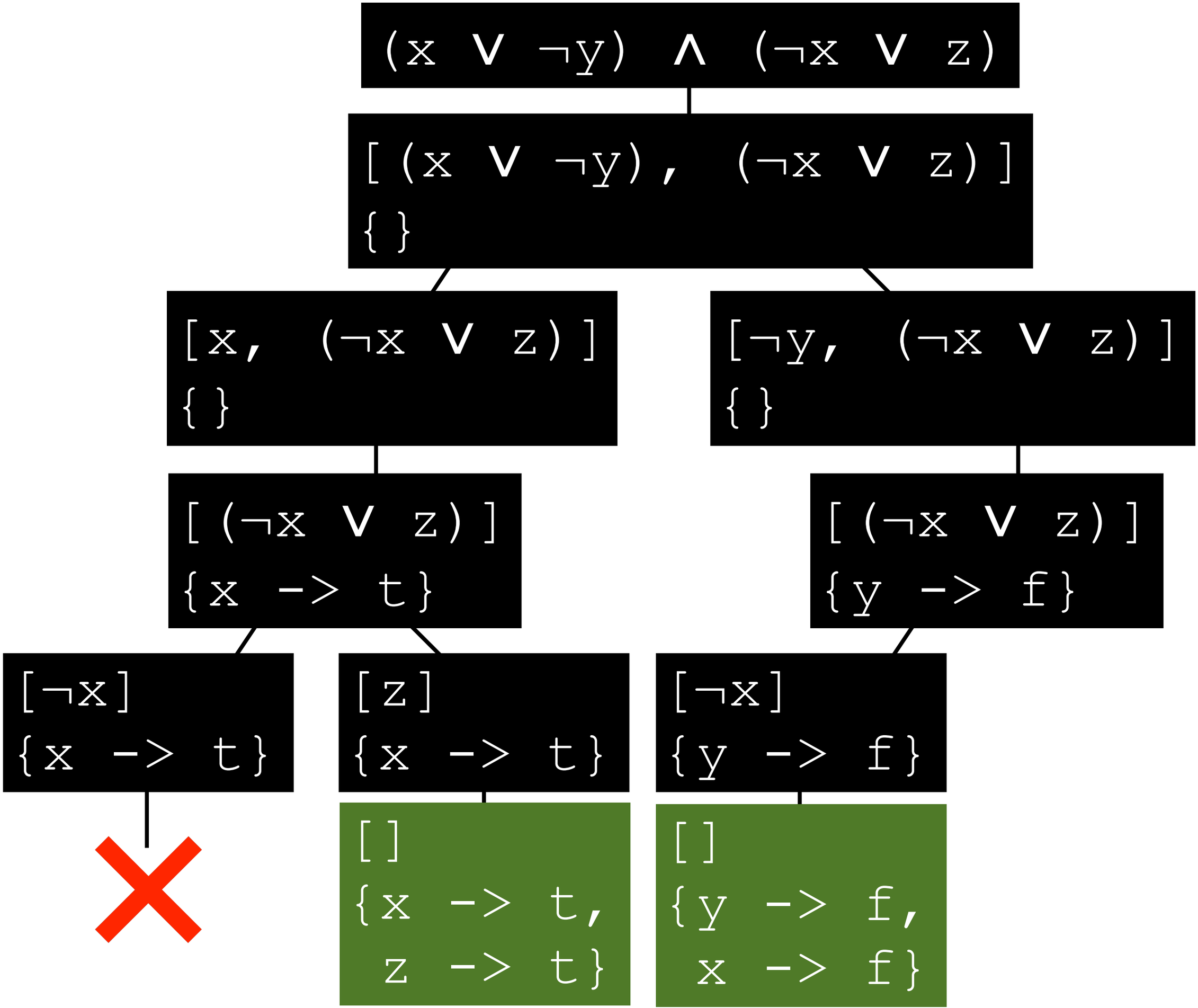

(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[¬x]
{x -> t}
[z]
{x -> t}

