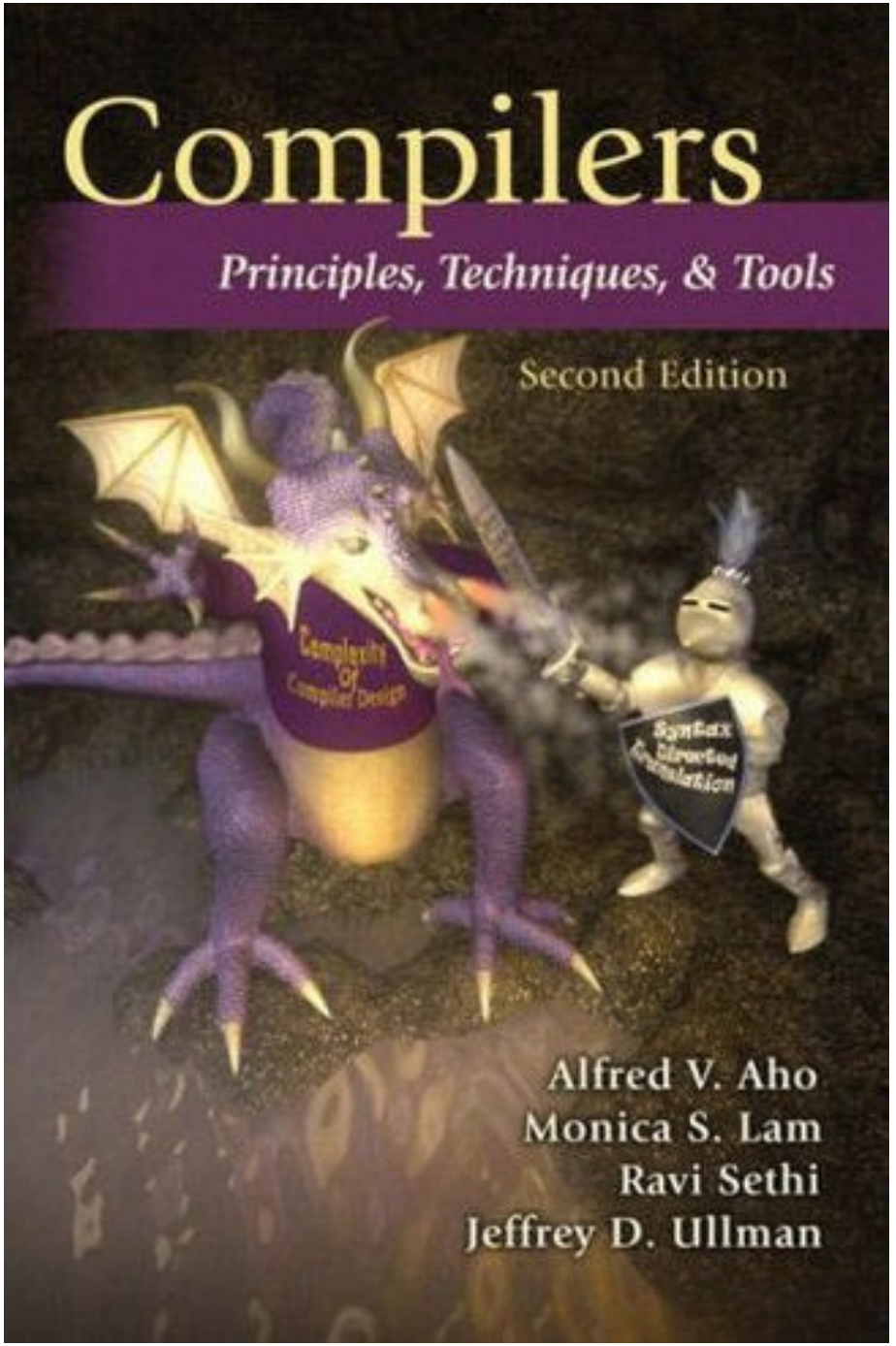
Welcome to CS143: Compilers

- Course Information
- Why Study Compilers?
- A Quick History of Compilers
- The Structure of a Compiler


Compilers
Principles, Techniques, & Tools
Second Edition
Alfred V. Aho
Monica S. Lam
Ravi Sethi
Jeffrey D. Ullman

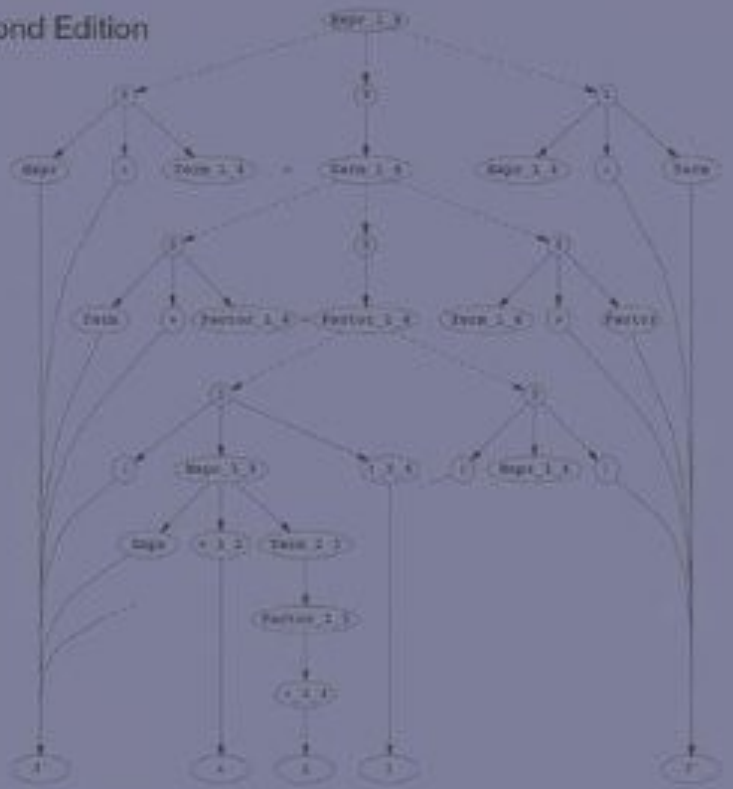
MONOGRAPHS IN COMPUTER SCIENCE

PARSING TECHNIQUES

A Practical Guide

Dick Grune
Ceriel J.H. Jacobs

Second Edition



Springer

A Word on the Honor Code...

Why Study Compilers?

- Build a **large, ambitious software system**.
- See theory **come to life**.
- Learn how to **build programming languages**.
- Learn **how programming languages work**.
- Learn **tradeoffs in language design**.

A Short History of Compilers

- First, there was nothing.
- Then, there was machine code.
- Then, there were assembly languages.
- Programming expensive; 50% of costs for machines went into programming.

High-Level Languages

Image: http://upload.wikimedia.org/wikipedia/commons/thumb/5/55/Grace_Hopper.jpg/300px-Grace_Hopper.jpg
http://www.nytimes.com/2007/03/20/business/20backus.html

High-Level Languages

Rear Admiral **Grace Hopper**, inventor of A-0, COBOL, and the term "compiler."

Image: http://upload.wikimedia.org/wikipedia/commons/thumb/5/55/Grace_Hopper.jpg/300px-Grace_Hopper.jpg
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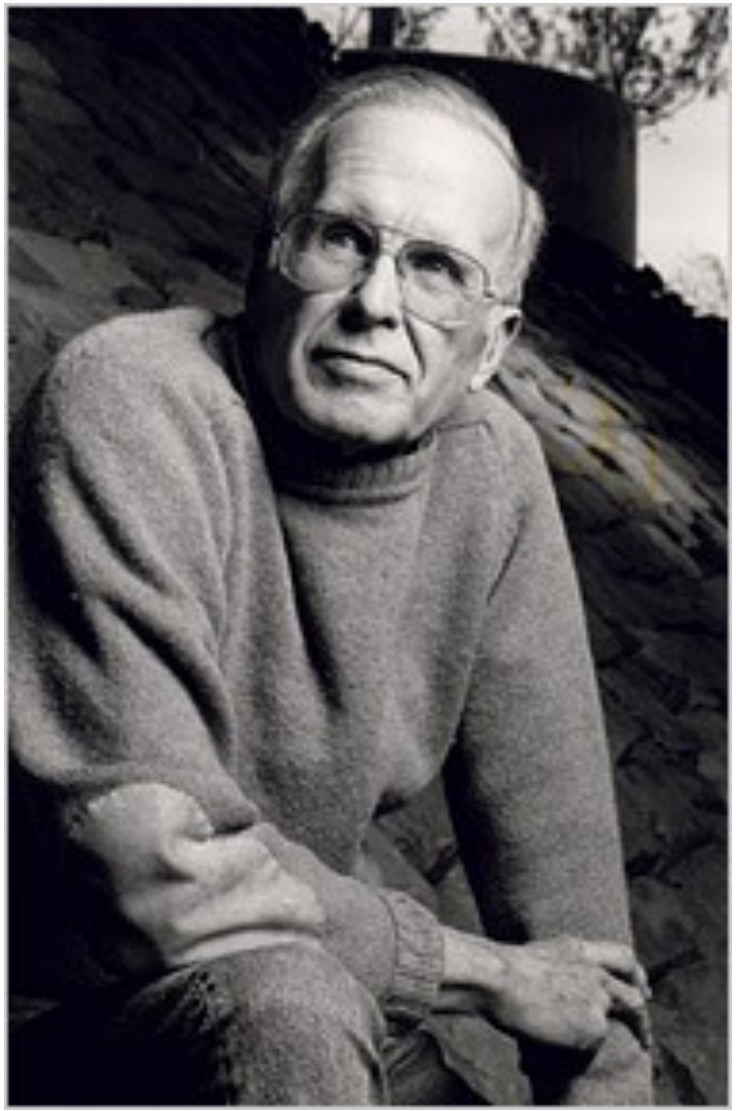
High-Level Languages



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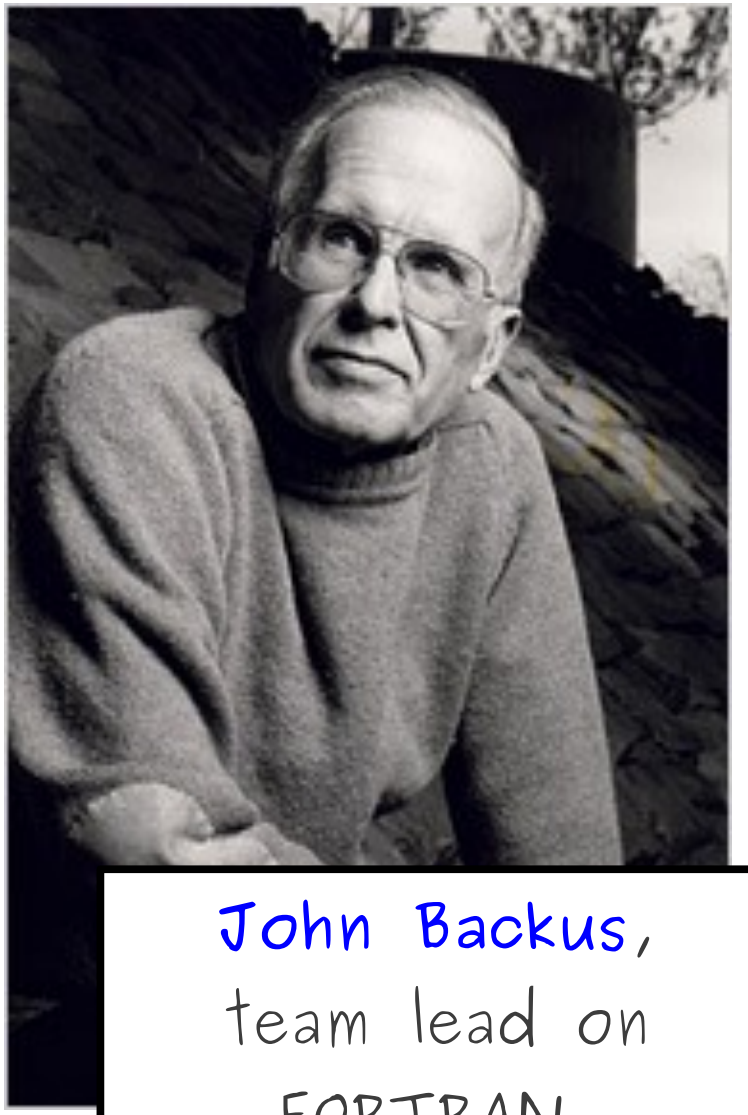
High-Level Languages



John Backus,
team lead on
FORTRAN.

