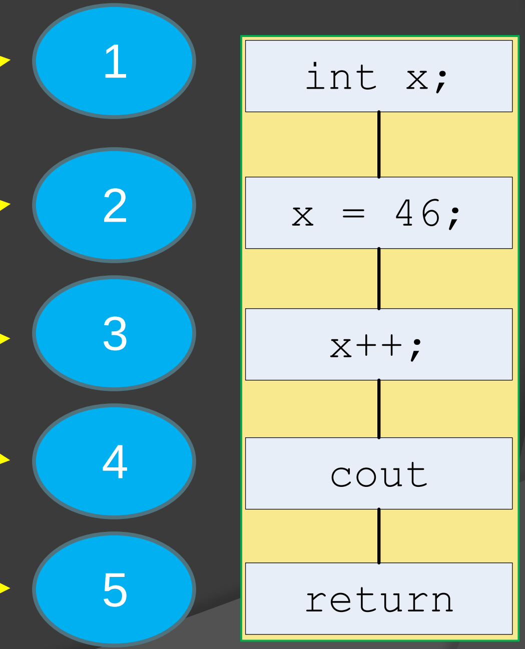
SELECTION STRUCTURES

Flow of Control

- Statements execute in sequential (linear) order
  - ***Top-to-bottom***

```
int main()
{
   int x;

   x = 46;
   x++;
   cout << x << endl;

   return 0;
}
```



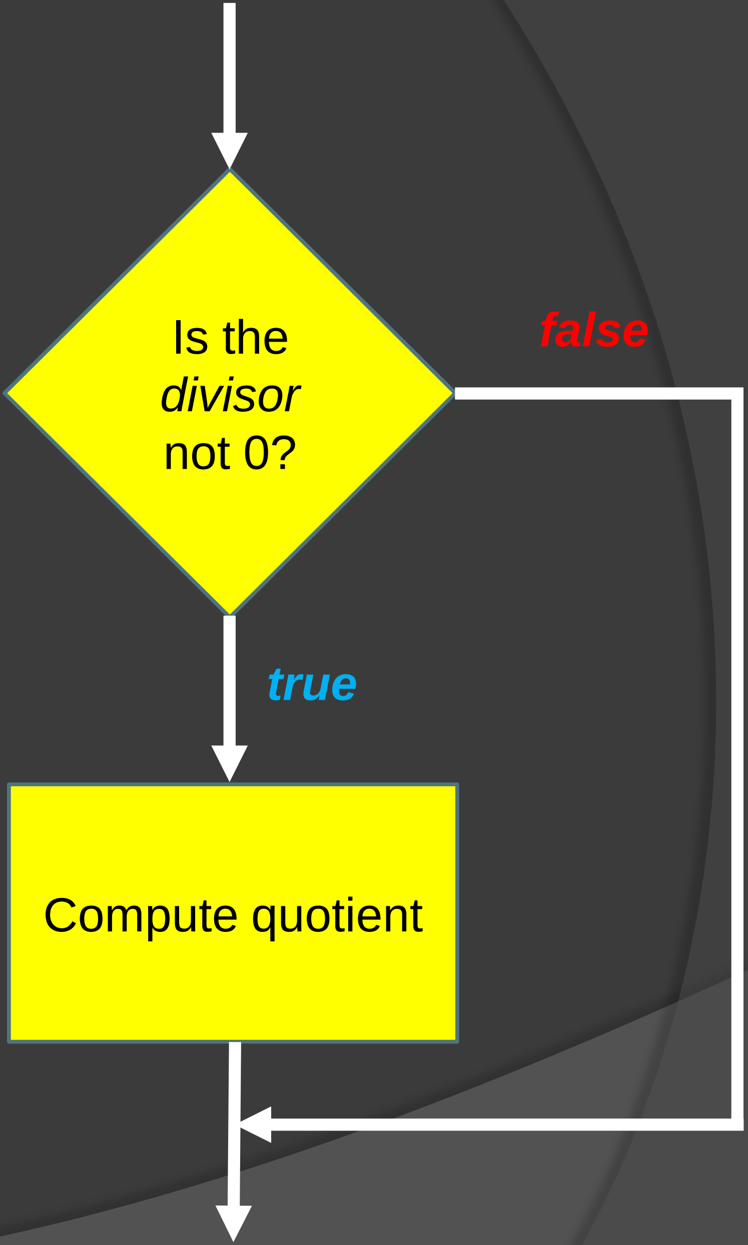
Flow of Control

- What if we want to execute code only some times?

- Write a C++ program that asks for the *dividend* and *divisor* and then computes the *quotient*
  - $quotient = \frac{dividend}{divisor}$
  - But only if the divisor is not zero!