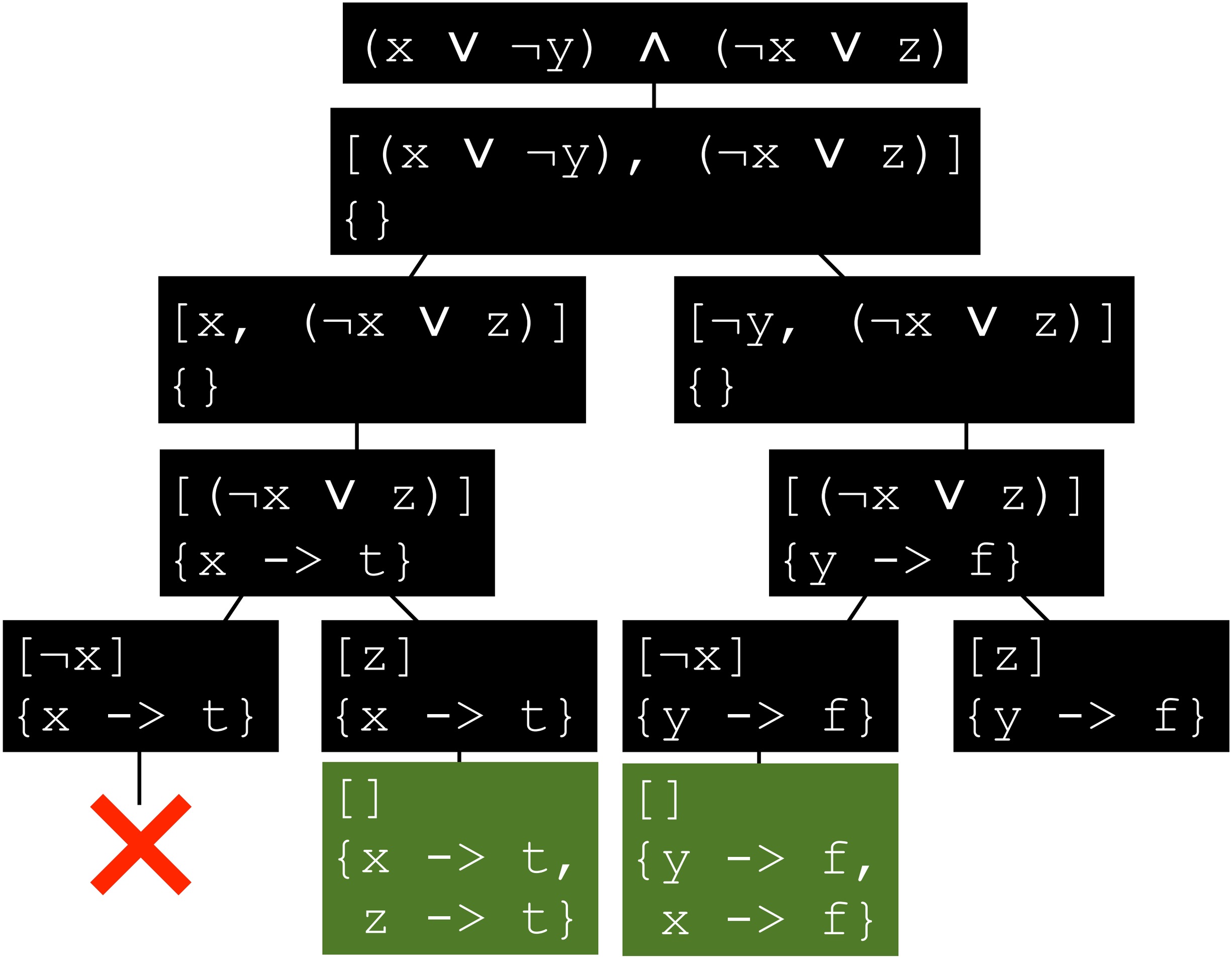

(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[¬x]
{x -> t}
[z]
{x -> t}
[]
{x -> t,
z -> t}