Image: http://upload.wikimedia.org/wikipedia/commons/thumb/5/55/[illegible]er.jpg
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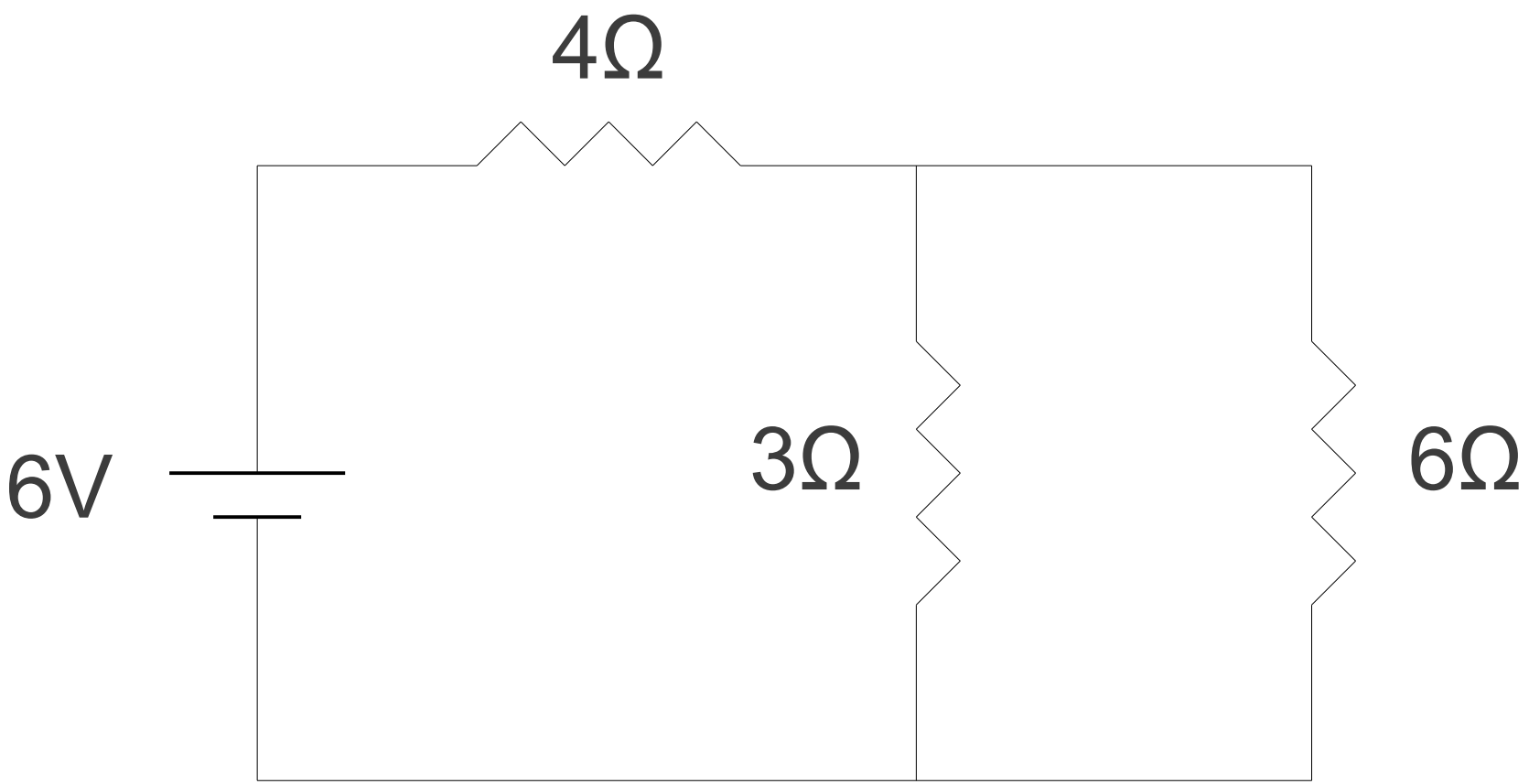
How does a compiler work?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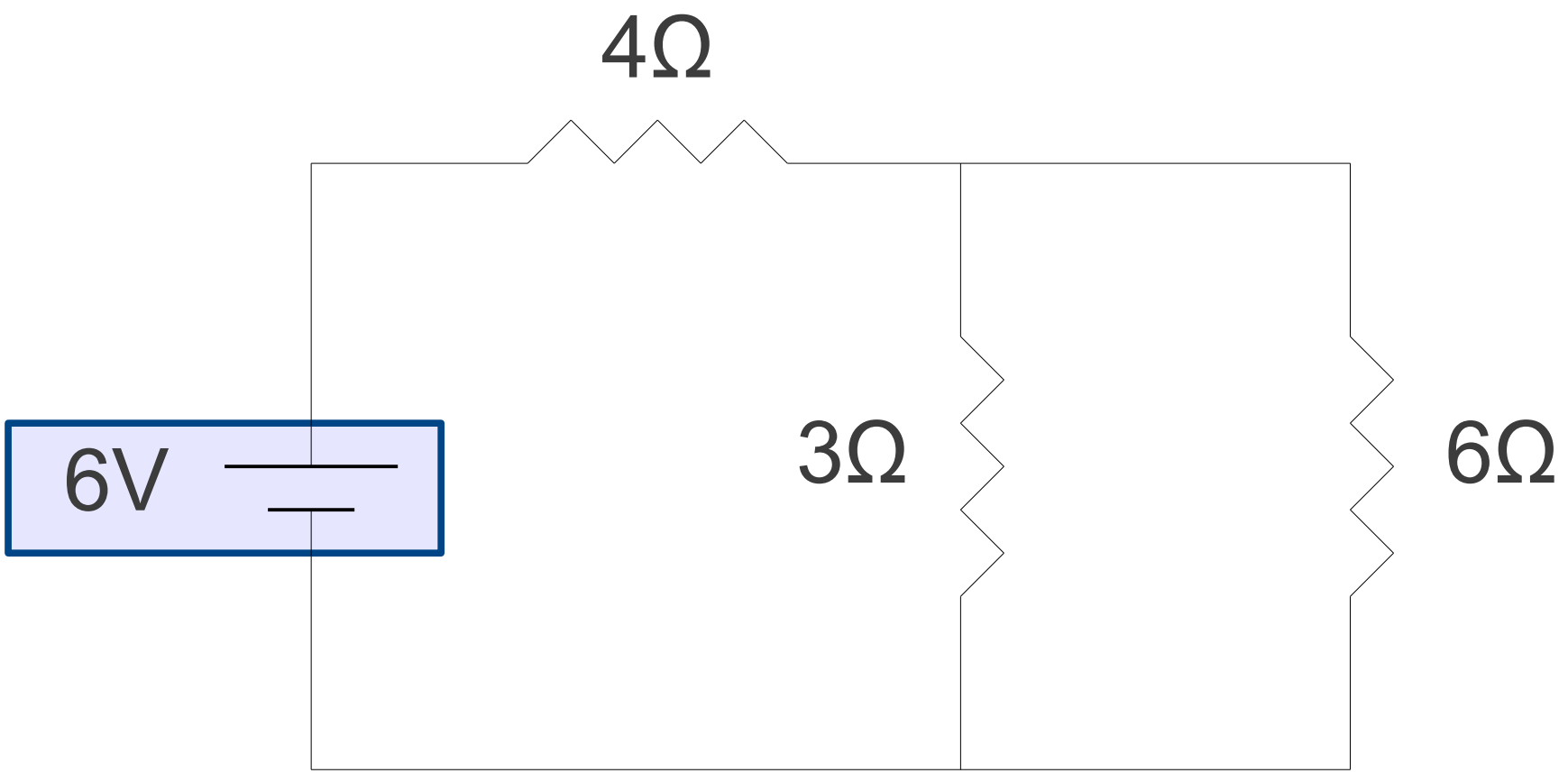
6V
3Ω
6Ω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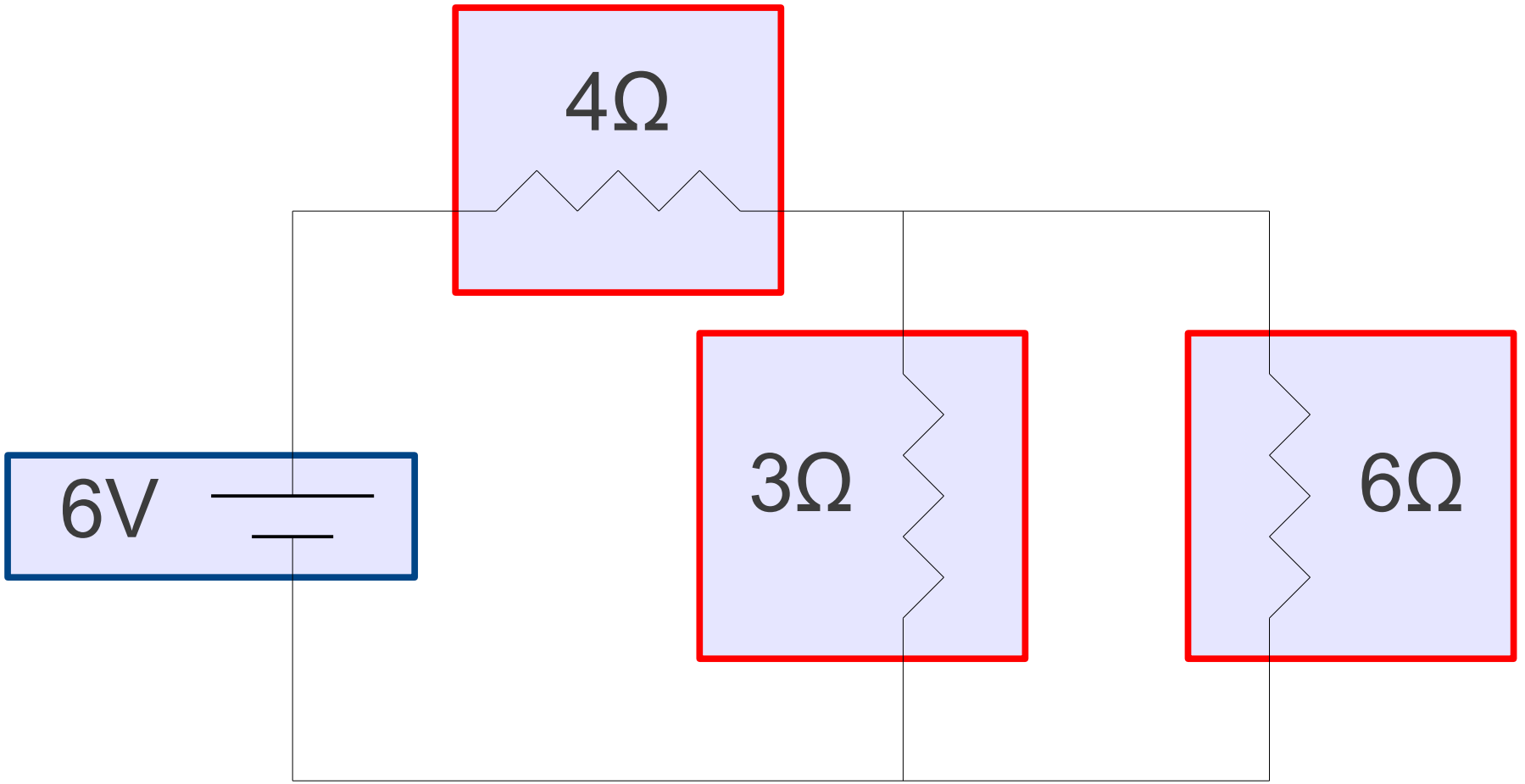
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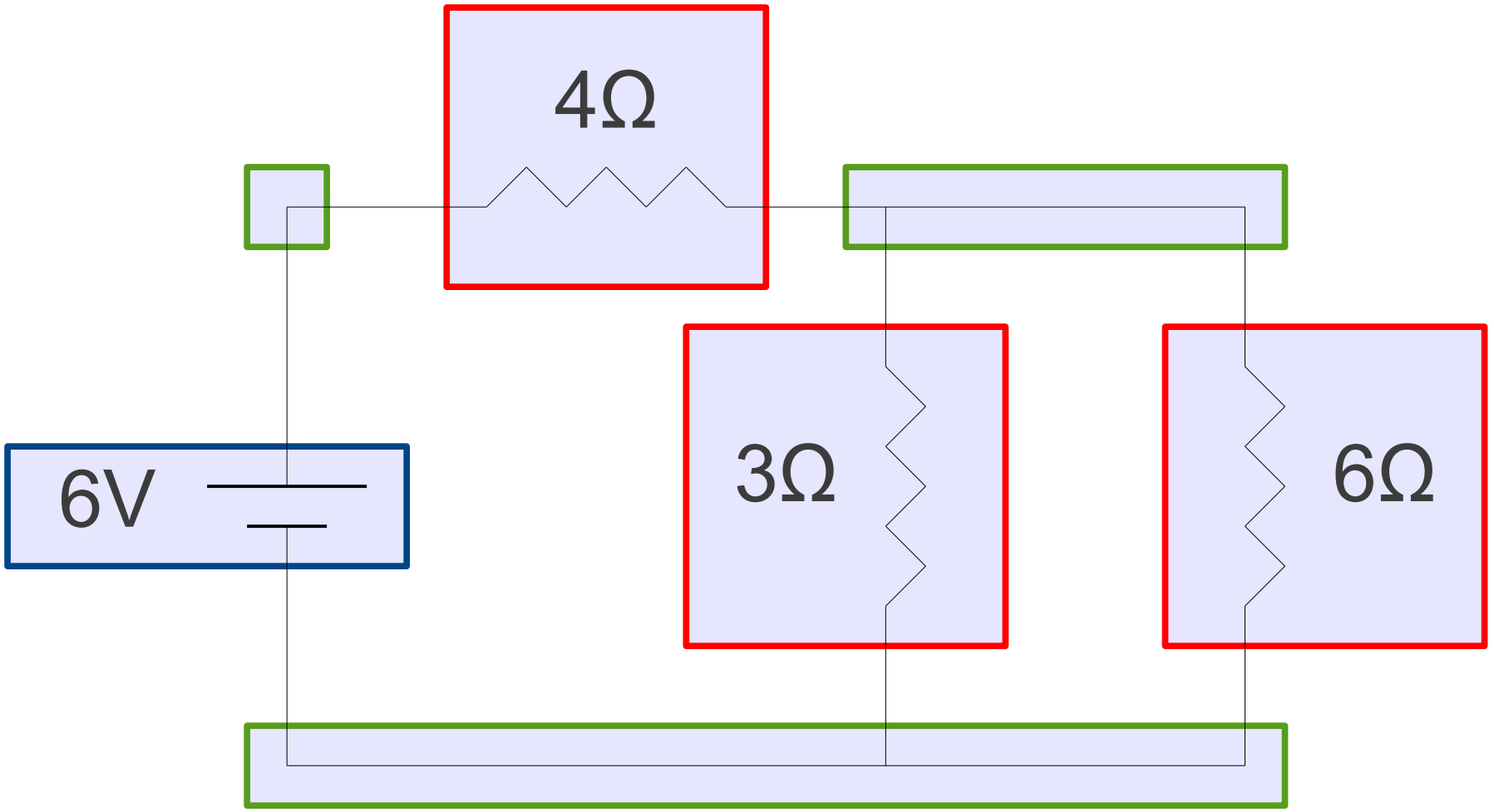
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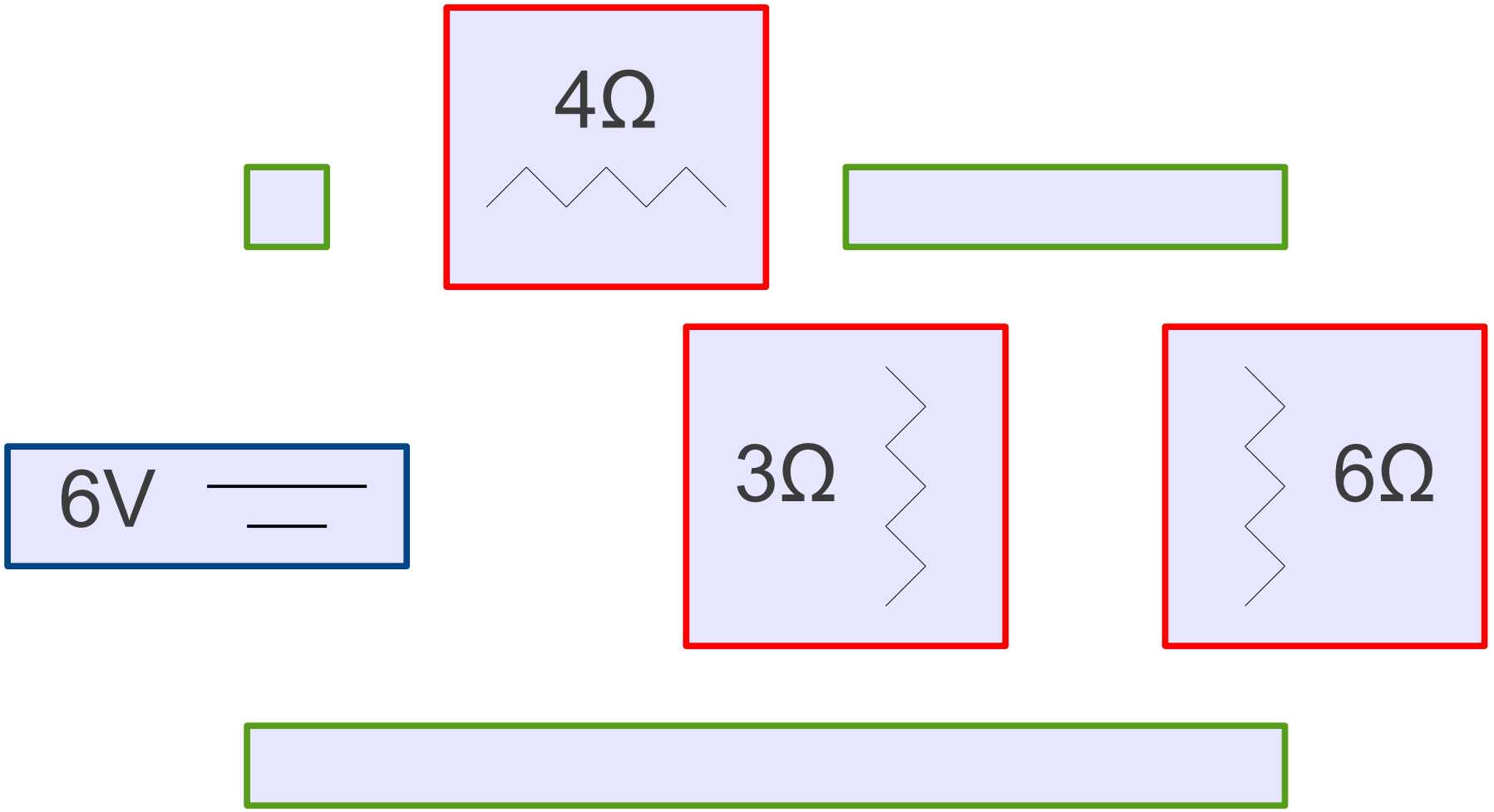
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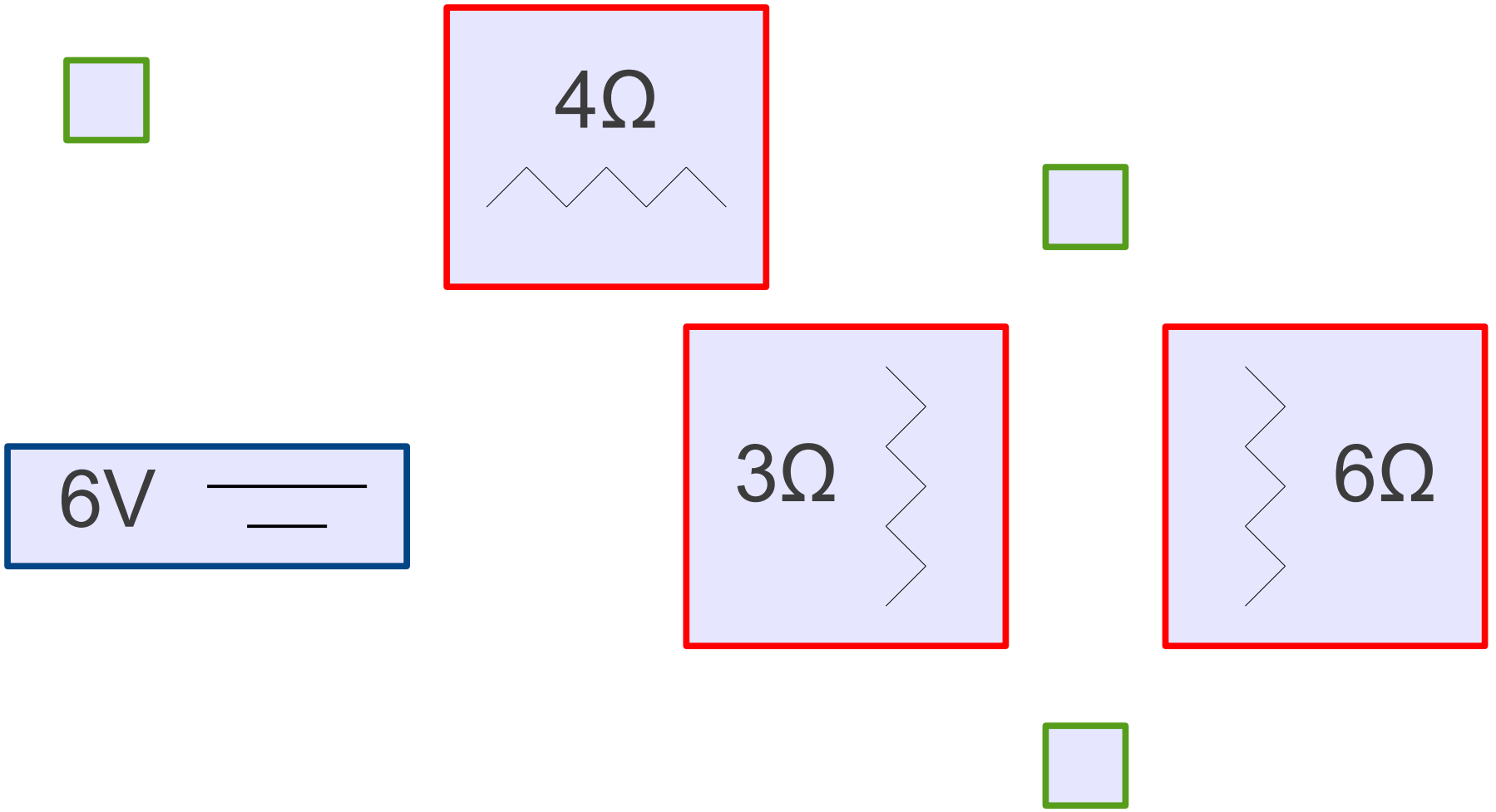
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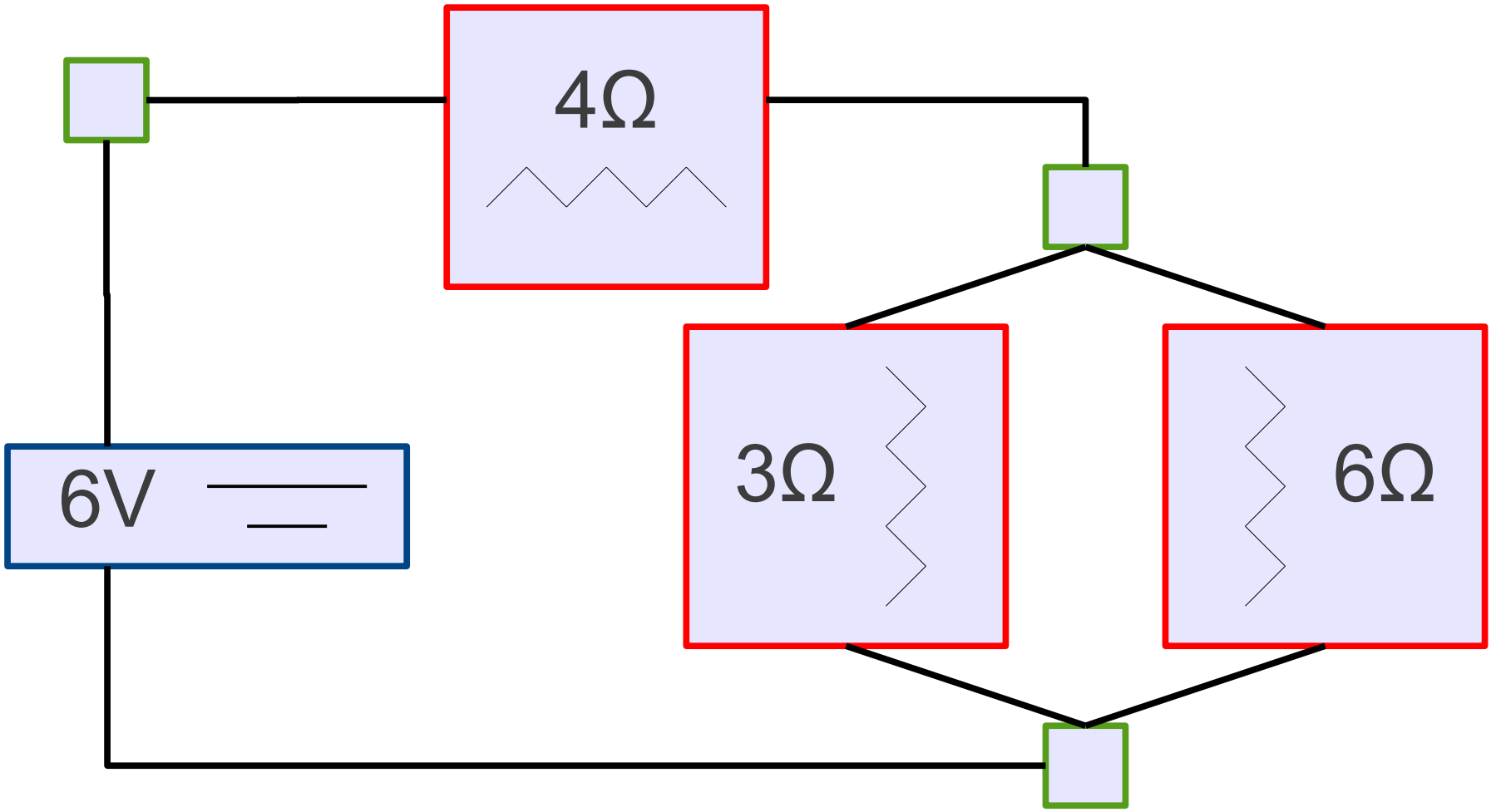
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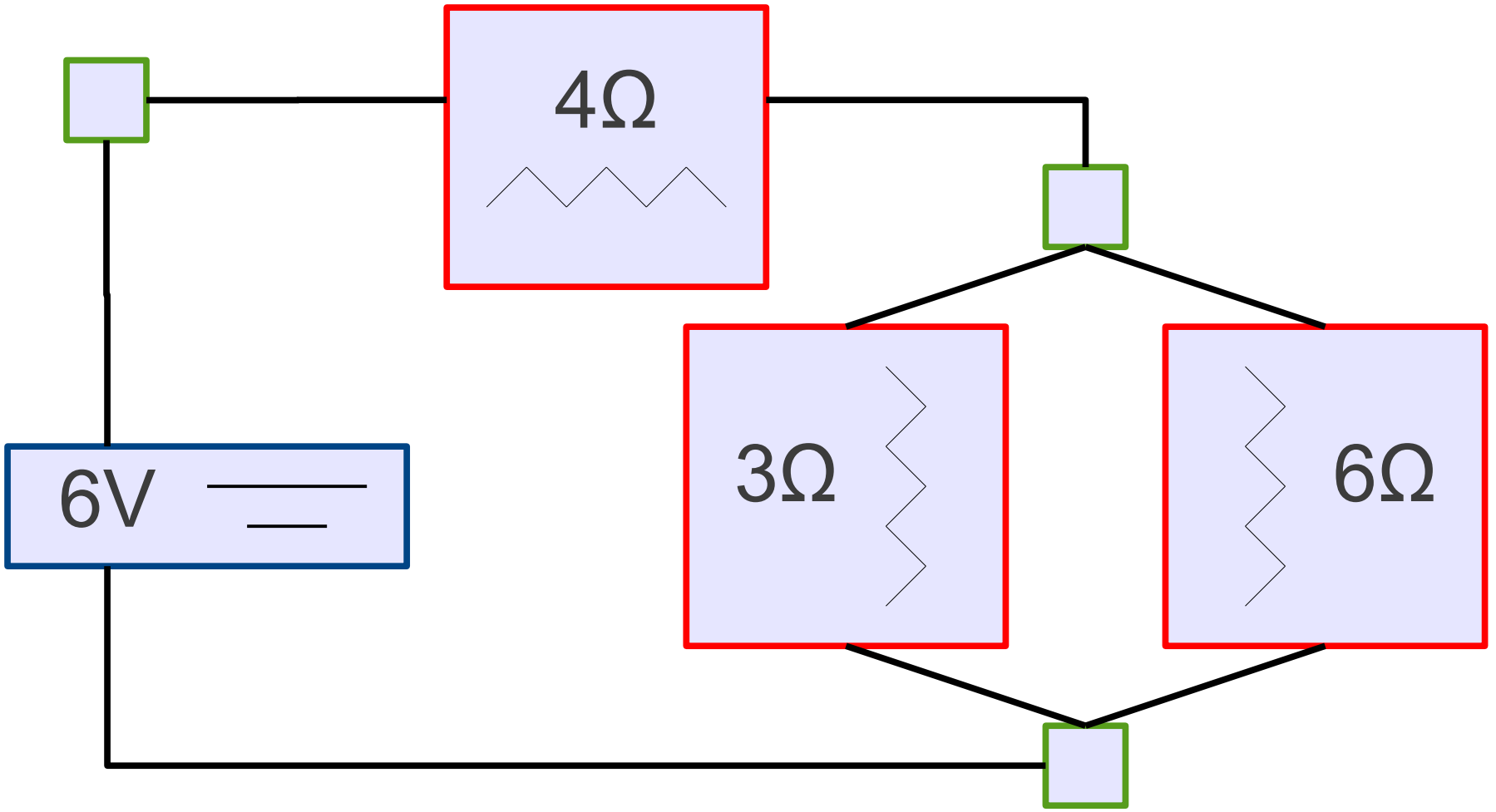
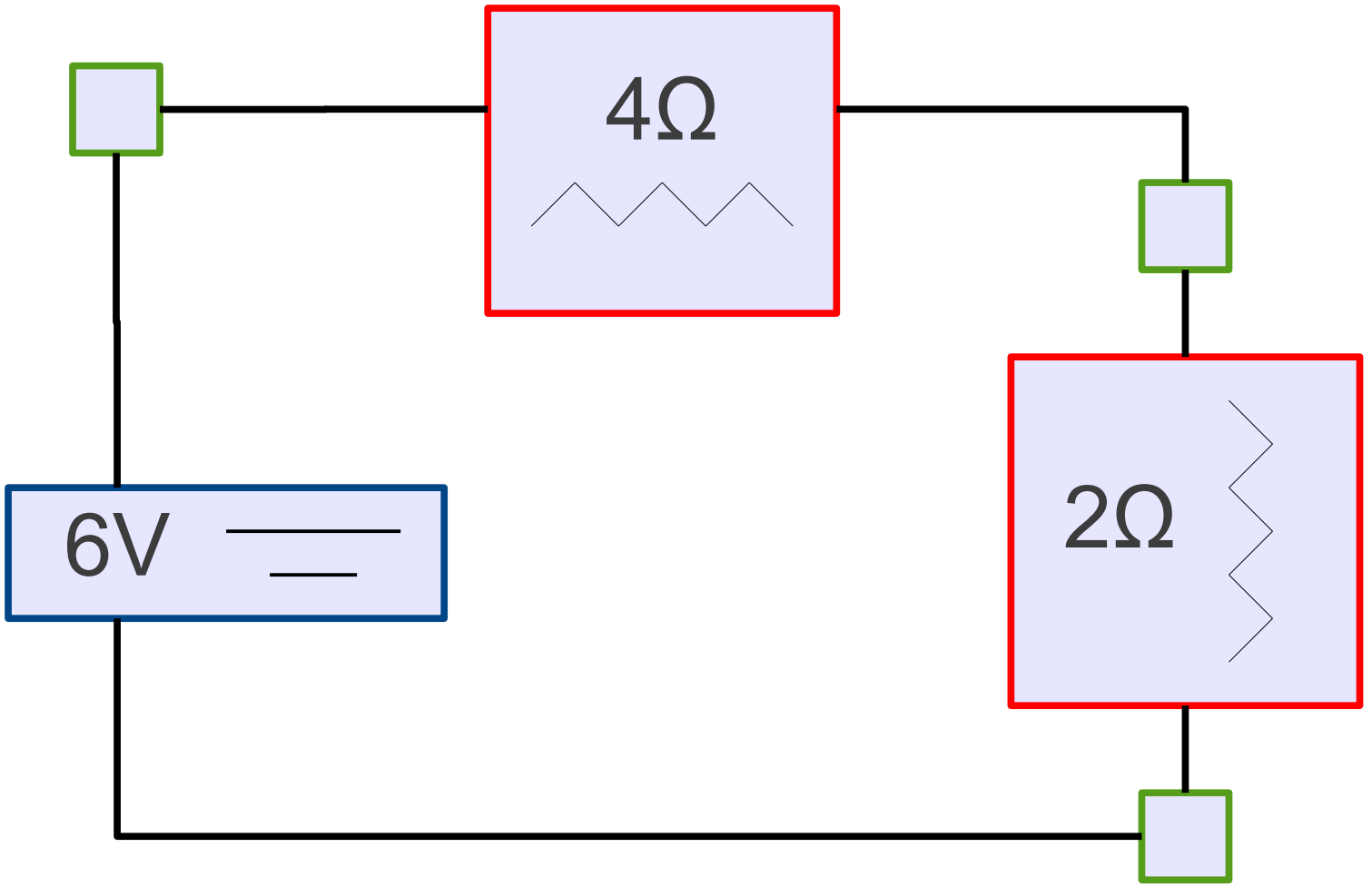