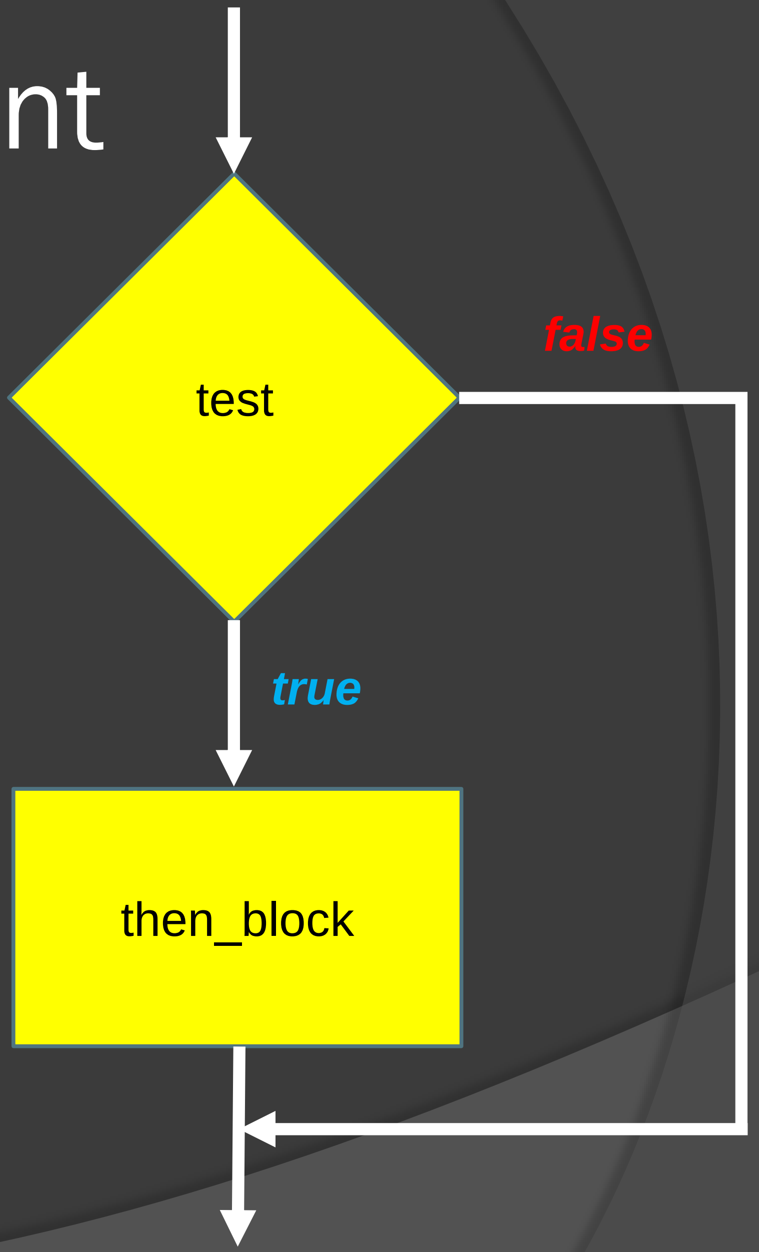
Flow of Control

- Flow chart:
  - Ask *yes*/*no* decision
  - Execute code if *yes*
  - Don’t execute if *no*



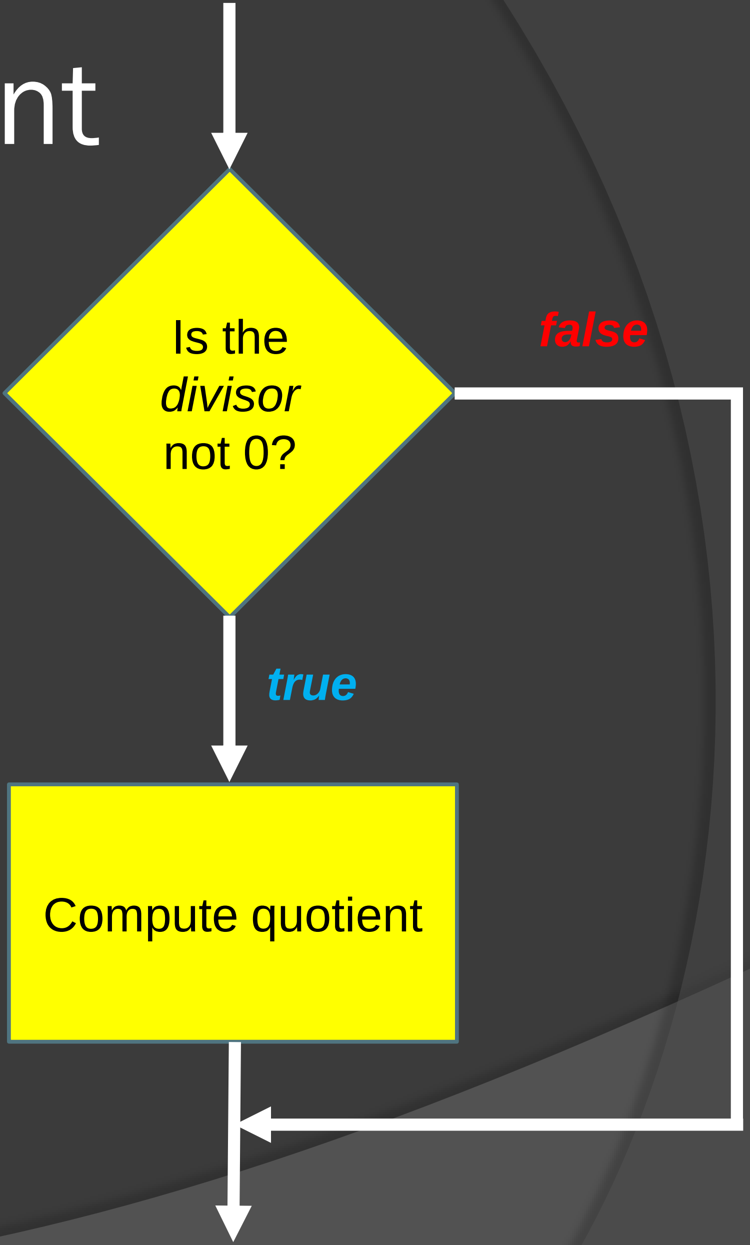
if-then statement

```
if (test)
{
    then_block
}
```



if-then statement

```
if (divisor != 0)
{
   quotient = dividend/divisor;
}
```



`if-then` statement

```
if (conditional expression)
{
     Statements executed
     only if condition is true
}
```

- The conditional expression is a ***Boolean expression*** (formula)
  - Evaluates to **`true`** or **`false`**

Boolean Expression

- Remember: An expression contains constants, variables, operators (relational & logical), and function calls, i.e. a formula
- The simplest Boolean expressions are **true** and **false**
- For example

```
if (true)
{
   cout << "This is always executed" << endl;
}
```