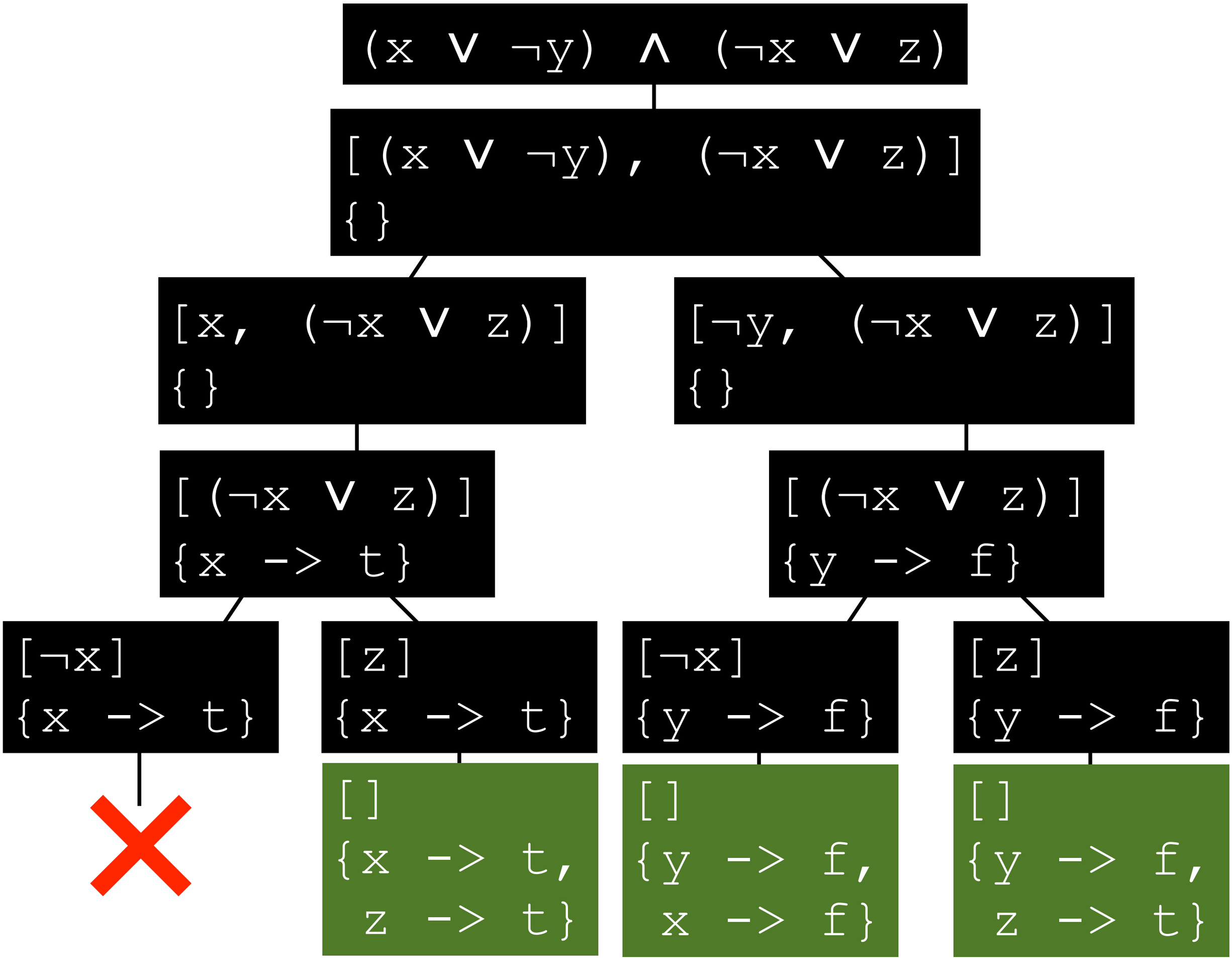

(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[¬y, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[¬x]
{x -> t}
[z]
{x -> t}
[]
{x -> t,
z -> t}


(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[¬y, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[(¬x ∨ z)]
{y -> f}
[¬x]
{x -> t}
[z]
{x -> t}
[]
{x -> t,
z -> t}


(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[¬y, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[(¬x ∨ z)]
{y -> f}
[¬x]
{x -> t}
[z]
{x -> t}
[¬x]
{y -> f}
[]
{x -> t,
z -> t}


(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[¬y, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[(¬x ∨ z)]
{y -> f}
[¬x]
{x -> t}
[z]
{x -> t}
[¬x]
{y -> f}
[]
{x -> t,
z -> t}
[]
{y -> f,
x -> f}


(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[¬y, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[(¬x ∨ z)]
{y -> f}
[¬x]
{x -> t}
[z]
{x -> t}
[¬x]
{y -> f}
[z]
{y -> f}
[]
{x -> t,
z -> t}
[]
{y -> f,
x -> f}


(x ∨ ¬y) ∧ (¬x ∨ z)
[(x ∨ ¬y), (¬x ∨ z)]
{}
[x, (¬x ∨ z)]
{}
[¬y, (¬x ∨ z)]
{}
[(¬x ∨ z)]
{x -> t}
[(¬x ∨ z)]
{y -> f}
[¬x]
{x -> t}
[z]
{x -> t}
[¬x]
{y -> f}
[z]
{y -> f}
[]
{x -> t,
z -> t}
[]
{y -> f,
x -> f}
[]
{y -> f,
z -> t}

Exercise: Second Side of SAT Sheet