$$\frac{1}{\frac{1}{3\,\Omega}+\frac{1}{6\,\Omega}}=2\,\Omega$$



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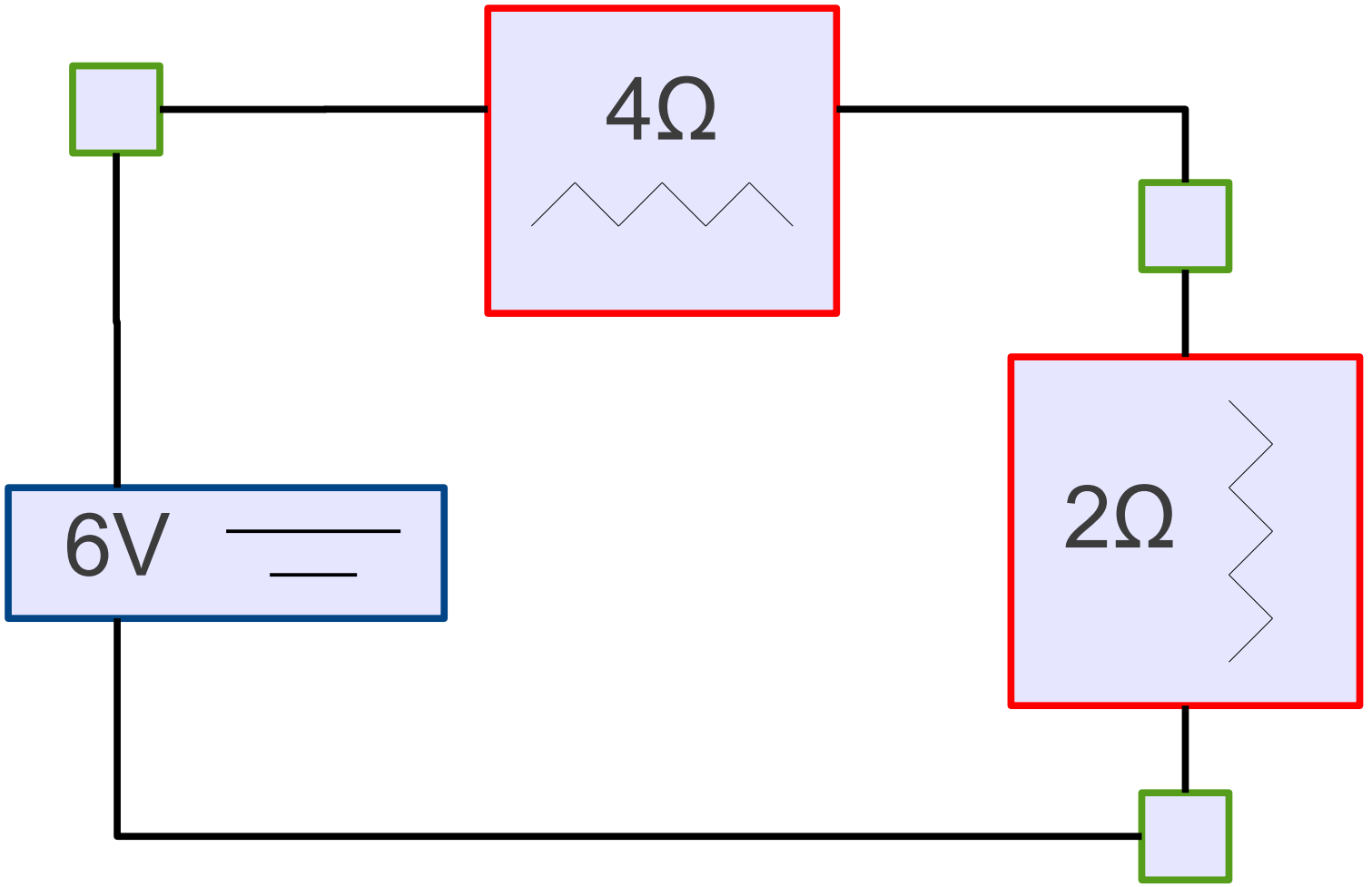
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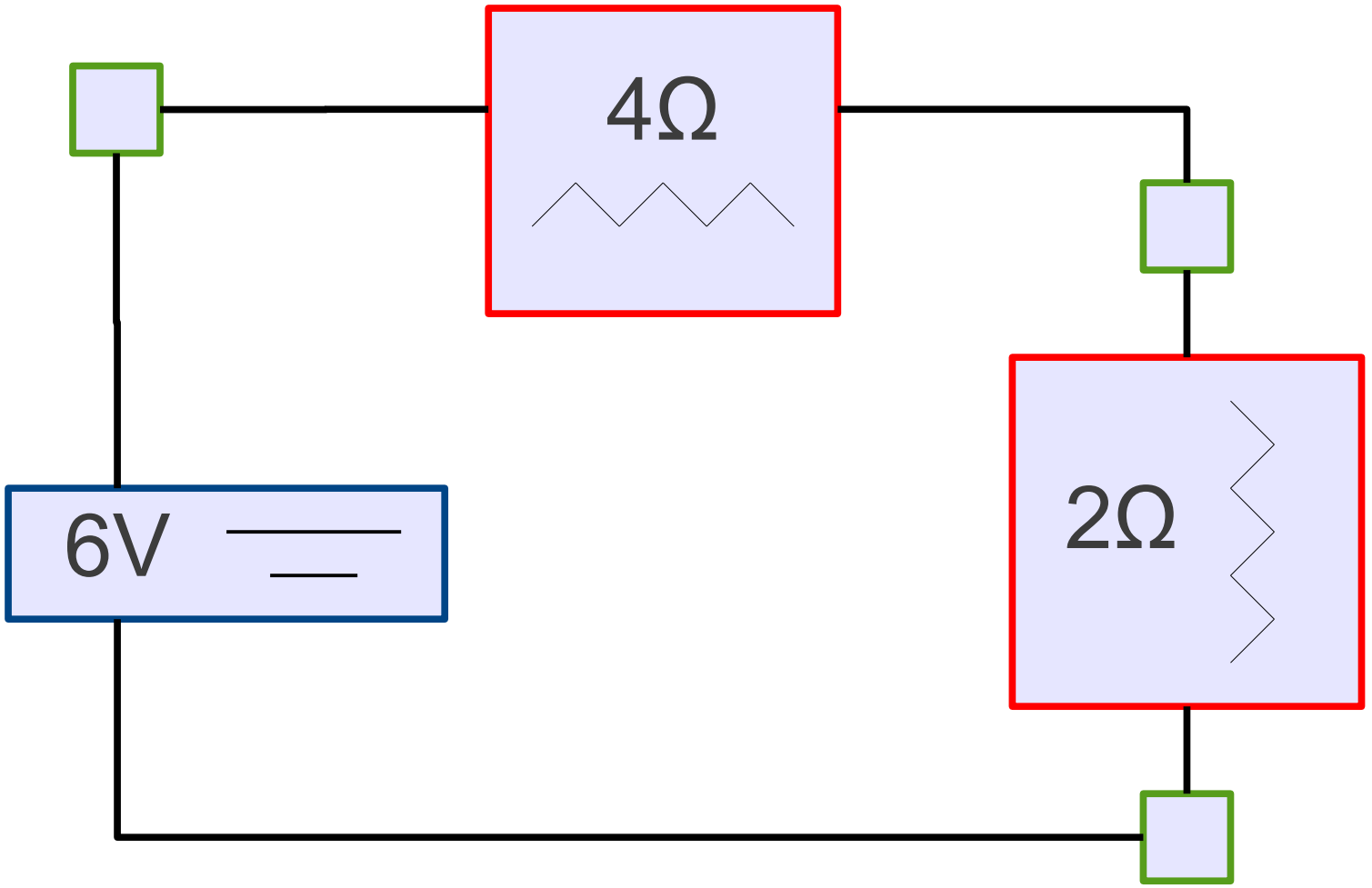
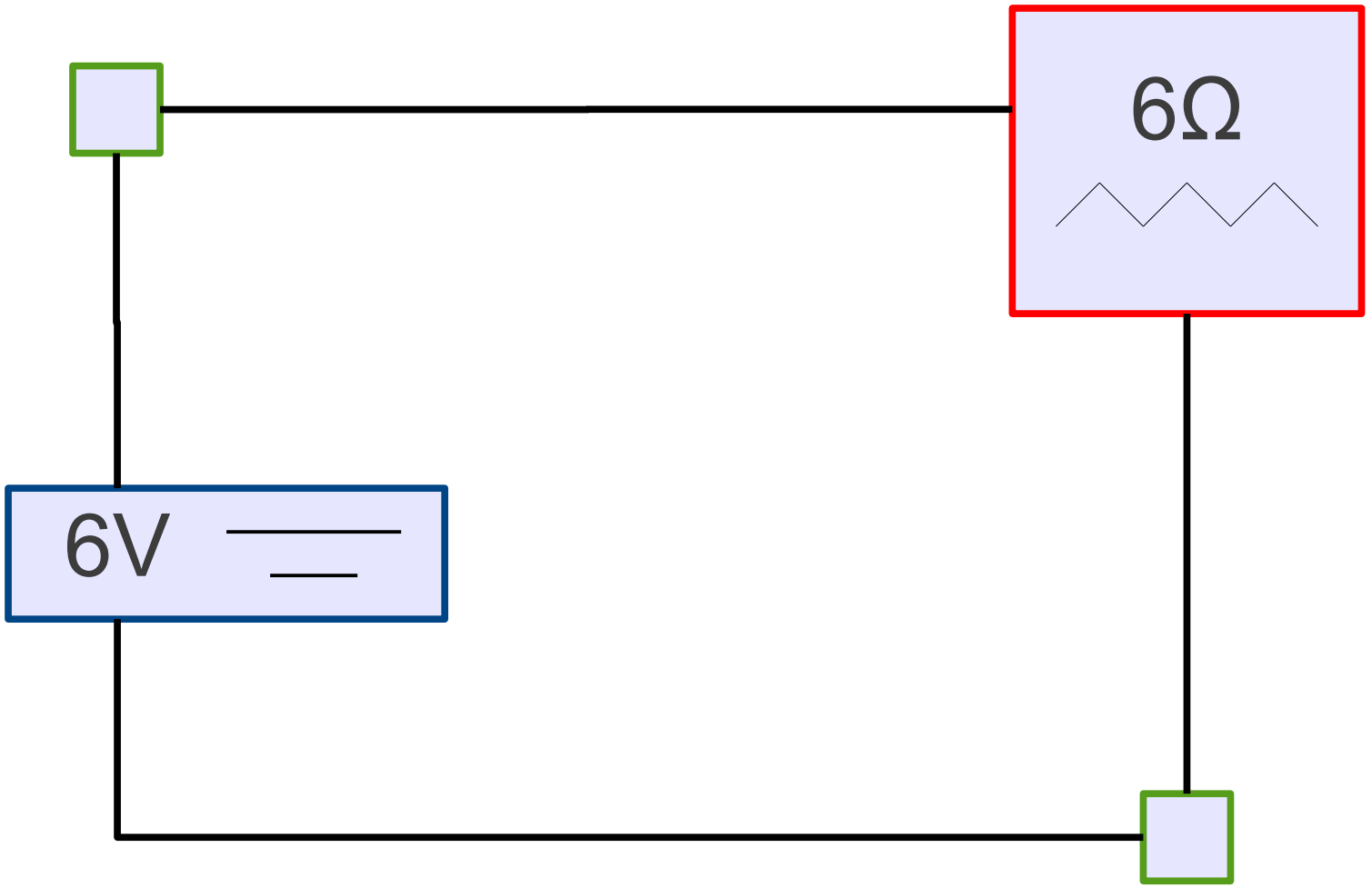