- The **then_block** is ALWAYS executed

Relational Operators

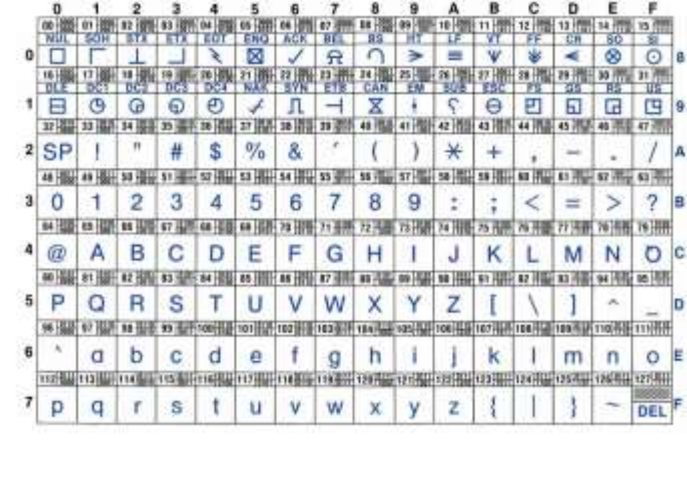
Operator	Meaning	Example
<	less than	x < 0
>	greater than	speed > 65
<=	less than or equal to	age <= 17
>=	greater than or equal to	gpa >= 3.5
==	equal to	initial == ‘a’
!=	not equal to	divisor != 0

- Relational operators return **false** (0) and **true** (1)

Relational Operators are *Binary Operators*

- Make sure operands have *similar* types

ASCII Table



	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	
0	00 NUL	01 SOH	02 STX	03 ETX	04 EOT	05 ENQ	06 ACK	07 BEL	08 BS	09 HT	10 LF	11 VT	12 FF	13 CR	14 SO	15 SI	8
1	16 DLE	17 DC1	18 DC2	19 DC3	20 DC4	21 NAK	22 SYN	23 ETB	24 CAN	25 EM	26 SUB	27 ESC	28 FS	29 GS	30 RS	31 US	9
2	32 SP	33 !	34 "	35 #	36 $	37 %	38 &	39 '	40 (	41)	42 *	43 +	44 ,	45 -	46 .	47 /	A
3	48 0	49 1	50 2	51 3	52 4	53 5	54 6	55 7	56 8	57 9	58 :	59 ;	60 <	61 =	62 >	63 ?	B
4	64 @	65 A	66 B	67 C	68 D	69 E	70 F	71 G	72 H	73 I	74 J	75 K	76 L	77 M	78 N	79 O	C
5	80 P	81 Q	82 R	83 S	84 T	85 U	86 V	87 W	88 X	89 Y	90 Z	91 [	92 \	93]	94 ^	95 _	D
6	96 `	97 a	98 b	99 c	100 d	101 e	102 f	103 g	104 h	105 i	106 j	107 k	108 l	109 m	110 n	111 o	E
7	112 p	113 q	114 r	115 s	116 t	117 u	118 v	119 w	120 x	121 y	122 z	123 {	124 |	125 }	126 ~	127 DEL	F

- Compare numbers

  `2 < 0` evaluates to `false`

- Compare characters

  `'a' < 'b'` evaluates to `true` (why???)
  `'G' > 'M'` evaluates to `false`
  `'E' != 'e'` evaluates to `true`

Boolean Expression

- A ***boolean expression*** asks a yes/no question, i.e. `true`/`false`

- Is the value in variable `dogs` positive?

```
dogs > 0
```

- Is the value in variable `age` at least 18?

```
age >= 18
```

- Is the value in variable `cats` at most 10?

```
cats <= 10
```

Your Turn – Write the Conditional Expression for:

- Is the value in variable `i` even?

```
if( i%2 ==0) {
```

- Is the value in variable `j` odd?

```
if( j%2 ==1) {
```

- Is the sum of `i` and `j` positive?

```
if( i+j >0){
```

booleanExpr.cpp

```
// Examples of Boolean expressions
#include <iostream>
using namespace std;

int main()
{
  double x(10);

  cout << "(4 != 4) evaluates to " << (4 != 4) << endl;
  cout << "('a' <= 'b') evaluates to " << ('a' <= 'b') << endl;
  cout << "('B' < 'b') evaluates to " << ('B' < 'b') << endl;
  cout << "((2.0 + 5.0) == 7) evaluates to " << ((2.0 + 5.0) ==
     7) << endl;
  cout << "((5/3) > 1.0) evaluates to " << ((5/3) > 1.0) << endl;

  cout << "(x == 10) evaluates to " << (x == 10) << endl;
  cout << "(x = 8) evaluates to " << (x = 8) << endl;

  return 0;
}
```

Note the single =

booleanExpr.cpp executed

```
g++ booleanExpr.cpp
a.out
(4 != 4) evaluates to 0
('a' <= 'b') evaluates to 1
('B' < 'b') evaluates to 1
((2.0 + 5.0) == 7) evaluates to 1
((5/3) > 1.0) evaluates to 0
(x == 10) evaluates to 1
(x = 8) evaluates to 8
```

Boolean vs Arithmetic Expressions

- A ***Boolean expression*** evaluates to `true` or `false`

```
age >= 16
```

- An ***arithmetic expression*** evaluates to a numeric value

```
age + 1
```

- A Boolean expression may contain arithmetic expressions
  - What are the arithmetic expressions in this Boolean expression?

```
age - 1 >= 15 + 1
```

- `age - 1`
- `15 + 1`
- `+` and `–` are arithmetic operators
- `>=` is a Boolean operator

Logical Operators

- Write a Boolean expression that asks:
- Is the temperature in variable `temp` between 10 and 32 degrees inclusive?