$$4\,\Omega + 2\,\Omega = 6\,\Omega$$



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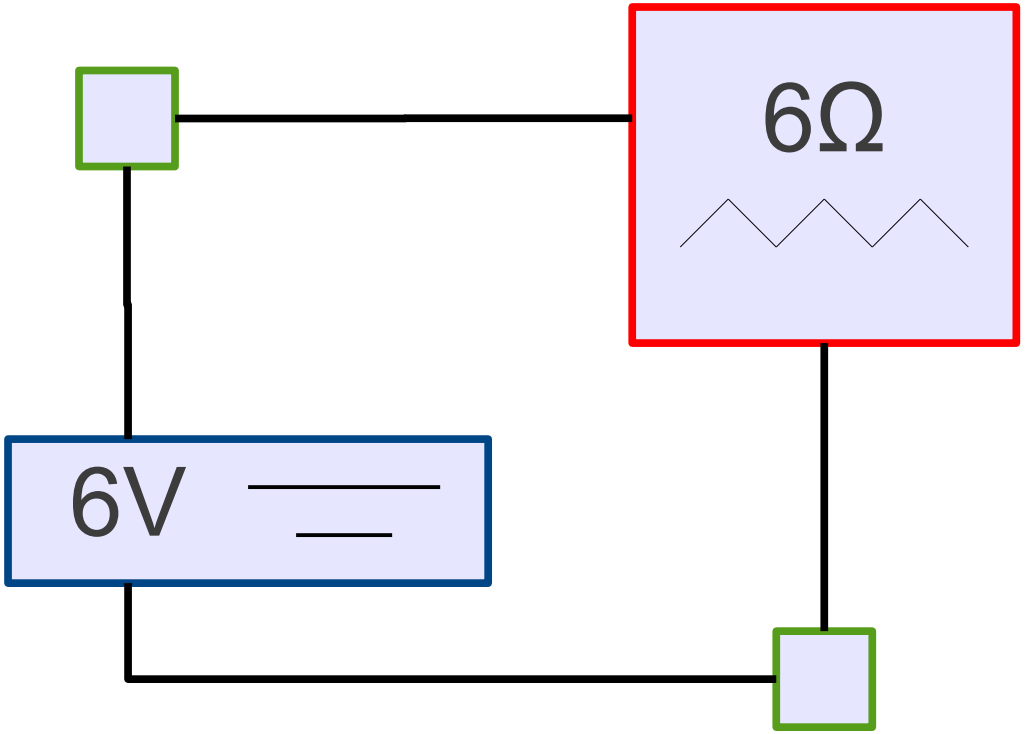
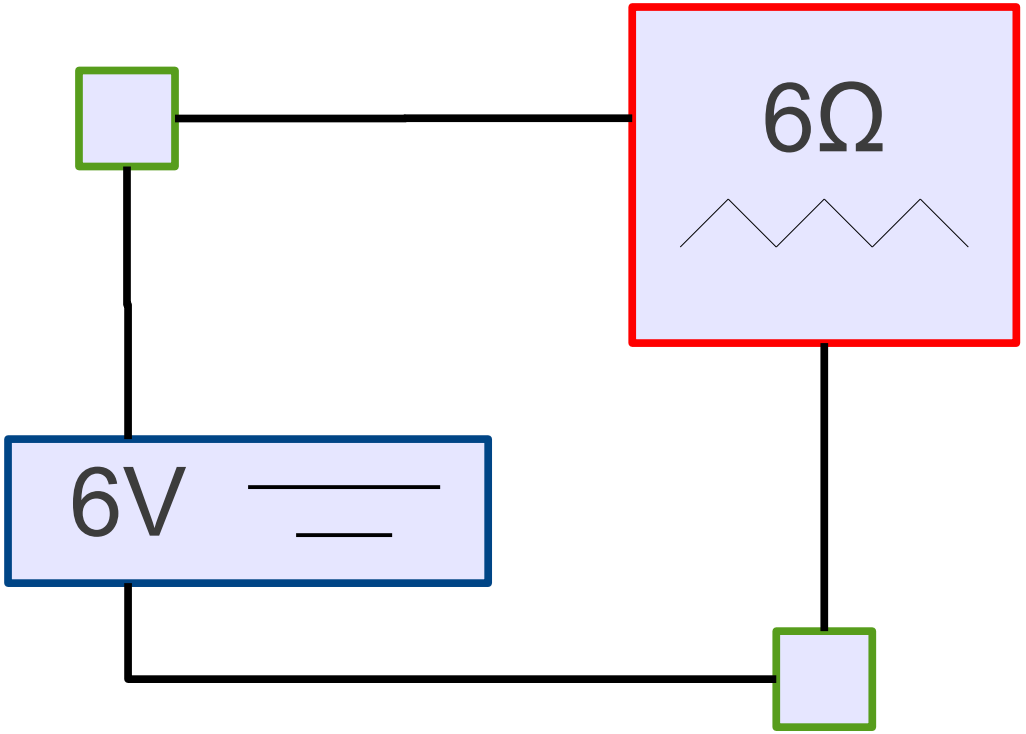

6Ω
6V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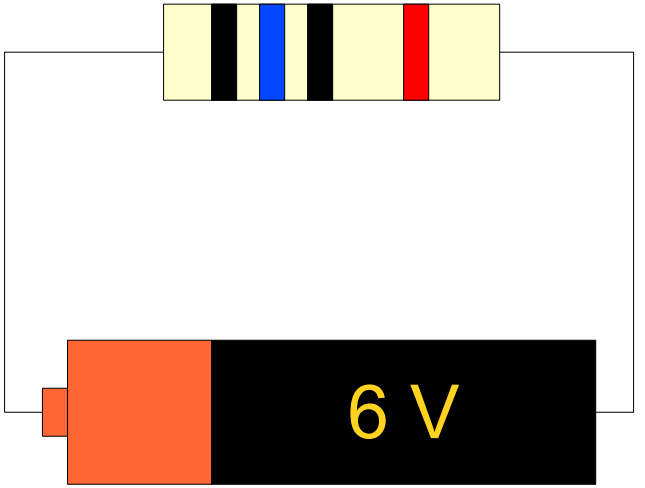
6V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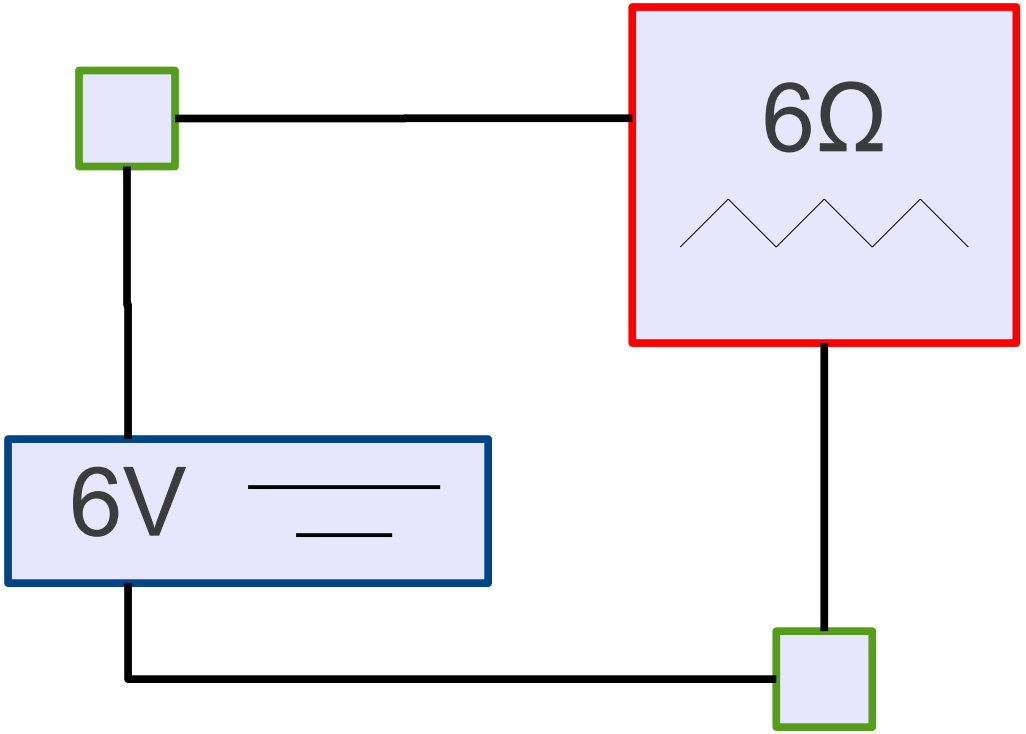
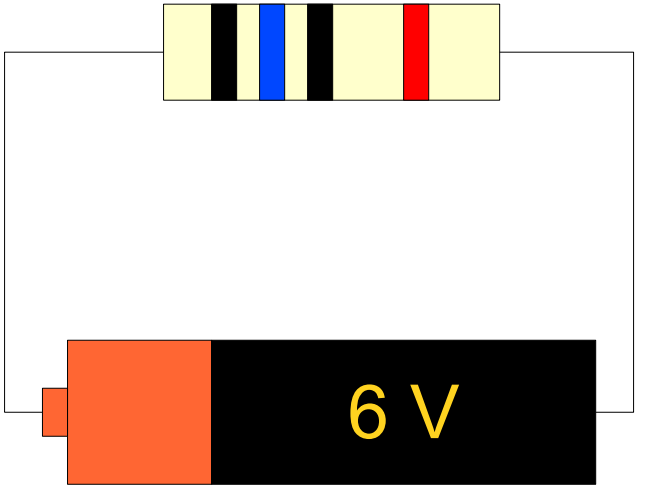
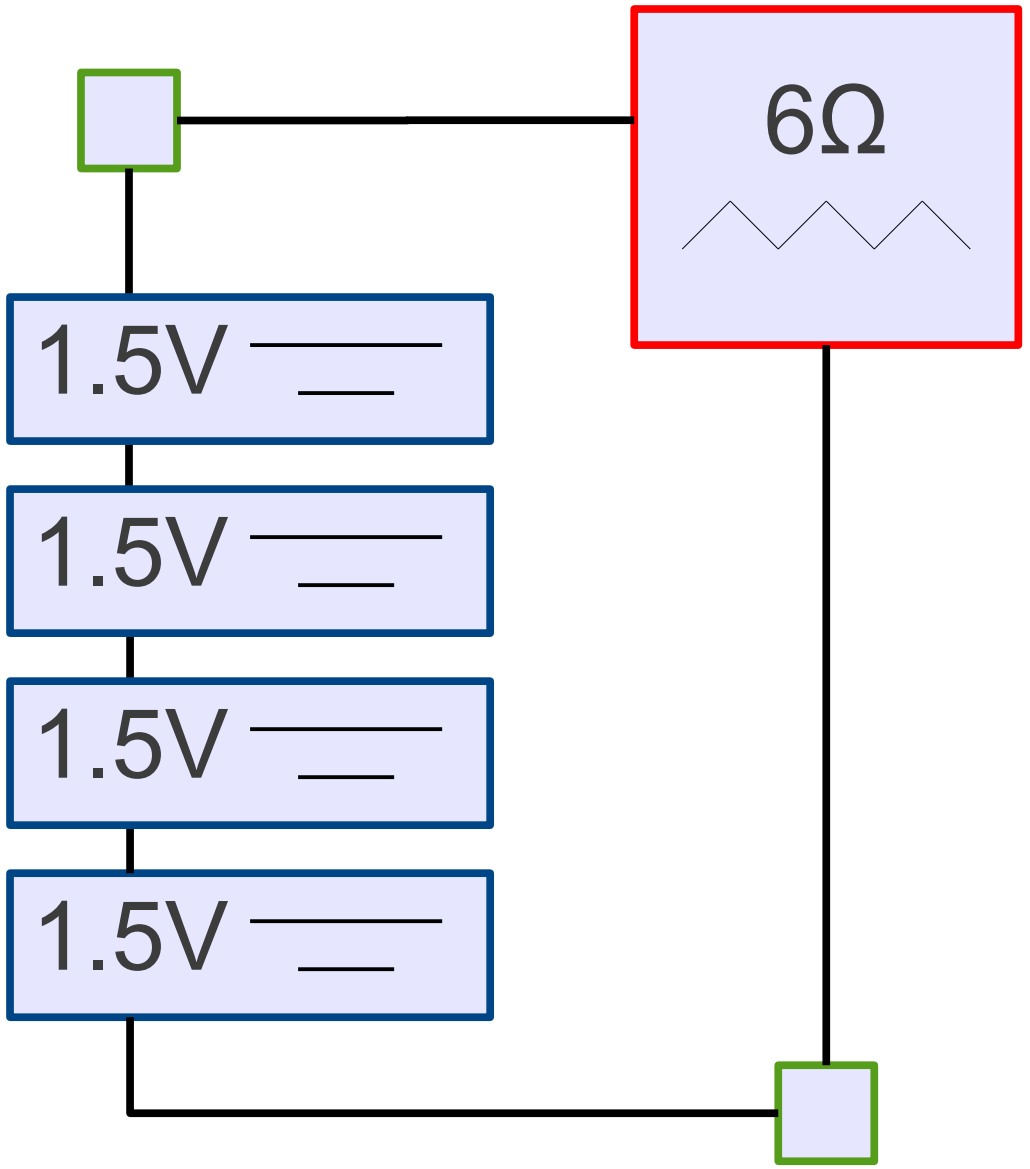


Total Cost: $4.75




6Ω
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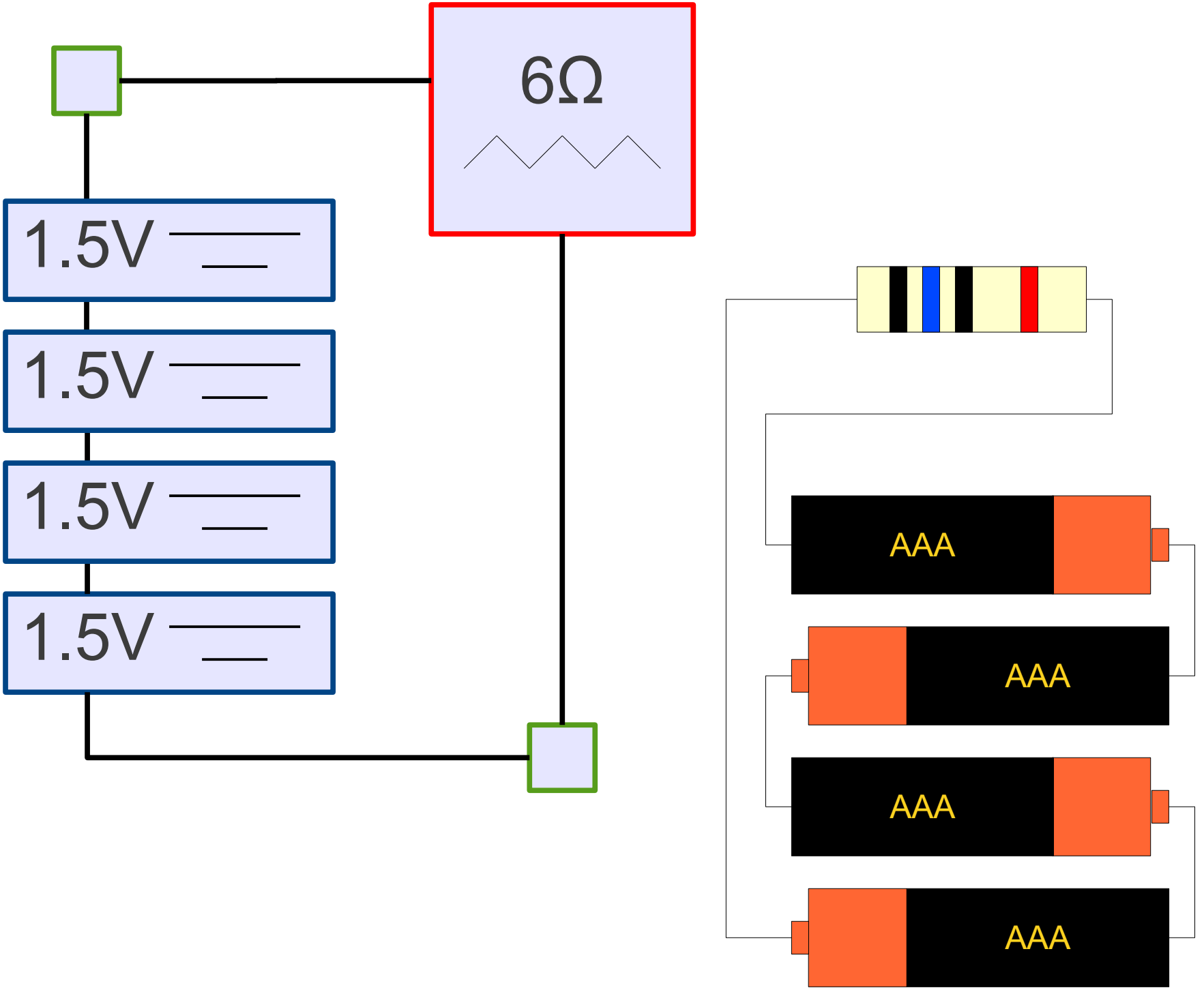
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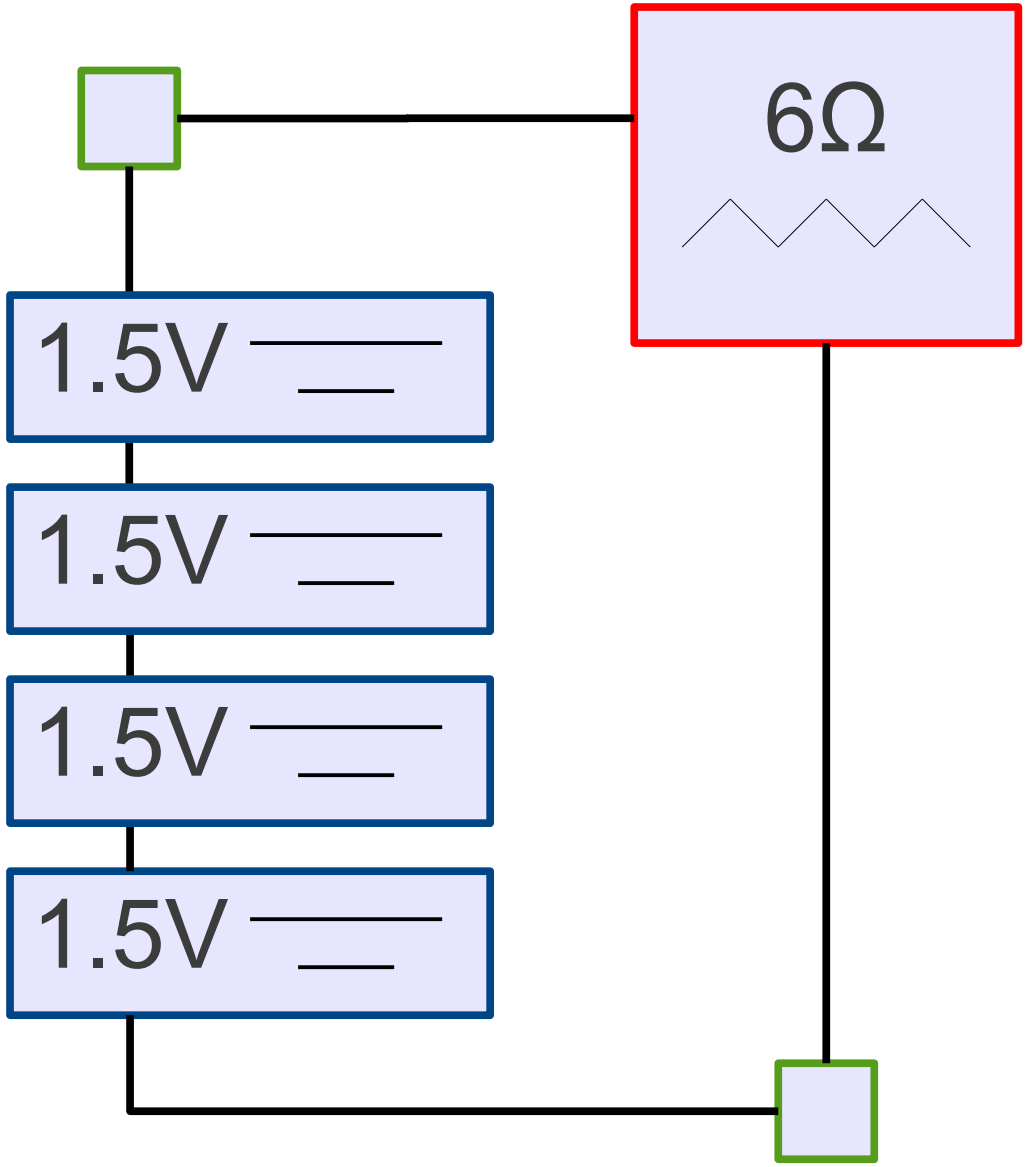
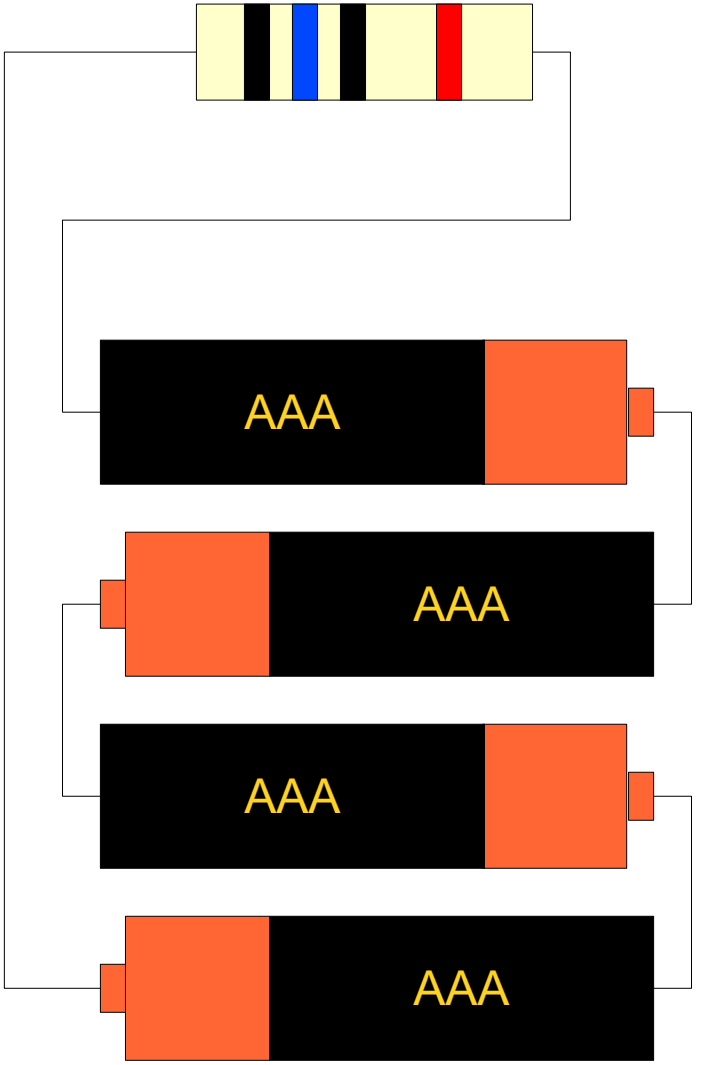


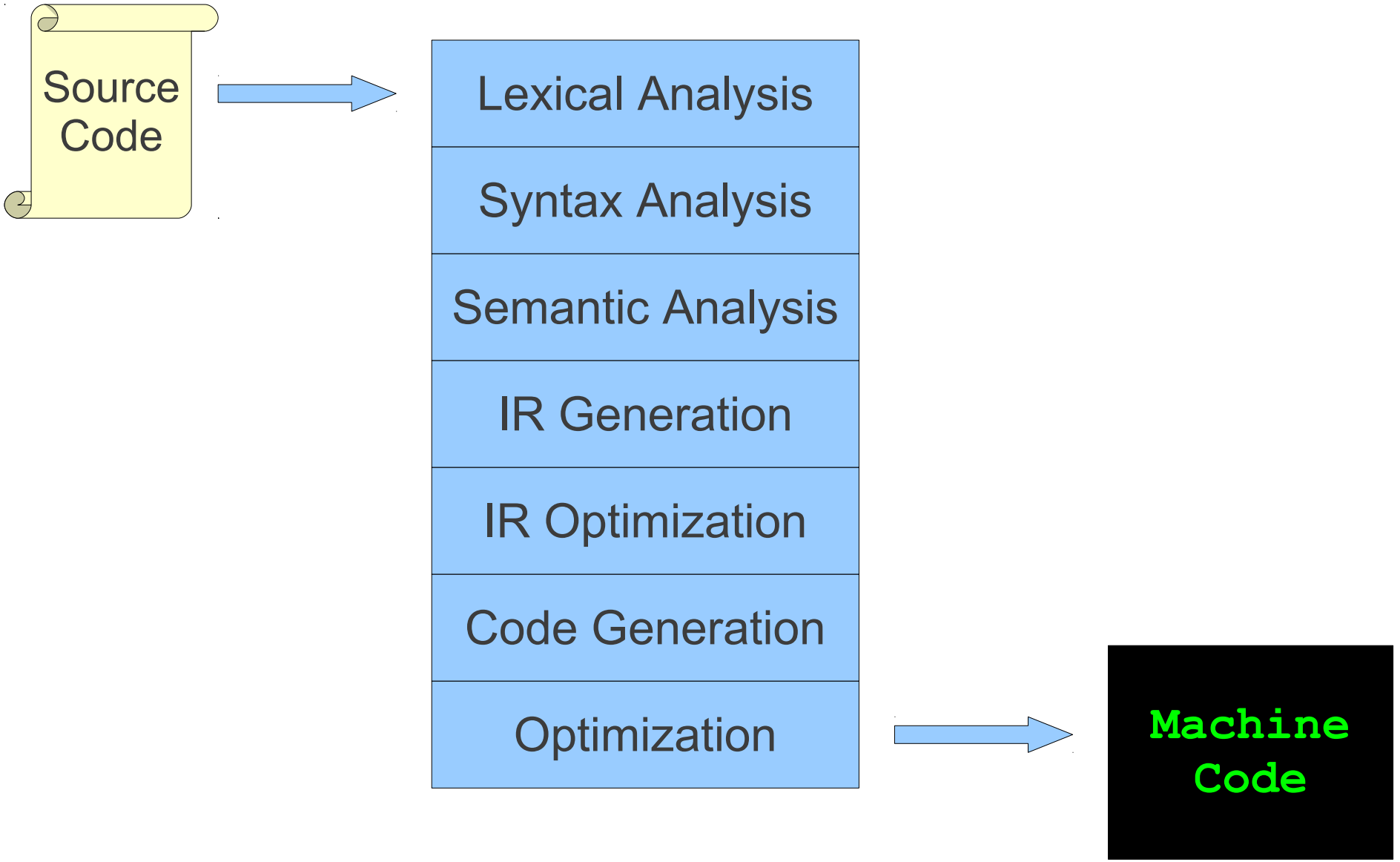
Total Cost: $1.00



From Description to Implementation

- **Lexical analysis (Scanning):** Identify logical pieces of the description.
- **Syntax analysis (Parsing):** Identify how those pieces relate to each other.
- **Semantic analysis:** Identify the meaning of the overall structure.
- **IR Generation:** Design one possible structure.
- **IR Optimization:** Simplify the intended structure.
- **Generation:** Fabricate the structure.
- **Optimization:** Improve the resulting structure.

The Structure of a Modern Compiler



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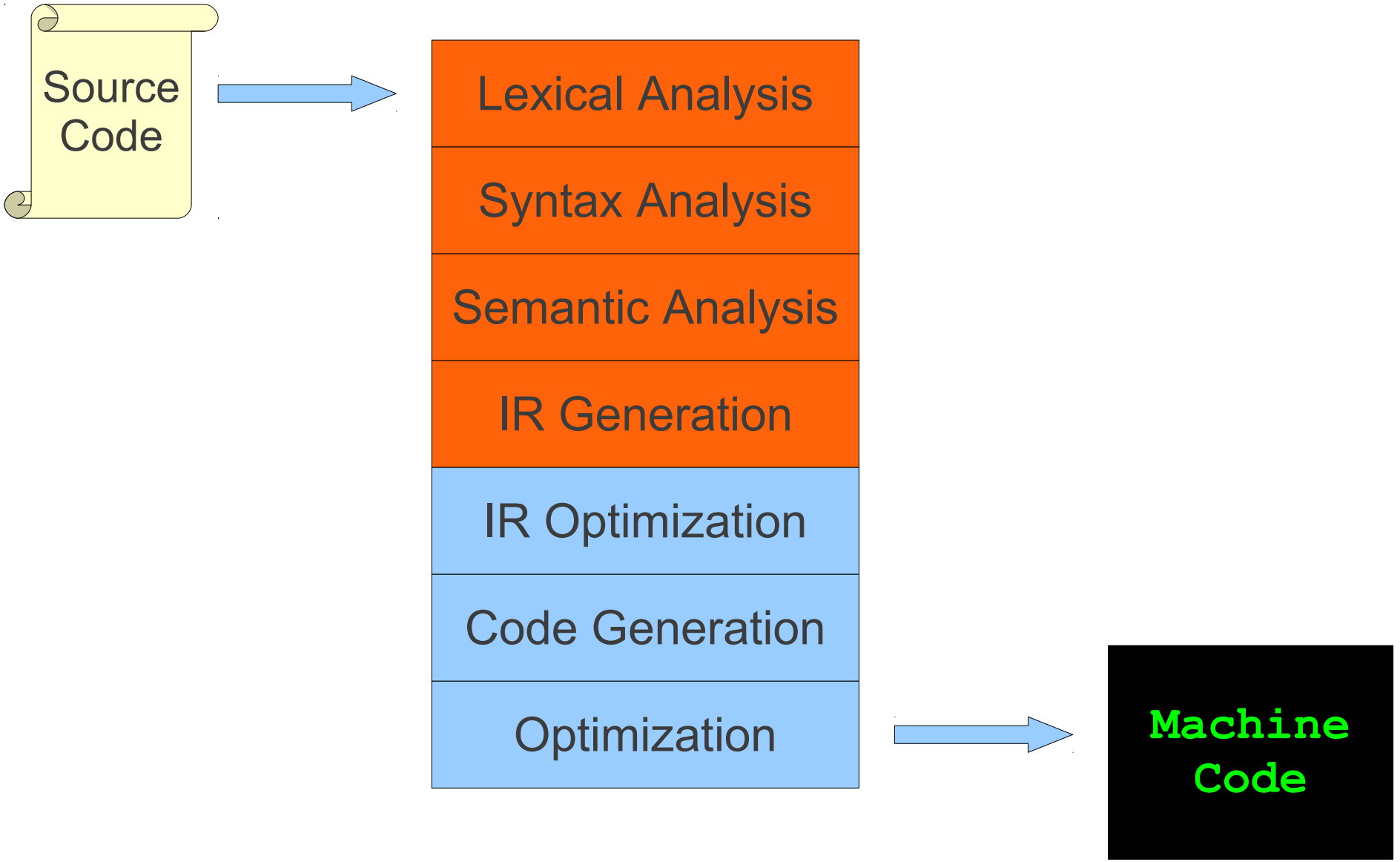

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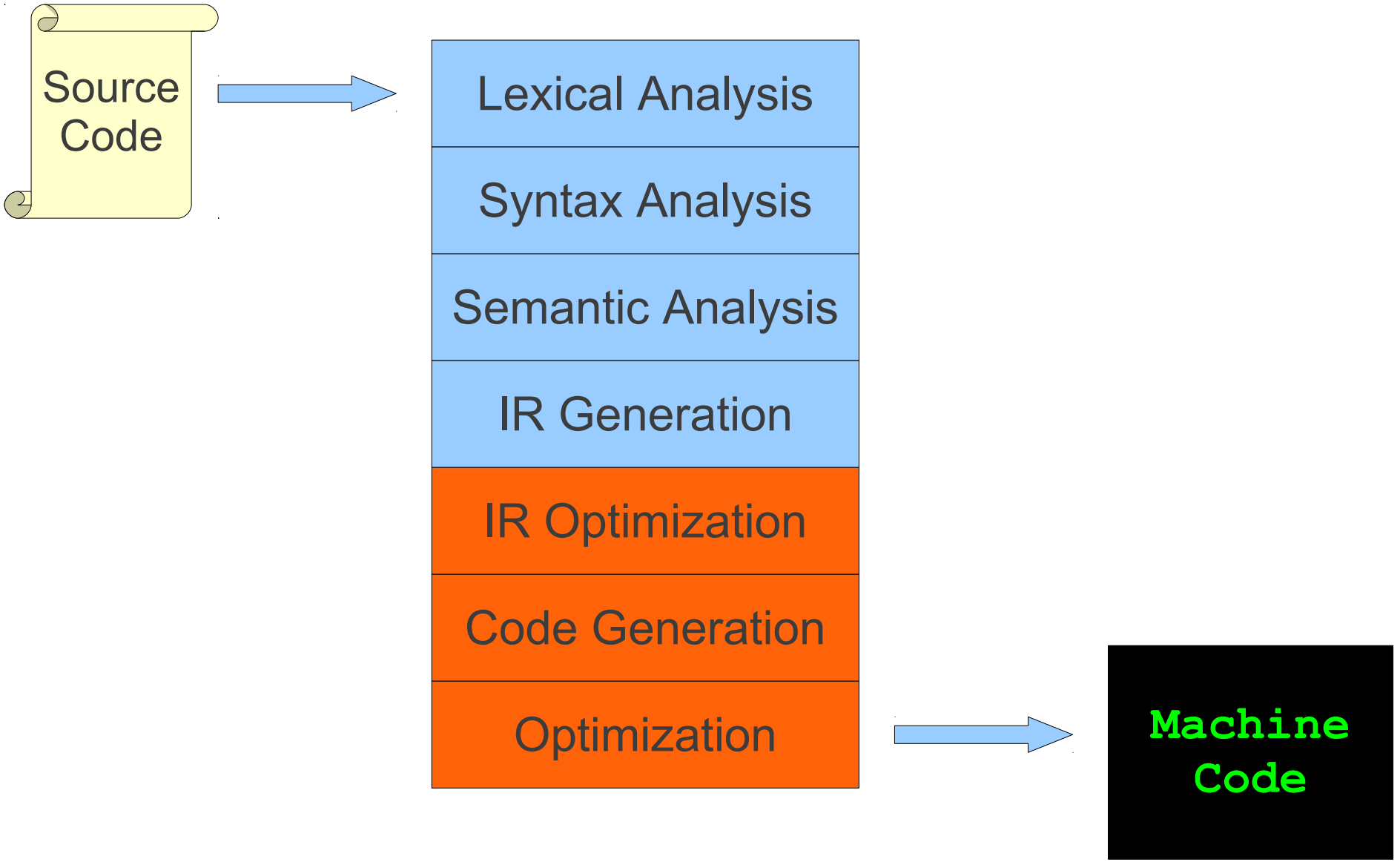