- How about?

```
10 <= temp <= 32
```

  - Problem: `<=` is a binary operator and variable `temp` cannot be used as an operand in both operators

- We want to ask two questions!
  - Is temp at least 10 and is temp at most 32?
  - This is a compound statement

Logical Operators

- Logical operators
  - And (`&&`)
  - Or (`||`)

allow us to create compound statements

- Is variable `temp` between 10 and 32 inclusive?
  - Is `temp` at least 10?
  - Is `temp` at most 32?

```
temp >= 10 && temp <= 32
```

Compound Logical Operators: && and ||

- Binary operators
- Operands are Boolean expressions

- The AND (`&&`) operator is true when BOTH operands evaluate to **`true`**
- The OR (`||`) operator is true if EITHER operand evaluates to **`true`**
- AND (`&&`) higher precedence than OR (`||`)

Your turn

- Write a Boolean expression that asks:
- Is a person a *teenager* or a *senior*?
  - Variable `age` contains the person’s age

- A teenager’s age between 13 and 19
- A senior has age more than 80

- The question is yes, i.e. `true`, if EITHER of these two statements is true

Logical Operators

- The NOT (`!`) operator asks if a question is false, i.e. not true
  - It negates a Boolean expression evaluation
  - **Unary** operator
  - The single operand is placed to the right of the !

- Is a person's age at least 18?

```
age >= 18
```

- Is a person's age NOT at least 18?

```
!(age >= 18)
```

  - Though, you probably want to use `age < 18`

Your Turn

- Write at least two different Boolean expressions that ask:
- Is the temperature NOT between 10 and 32? Use variable `temp`.

Operator Precedence

Operator	Associativity
`!` `unary -` `++` `--`	
`*` `/` `%`	left to right
`+` `-`	left to right
`<` `<=` `>` `>=`	left to right
`==` `!=`	left to right
`&&`	left to right
`||`	left to right
`=` `+=` `-=` `*=` `/=`	right to left

Note on truth values

- Any integer that is not 0 is considered to be a Boolean `true` in C++

- Relational and logical operators only evaluate to `false` (0) and `true` (1)

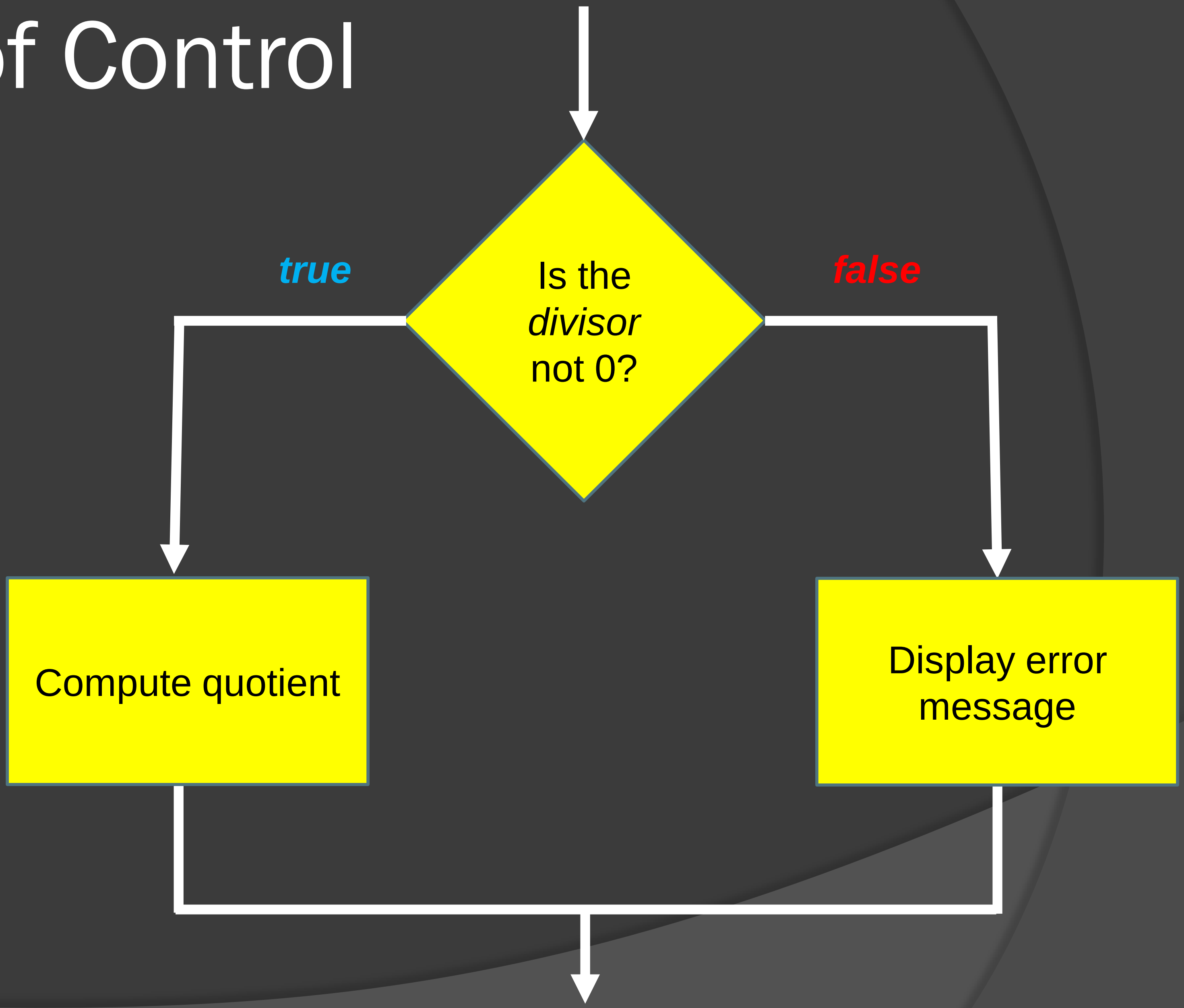
Your Turn

- What do each of the following Boolean expressions evaluate to?

```
int x(5), y(12);
```