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while (y < z) {
    int x = a + b;
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}
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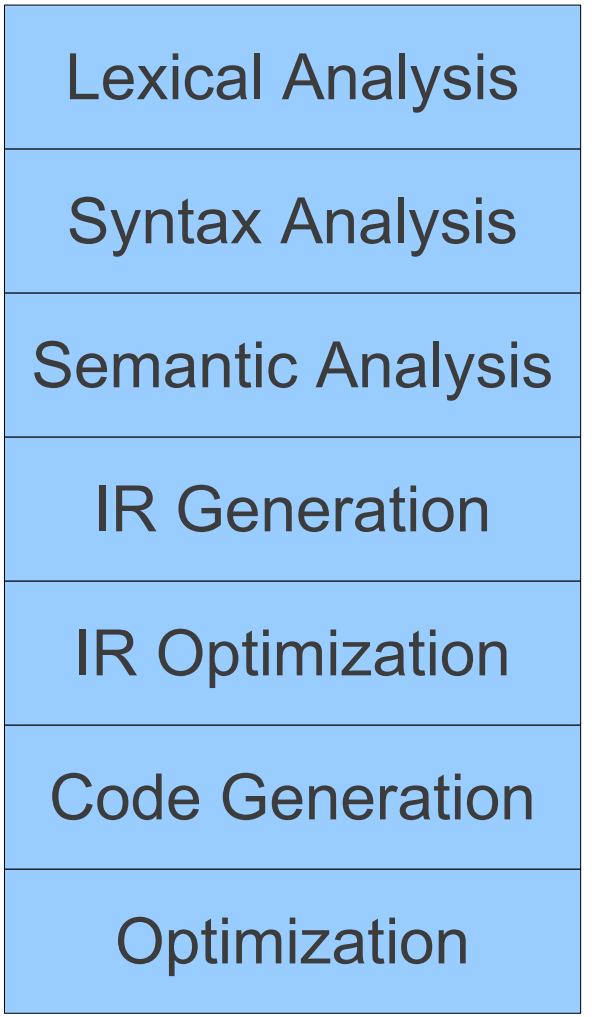

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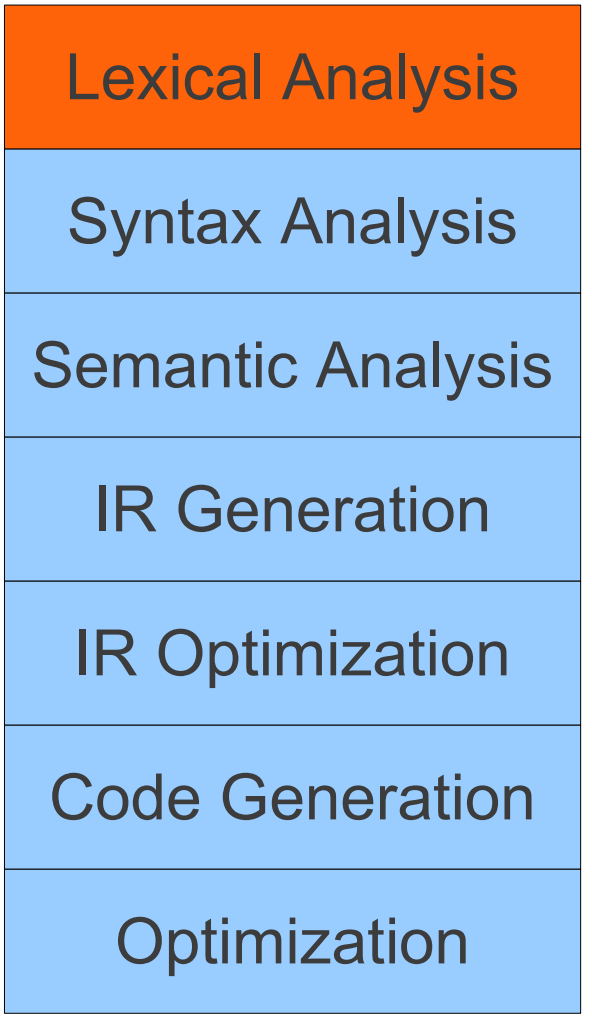

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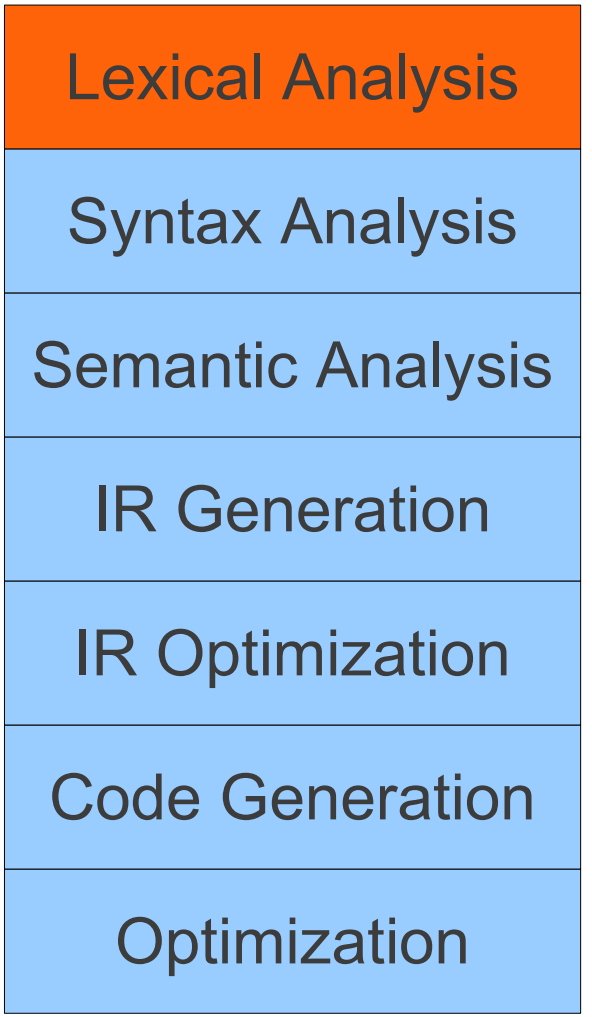
```
T_While
T_LeftParen
T_Identifier y
T_Less
T_Identifier z
T_RightParen
T_OpenBrace
T_Int
T_Identifier x
T_Assign
T_Identifier a
T_Plus
T_Identifier b
T_Semicolon
T_Identifier y
T_PlusAssign
T_Identifier x
T_Semicolon
T_CloseBrace
```



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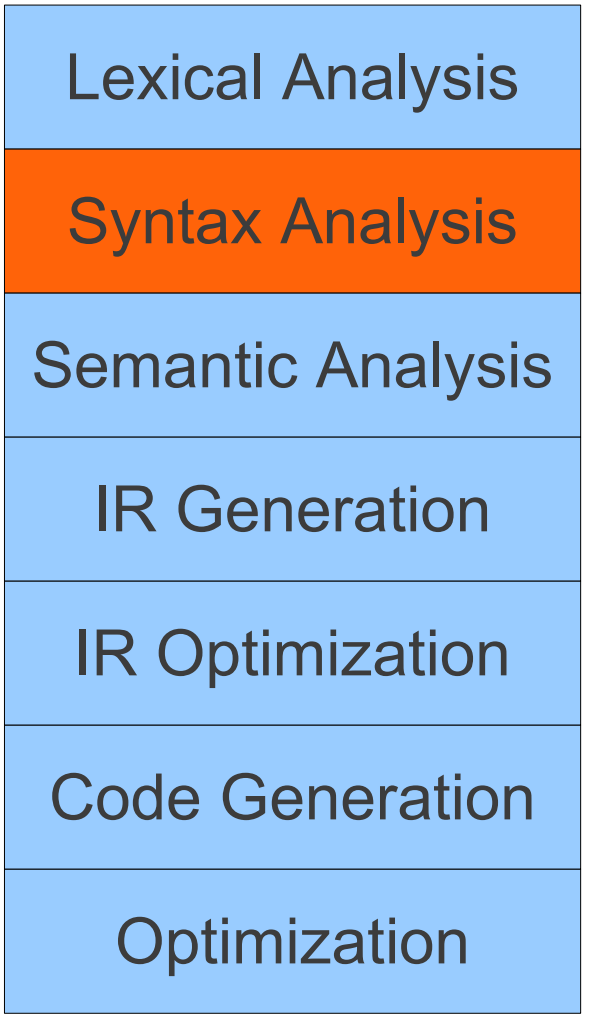

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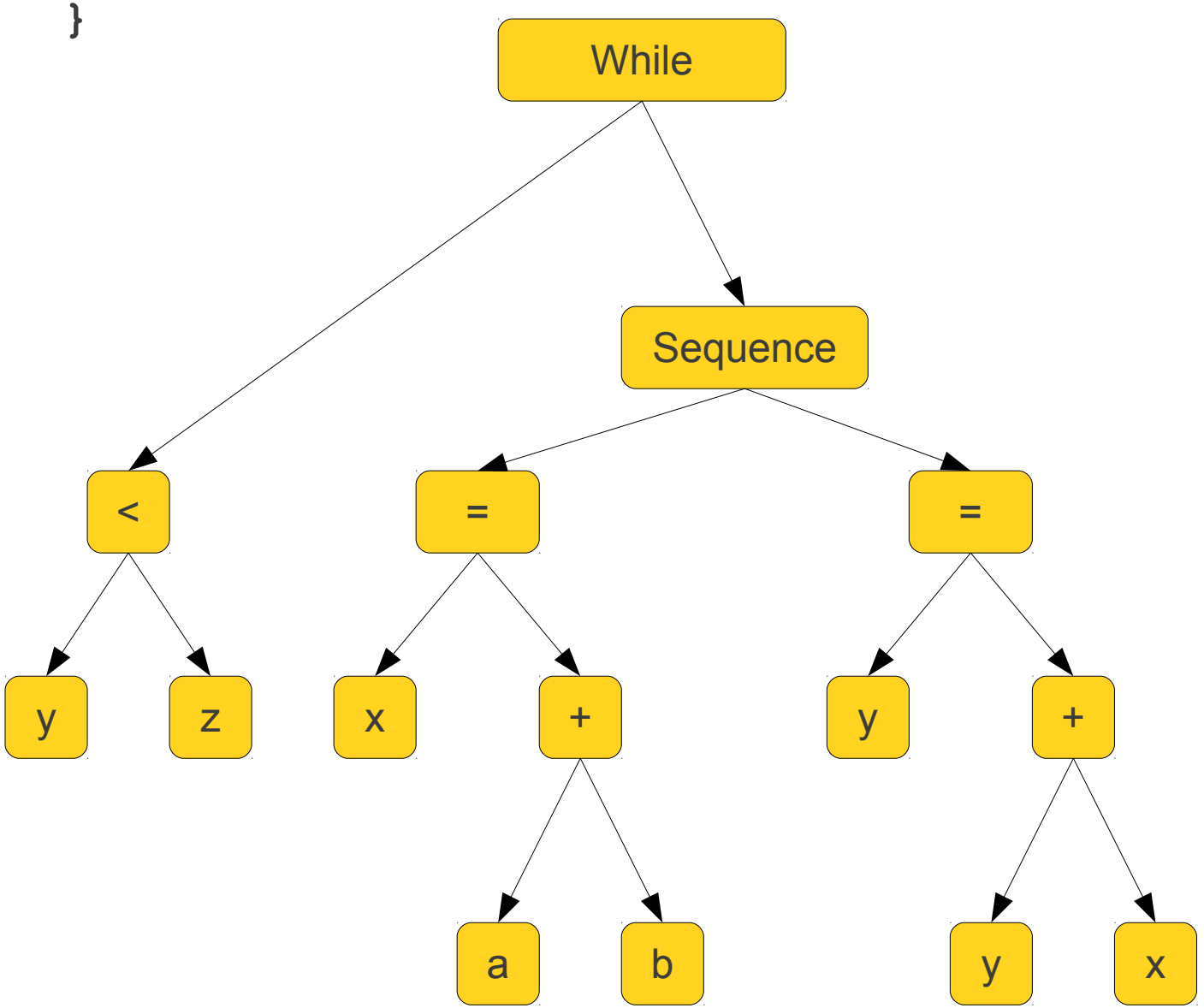

- Lexical Analysis
- **Syntax Analysis**
- Semantic Analysis
- IR Generation
- IR Optimization
- Code Generation
- Optimization

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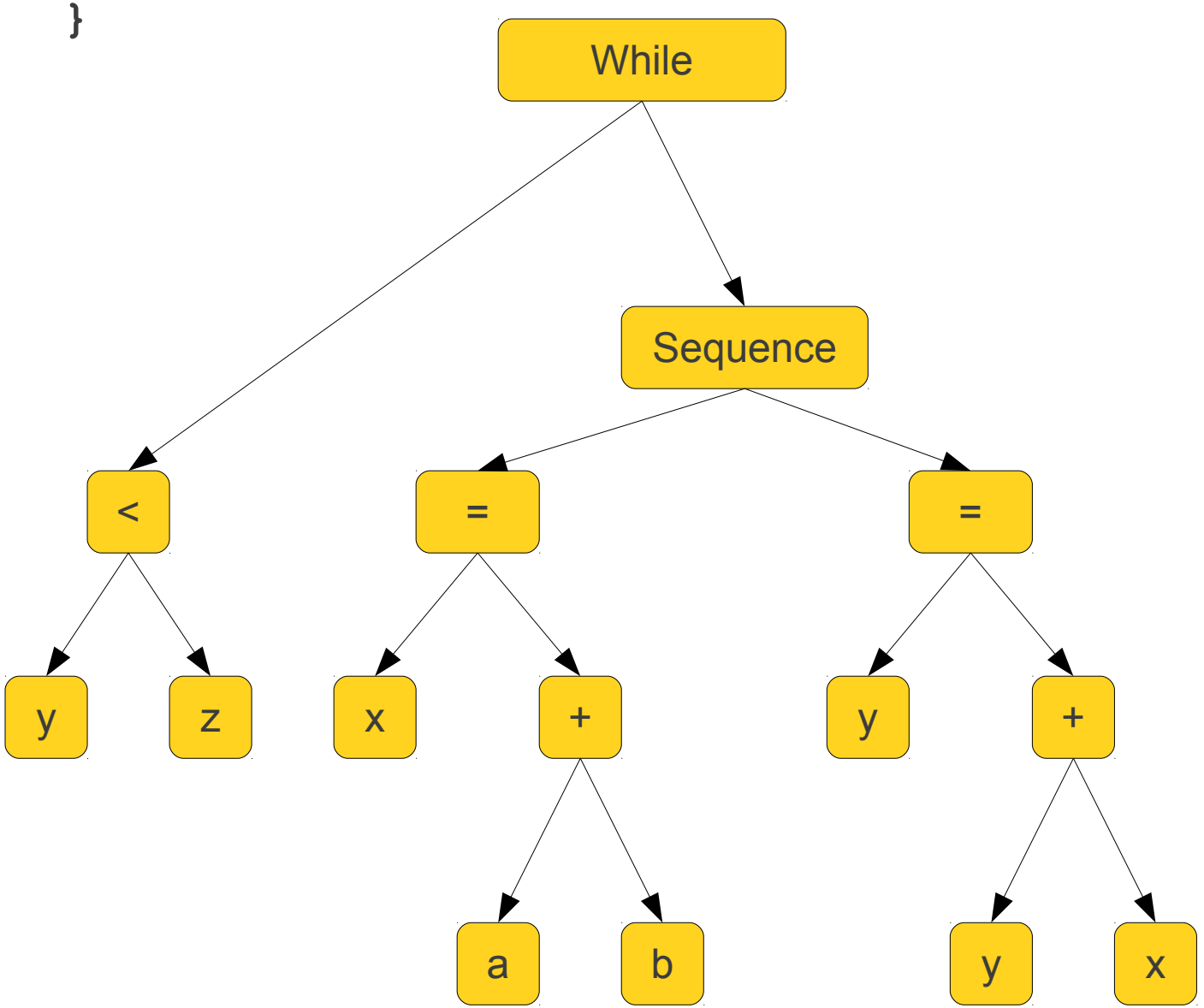

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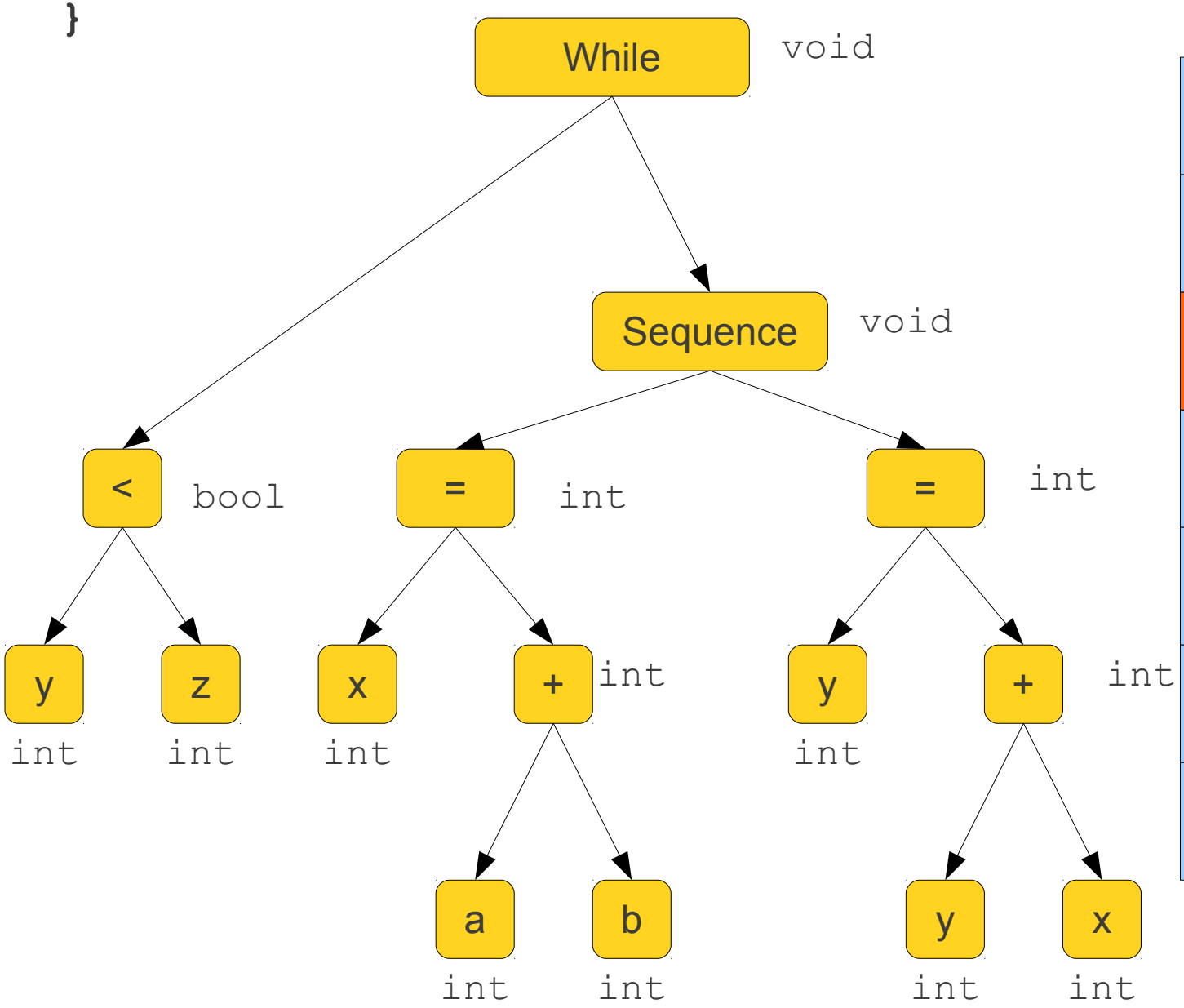

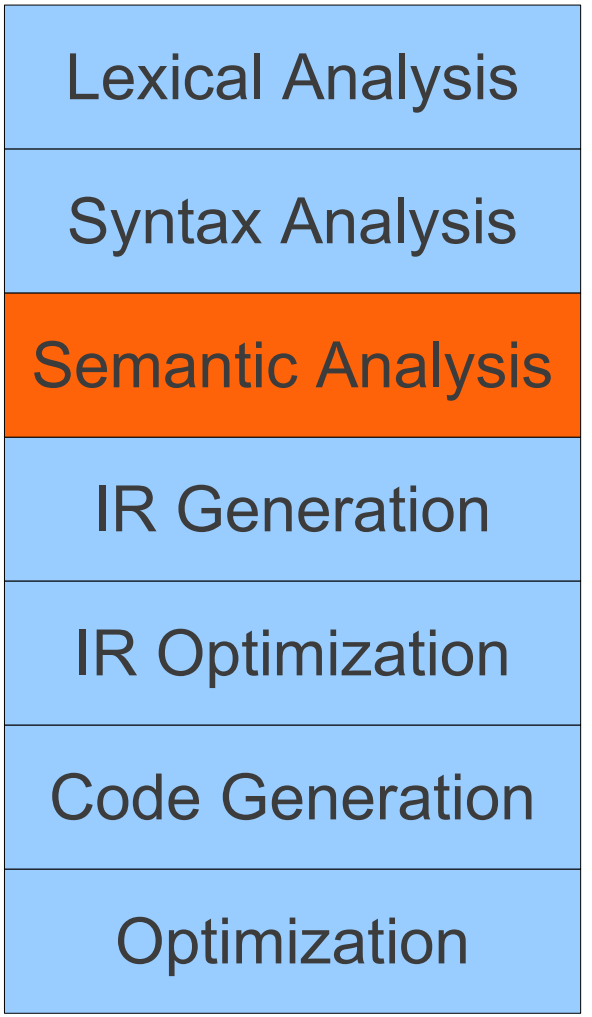

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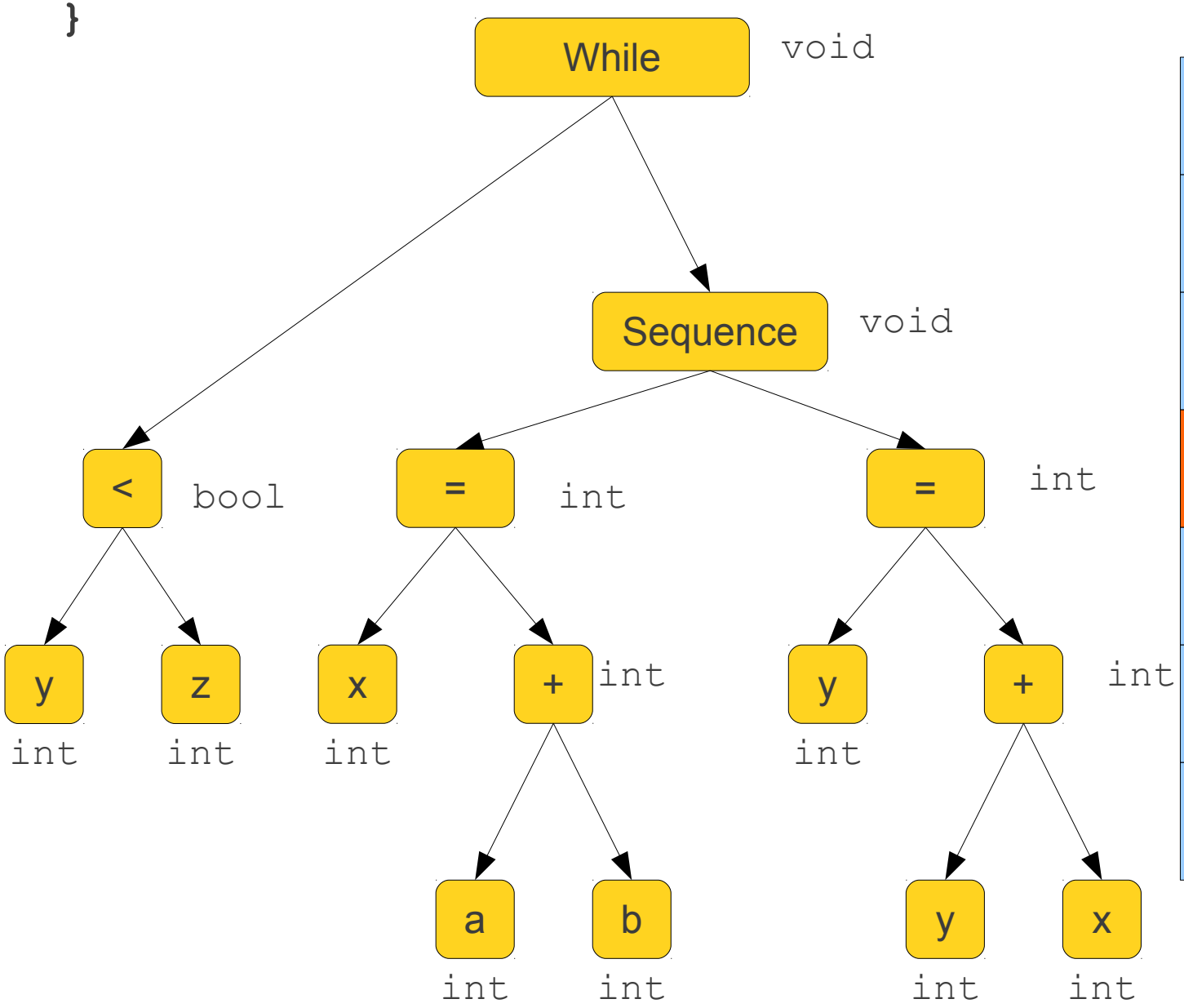

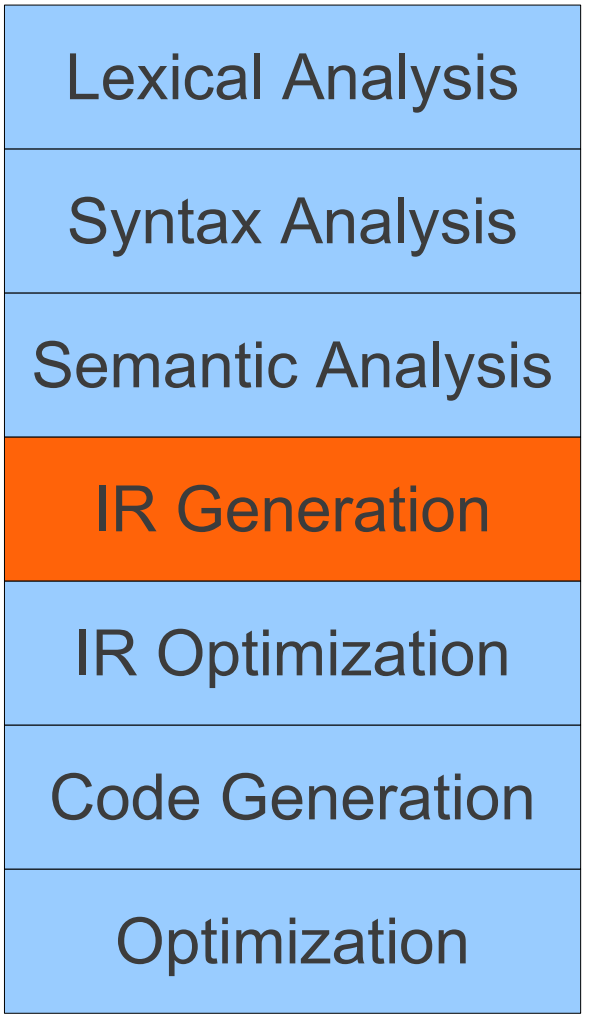

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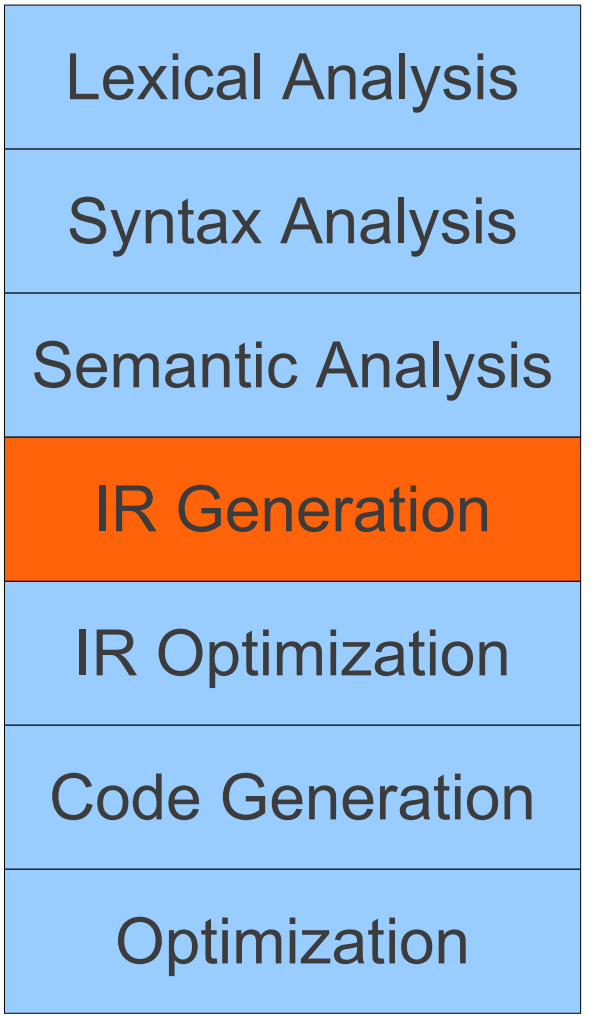
```
Loop: x   = a + b
      y   = x + y
      _t1 = y < z
      if _t1 goto Loop
```



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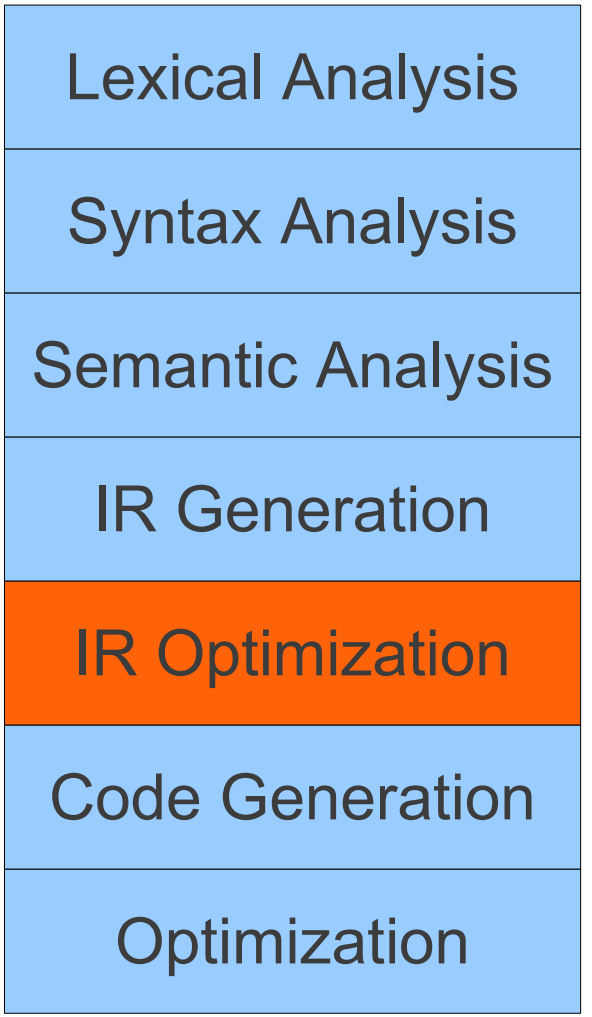
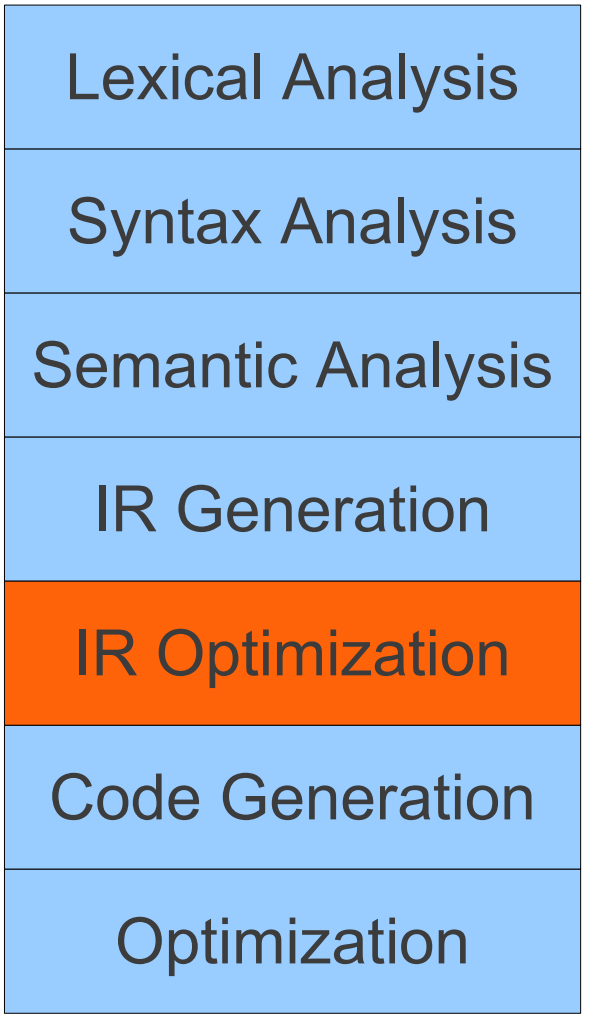


```
while (y < z) {
    int x = a + b;
    y += x;
}
```

```
        x    = a + b
Loop:   y    = x + y
        _t1  = y < z
        if _t1 goto Loop
```