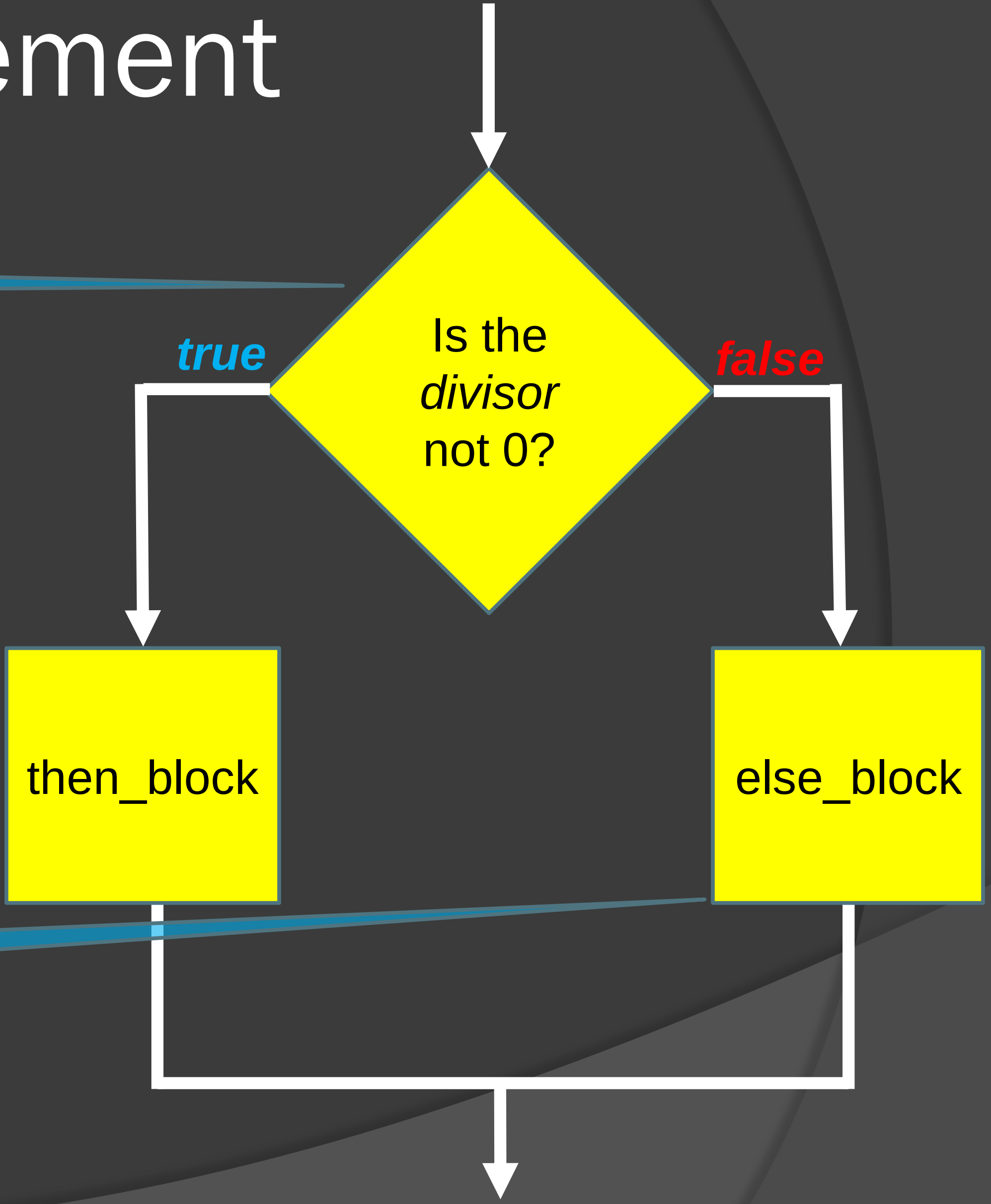
- `x > 0 && x < 10`
- `x <= 0 || x >= 10`
- `x - 1 == y / 5 + y % 5`
- `x != y || !(x == y)`

Flow of Control



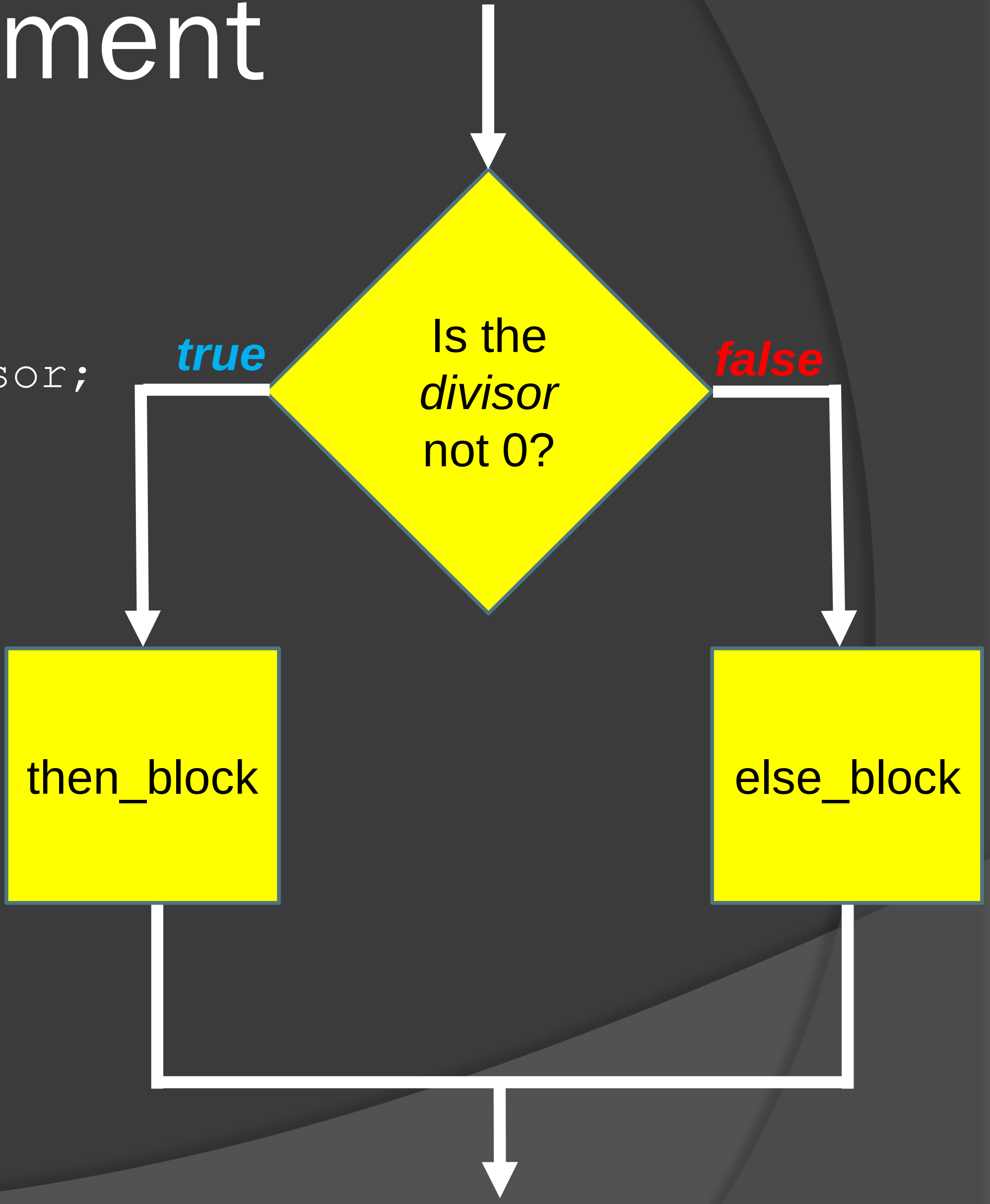
if-else statement

```
if (test)
{
    then_block
}
else
{
    else_block
}
```



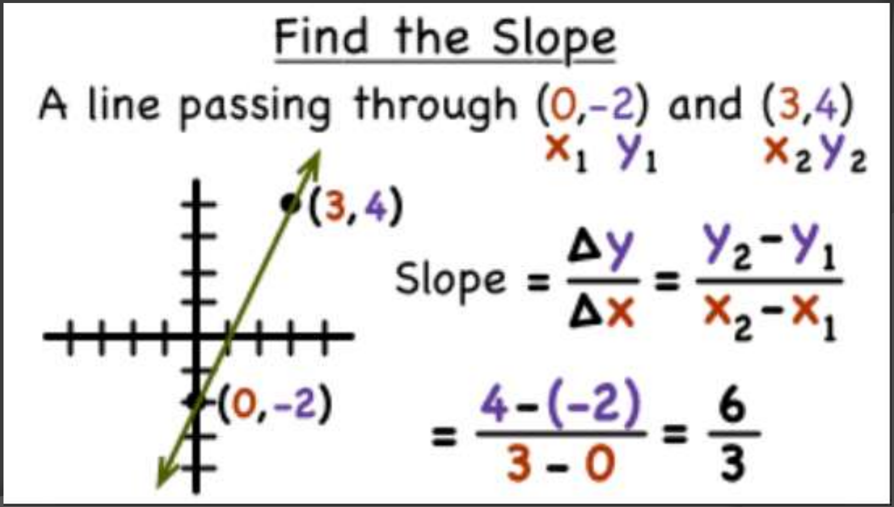
if-then statement

```
if (divisor != 0)
{
   quotient = dividend/divisor;
}
else
{
   cout << “Divide by 0”;
}
```



Your Turn: Line Slope Revisited

- Write a C++ program to compute the slope of a line in Cartesian coordinates, i.e. the x-y plane given two points
  - If Δx is 0 the slope is *infinite*
  - If (x_1, y_1) is the same point as (x_2, y_2) then the slope is *undefined*



Find the Slope

A line passing through $\underset{x_1\ y_1}{(0,-2)}$ and $\underset{x_2\ y_2}{(3,4)}$

$$\text{Slope} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$$

$$= \frac{4-(-2)}{3-0} = \frac{6}{3}$$

slope.cpp

```
#include <iostream>
using namespace std;

int main()
{
  double x1, y1, x2, y2, xdiff, ydiff, slope;

  cout << "Enter x and y coordinates of first point : ";
  cin >> x1 >> y1;
  cout << "Enter x and y coordinates of second point : ";
  cin >> x2 >> y2;
...
```

slope.cpp (cont.)

```
. . .
  xdiff = x1 - x2;
  ydiff = y1 - y2;

  if (xdiff != 0.0)
  {
    slope = ydiff / xdiff;
    cout << "The slope is: " << slope << endl;
  }
  else
  {
    cout << "The slope is infinite." << endl;
  }

  return 0;
}
```

Δx is 0

```
...
  xdiff = x1 - x2;
  ydiff = y1 - y2;

  if (xdiff != 0.0)
  {
    slope = ydiff / xdiff;
    cout << "The slope is: " << slope << endl;
  }
  else
  {
    cout << "The slope is infinite." << endl;
  }
```

```
> slope.exe
Enter x and y coordinates of first point : 0 3
Enter x and y coordinates of second point : 4 1
The slope is: -0.5
```

```
. . .
  xdiff = x1 - x2;    // Execute program with a new set of points
  ydiff = y1 - y2;

  if (xdiff != 0.0)
  {
    slope = ydiff / xdiff;
    cout << "The slope is: " << slope << endl;
  }
  else
  {
    cout << "The slope is infinite." << endl;
  }
```

```
> slope.exe
Enter x and y coordinates of first point : 4 3
Enter x and y coordinates of second point : 4 1
The slope is infinite.
```