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Loop:   y    = x + y
        _t1  = y < z
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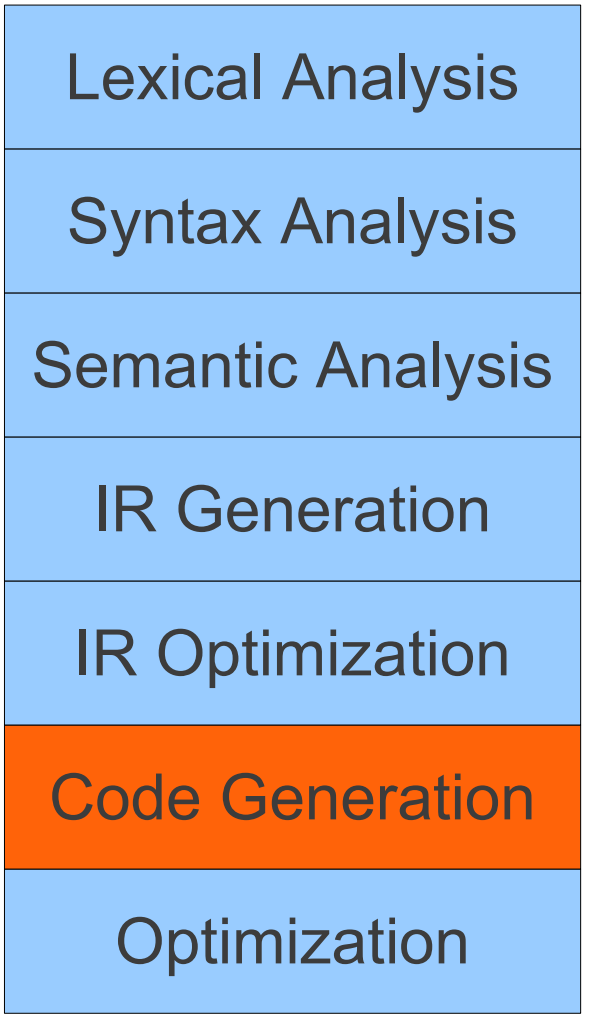
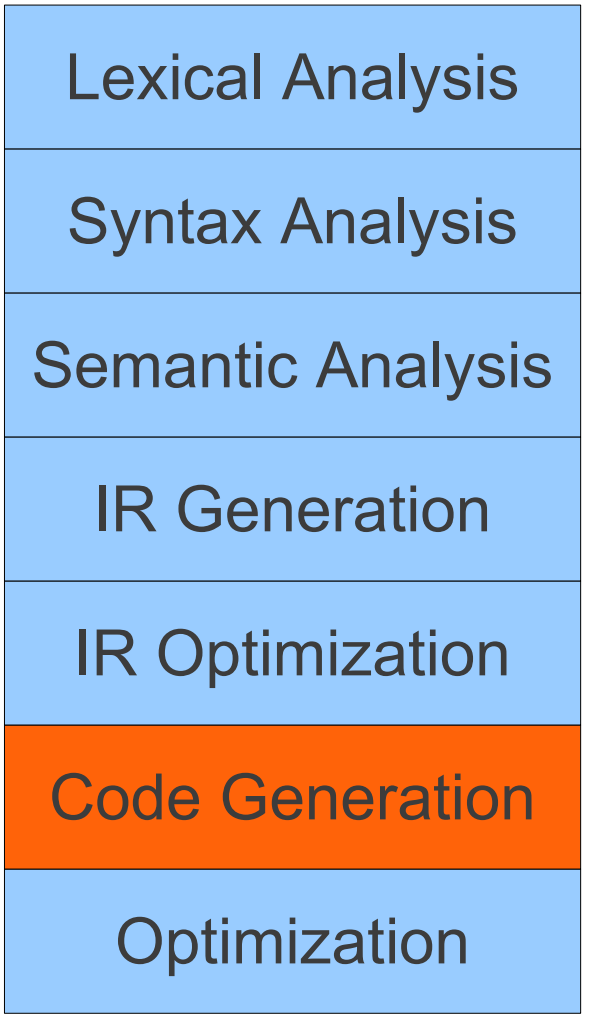
```



```
while (y < z) {
    int x = a + b;
    y += x;
}
```

```
        add $1, $2, $3
Loop:   add $4, $1, $4
        slt $6, $1, $5
        beq $6, loop
```



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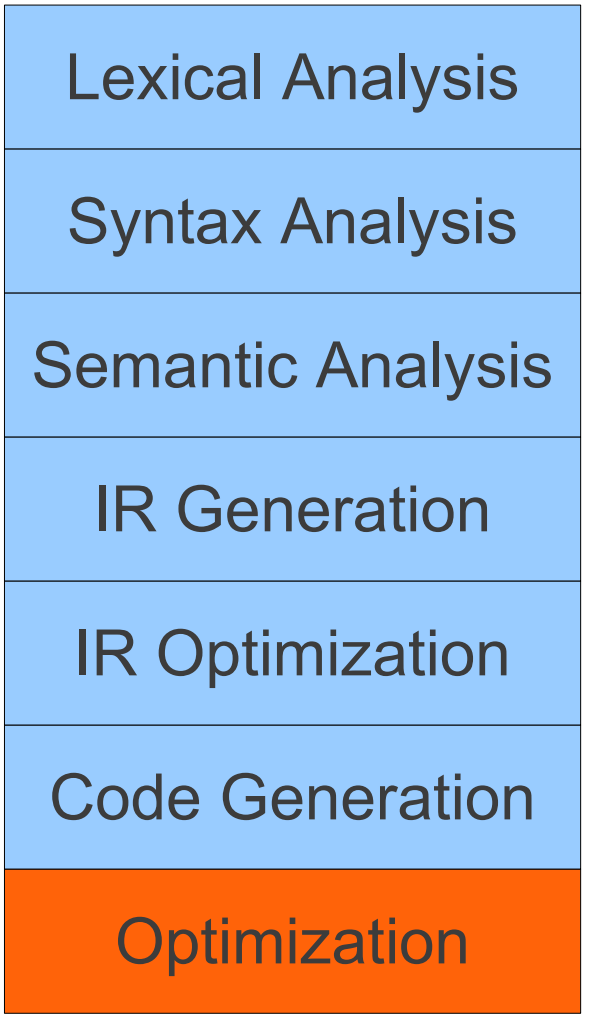
        slt $6, $1, $5
        beq $6, loop
```



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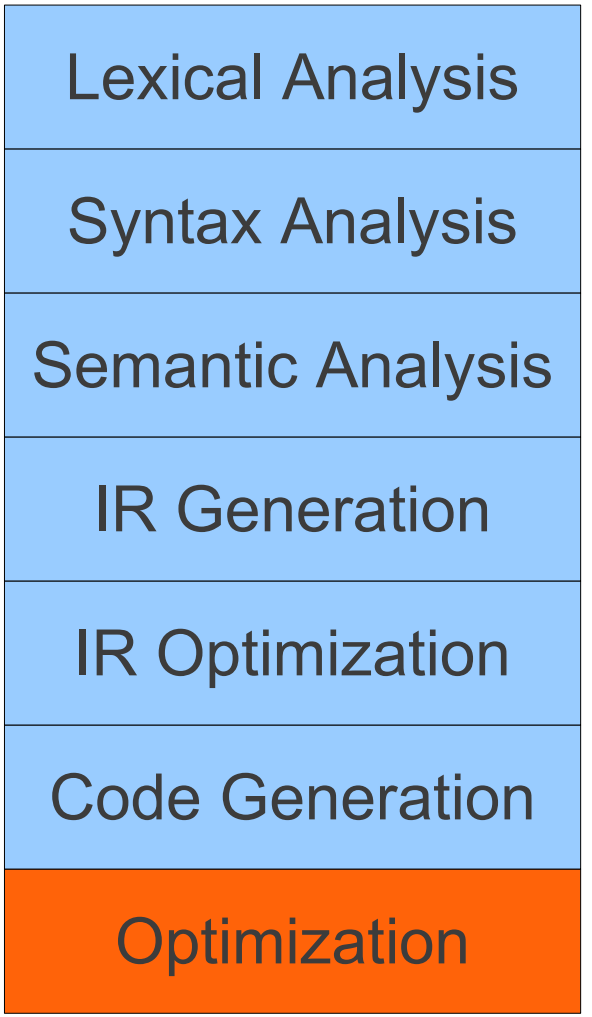
while (y < z) {
    int x = a + b;
    y += x;
}
```

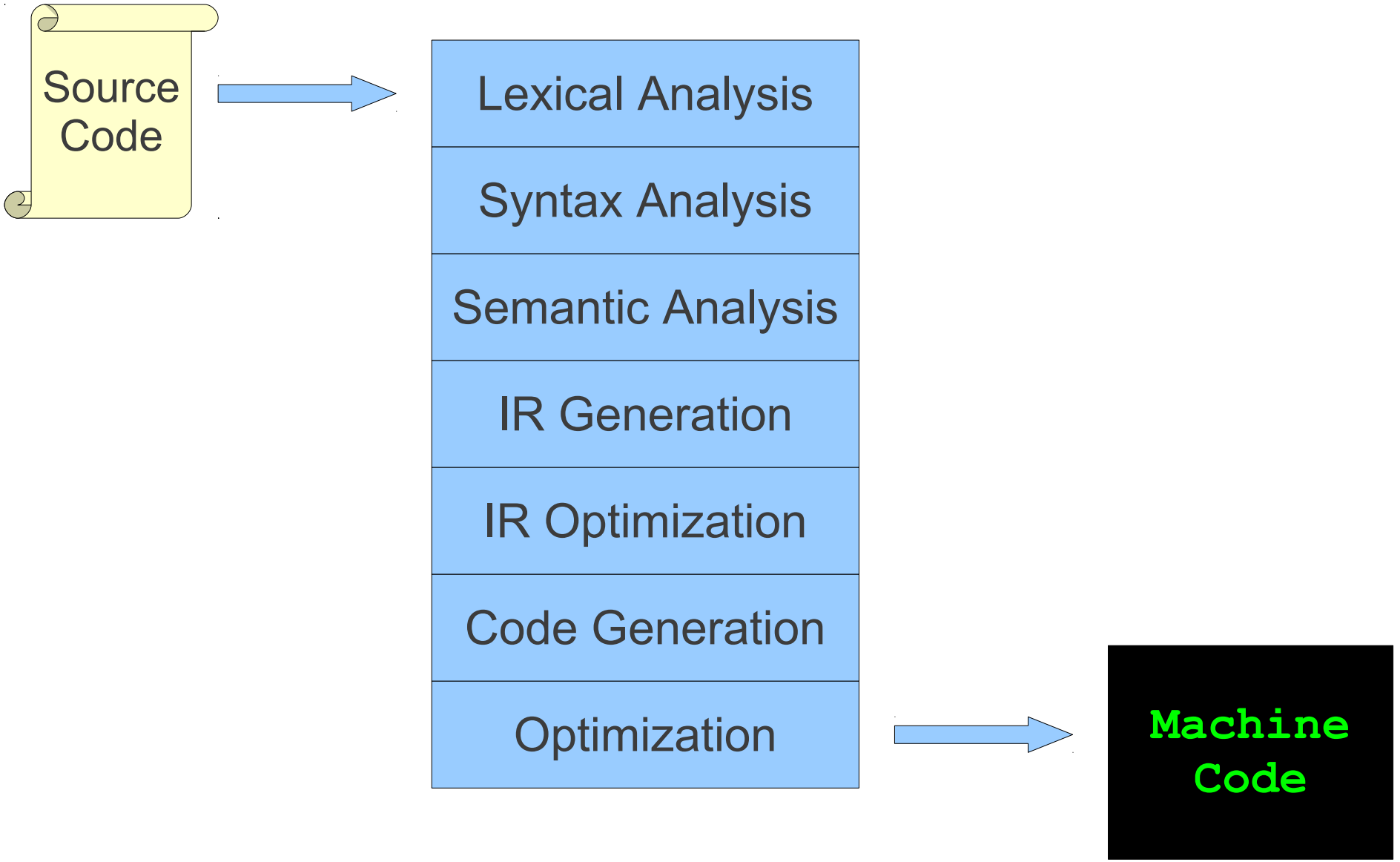
```
        add $1, $2, $3
Loop:   add $4, $1, $4
        blt $1, $5, loop
```



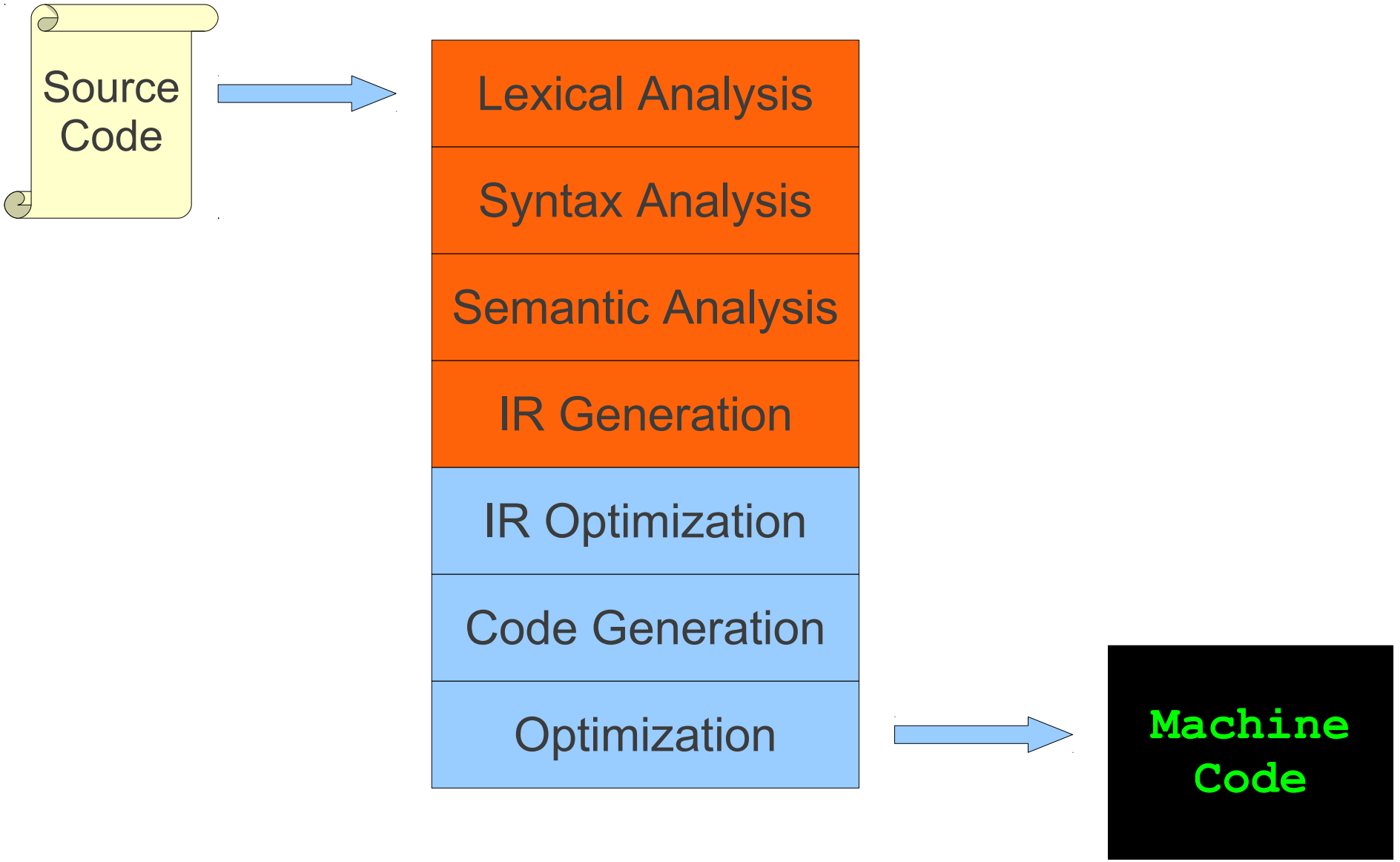
The Course Project: **Decaf**

- Custom programming language similar to Java or C++.
- Object-oriented with free functions.
- Single inheritance with interfaces.

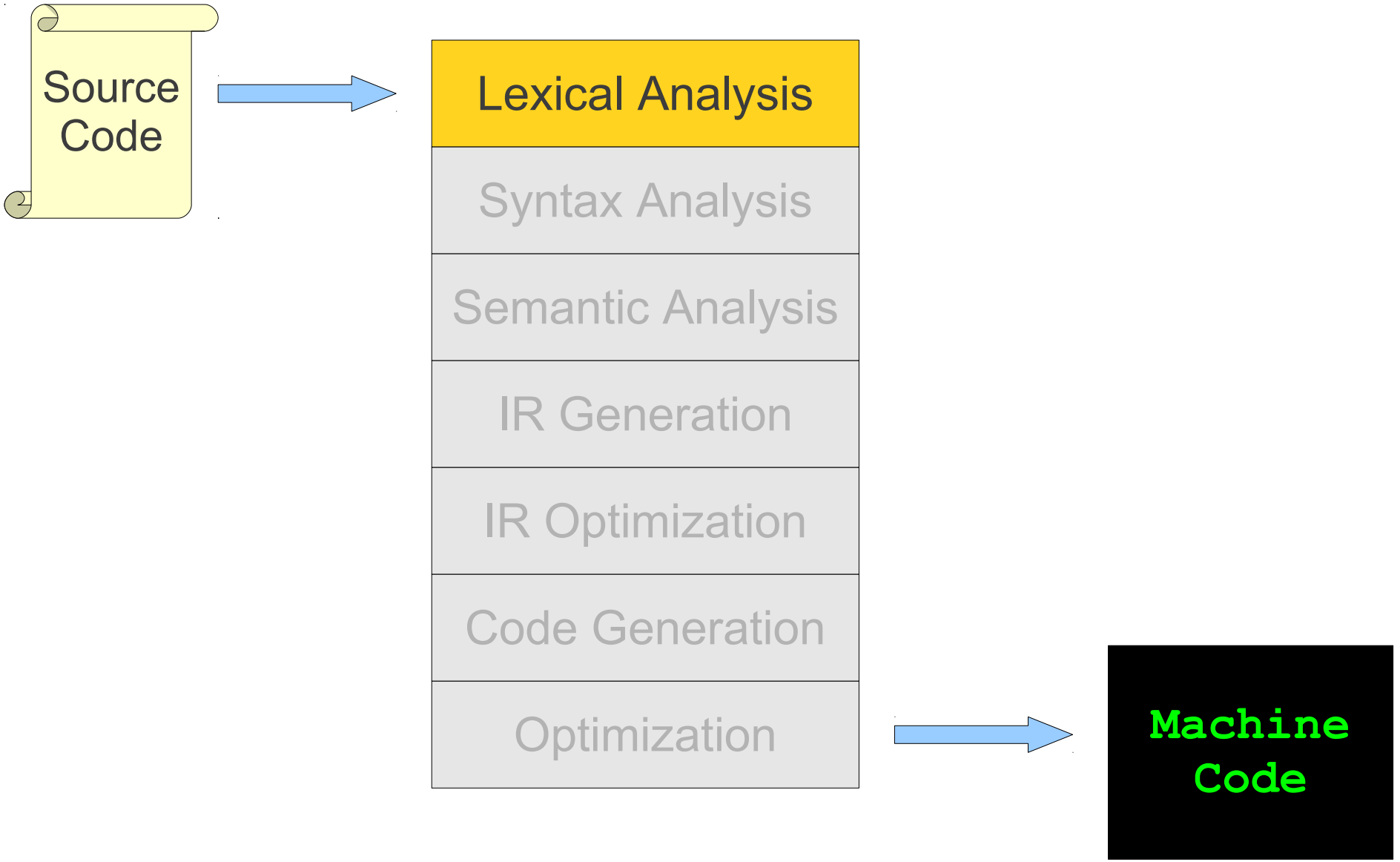
Programming Assignments



Programming Assignments



Next Time...


Source Code
Lexical Analysis
Syntax Analysis
Semantic Analysis
IR Generation
IR Optimization
Code Generation
Optimization
Machine Code