Δx is 0

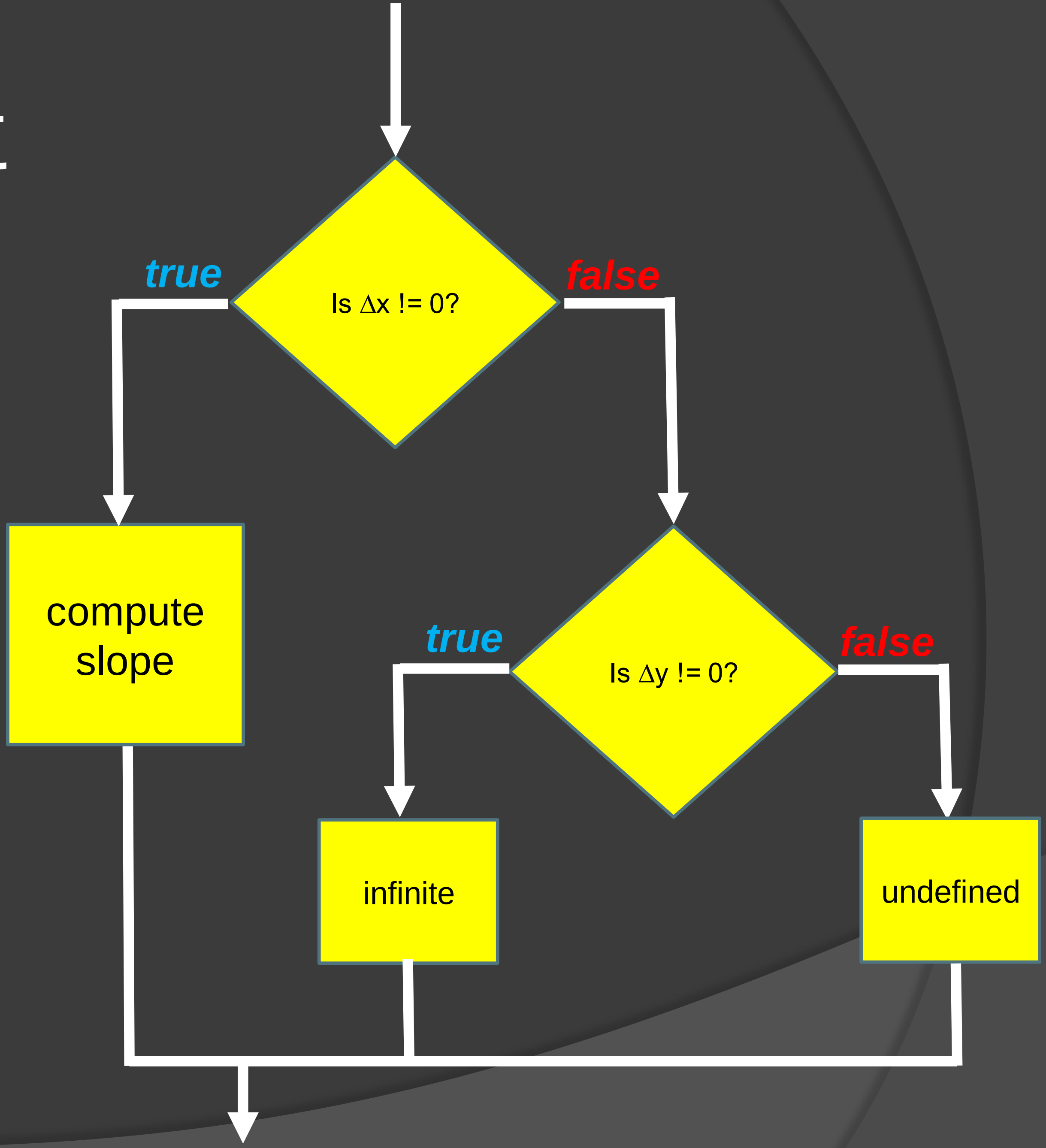
```
. . .
  xdiff = x1 - x2;    // Execute program with a new set of points
  ydiff = y1 - y2;

  if (xdiff != 0.0)
  {
    slope = ydiff / xdiff;
    cout << "The slope is: " << slope << endl;
  }
  else
  {
    cout << "The slope is infinite." << endl;
  }
```

```
> slope.exe
Enter x and y coordinates of first point : 4 3
Enter x and y coordinates of second point : 4 3
The slope is infinite.
```

Same points!

WRONG! The slope is *undefined*

Flow Chart


Is Δx != 0?
true
false
compute slope
Is Δy != 0?
true
false
infinite
undefined

slope2.cpp: Nested ifs

```
...
  xdiff = x1 - x2;
  ydiff = y1 - y2;

  if (xdiff != 0.0)
  {
    slope = ydiff / xdiff;
    cout << "The slope is: " << slope << endl;
  }
  else // we now know xdiff is zero!
  {
    if (ydiff != 0.0) {
      cout << "The slope is infinite." << endl;
    }
    else {
      cout << "Input Error: First point equals second point."
           << endl;
      cout << "Slope undefined." << endl;
    }
  }
...
```

```
...
  if (xdiff != 0.0)
  {
    slope = ydiff / xdiff;
    cout << "The slope is: " << slope << endl;
  }
  else
  {
    if (ydiff != 0.0) {
      cout << "The slope is infinite." << endl;
    }
    else {
      cout << "Input Error: First point equals second point."
           << endl;
      cout << "Slope undefined." << endl;
    }
  }
...
```

```
> slope.exe
Enter x and y coordinates of first point : 4 3
Enter x and y coordinates of second point : 4 3
Input Error: First point equals second point.
Slope undefined.
```

Nested Conditional Statements

```
...
int main()
{
  int age(0);

  cout << "Enter your age: ";
  cin >> age;

  if (age >= 15)
  {
    if (age == 15)
    { cout << "You can get a learners permit." << endl; }
    else
    { cout << "You can get a license." << endl; }
  }
  else
  { cout << "You are too young to drive." << endl; }

  return 0;
}
```

What is the output on input:

10

15

20

Nested Conditional Statements

```
...
int main()
{
  int age(0);

  cout << "Enter your age: ";
  cin >> age;

  if (age >= 18)
  {
    cout << "You can vote." << endl;
    if (age >= 35)
    { cout << "You can become President." << endl; }
  }
  else
  { cout << "You are too young to vote." << endl; }

  return 0;
}
```

What is the output on input:

10

20

40

logicalOperators1.cpp

```
// Examples of logical operators
#include <iostream>
using namespace std;

int main()
{
  int x(5);
  int y(25);

  if (x < 7 && y < 12) { cout << “true” << endl; }
  else { cout << “false” << endl; };

  if (x < 7 || y < 12) { cout << “true” << endl; }
  else { cout << “false” << endl; };

  if (x < 7 && !(y < 12)) { cout << “true” << endl; }
  else { cout << “false” << endl; };

  return 0;
}
```

What is output?

logicalOperators2.cpp

```
// Examples of logical operators
#include <iostream>
using namespace std;

int main()
{
  int x(5);
  int y(25);

  if ((x < 7 && y < 12) || (x > 7 && y > 12))
  { cout << “true” << endl; }
  else { cout << “false” << endl; };

  if ((x < 7 || y < 12) && (x > 7 || y > 12))
  { cout << “true” << endl; }
  else { cout << “false” << endl; };

  return 0;
}
```

What is output?

Boolean Variables

- The Boolean data type is called *bool*

```
bool red(true);
if (red)
{
    cout << "It is red" << endl;
}
else
{
    cout << "It is not red" << endl;
}
```

Boolean Variables

```
bool red(true);
if (red == true) // Avoid this!
{
    cout << “It is red” << endl;
}
else
{
    cout << “It is not red” << endl;
}
```

Rewrite

- Ask “Is it not red?”

```
bool red(true);
if (!red)
{
    cout << “It is not red” << endl;
}
else
{
    cout << “It is red” << endl;
}
```

Rewrite

```
bool red(true);
if (red == false) // Avoid this!
{
    cout << “It is not red” << endl;
}
else
{
    cout << “It is red” << endl;
}
```

Example of Boolean variables

```
...
int main()
{
  int age(0);
  bool flag_discount(false);

  cout << "Enter your age: ";
  cin >> age;

  if (age < 18)
  { flag_discount = true; }

  if (age >= 65)
  { flag_discount = true; }

  if (flag_discount)
  { cout << "You receive a discount." << endl; }
  else
  { cout << "No discount." << endl; }
...
```

comparisonExample.cpp

```cpp
// comparison example
#include <iostream>
using namespace std;

int main()
{
  int year(0);

  cout << "Enter year:  ";
  cin >> year;

  int k = year%4;
  if (k == 0)
  {
    cout << year << " is a US presidential election year." << endl;
  }
  else
  {
    cout << year << " is NOT a US presidential election year." << endl;
  }

  return 0;
}
```

```
…
  int k = year%4;
  if (k == 0)        // if k is equal to 0, ...
  {
    cout << year << " is a US presidential election year." << endl;
  }
  else
  {
    cout << year << " is NOT a US presidential election year." << endl;
  }
...
```

```
> comparisonExample
Enter year: 2023
2021 is NOT a US presidential election year.

> comparisonExample
Enter year: 2024
2020 is a US presidential election year.
```

comparisonError.cpp

```
// comparison error
#include <iostream>
using namespace std;

int main()
{
  int year(0);

  cout << "Enter year: ";
  cin >> year;

  int k = year%4;
  if (k = 0)
  {
    cout << year << “ is a US presidential election year.” << endl;
  }
  else
  {
    cout << year << “ is NOT a US presidential election year.” << endl;
  }

  return 0;
}
```

Note the single =

```
…
  int k = year%4;
  if (k = 0)
  {
    cout << year << " is a US presidential election year." << endl;
  }
  else
  {
     cout << year << " is NOT a US presidential election year." << endl;
  }
…
```

```
> comparisonError
Enter year: 2023
2021 is NOT a US presidential election year.

> comparisonError
Enter year: 2024
2020 is NOT a US presidential election year.
```

WRONG!!!

Common Mistakes with Conditions

```
if (age = 18)
```

- The equality operator **==** is different from the assignment operator **=**
- We are actually assigning `age` to the value 18!!!
- The expression `age = 18` evaluates to `18`

- So the condition (boolean expression) becomes this when executed:

```
if (18)
{
     cout << "You are 18."
}
```

- 0 evaluates to **false** and any other number evaluates to **true**. Thus, the boolean expression in the condition, i.e. 18, evaluates to **true**

comparisonError2.cpp

```cpp
// comparison example
#include <iostream>
using namespace std;

int main()
{
  int year(0);

  cout << "Enter year: ";
  cin >> year;

  int k = year%4;
  if (k == 0)          // if k is equal to 0, ...
  {
    cout << year << " is a US presidential election year." << endl;
  };
  else
  {
    cout << year << " is NOT a US presidential election year." << endl;
  };

  return 0;
}
```

Note the ;

main.cpp:17:3: error: ‘else’ without a previous ‘if’ 17 | else | ^~~~

comparisonError2.cpp

```
…
 int k = year%4;
  if (k == 0)       // if k is equal to 0, ...
  {
    cout << year << " is a US presidential election year." <<
     endl;
  };
  else
  {
    cout << year << " is NOT a US presidential election
     year." << endl;
  };
…
```

- Syntax Error:

```
main.cpp:17:3: error: ‘else’ without a previous ‘if’
17 | else | ^~~~
```

comparisonError2.cpp

```
// comparison example
#include <iostream>
using namespace std;

int main()
{
  int year(0);

  cout << "Enter year: ";
  cin >> year;

  int k = year%4;
  if (k == 0);
  {
    cout << year << " is a US presidential election year." << endl;
  }
  else
  {
    cout << year << " is NOT a US presidential election year." << endl;
  };

  return 0;
}
```

Find the error.

Hint: there are actually 2 errors.

comparisonError2.cpp

Warning! Common Mistakes

- Use ‘==’ (equal to), not ‘=’ (assignment)
- Use ‘&&’ not ‘&’
- Use ‘| |’, not ‘|’
- Do not put a semi-colon before an “else” clause
- Do not put a semi-colon after the condition