CS303E: Elements of Computers and Programming

Conditionals and Boolean Logic

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Booleans

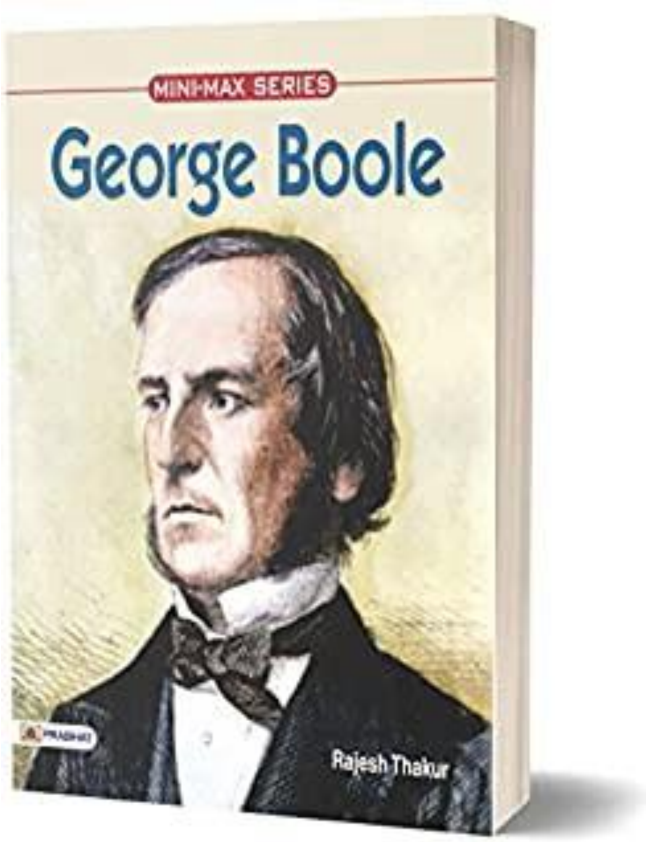
So far we've been considering *straight line code*, meaning executing one statement after another.

a.k.a. *sequential flow of control*

But often in programming, you need to ask a question, and *do different things* based on the answer.

Boolean values are a useful way to refer to the answer to a yes/no question.

The Boolean **literal values** are the values: True, False.
A Boolean **expression** evaluates to a Boolean value.



Using Booleans

```
>>> import math
>>> b = ( 30.0 < math.sqrt( 1024 ))
>>> print( b)
True
>>> x = 1                   # statement
>>> x < 0                   # boolean expression
False
>>> x >= -2                 # boolean expression
True
>>> b = ( x == 0 )          # statement containing
                            # boolean expression
>>> print (b)
False
```

Booleans are implemented in the bool class.

Booleans

Internally, Python uses 0 to represent False and anything not 0 to represent True. You can convert from Boolean to int using the int function and from int to Boolean using the bool function.

```
>>> b1 = (-3 < 3)
>>> print(b1)
True
>>> bool(1)
True
>>> bool(0)
False
>>> bool(4)
True
>>>
```

Boolean Context

In a **Boolean context**—one that expects a Boolean value—False, 0, "" (the empty string), and None all is considered False and *any other value* is considered True.

```
>>> bool("xyz")
True
>>> bool(0.0)
False
>>> bool("")
False
>>> if 4: print("xyz")          # boolean context
xyz
>>>if 4.2: print("xyz")
xyz
>>> if "ab": print("xyz")
xyz
```

This may be confusion but can be very useful in some programming situations.

Comparison Operators

The following comparison (or relational) operators are useful for comparing numeric values:

Operator	Meaning	Example
<	Less than	x < 0
<=	Less than or equal	x <= 0
>	Greater than	x > 0
>=	Greater than or equal	x >= 0
==	Equal to	x == 0
!=	Not equal to	x != 0

Each of these returns a Boolean value, True or False.

```
>>> x = 10
>>> (x == math.sqrt(100))
True
>>> (x = math.sqrt(100))
SyntaxError: invalid syntax
```

What happened on that last line?

Caution

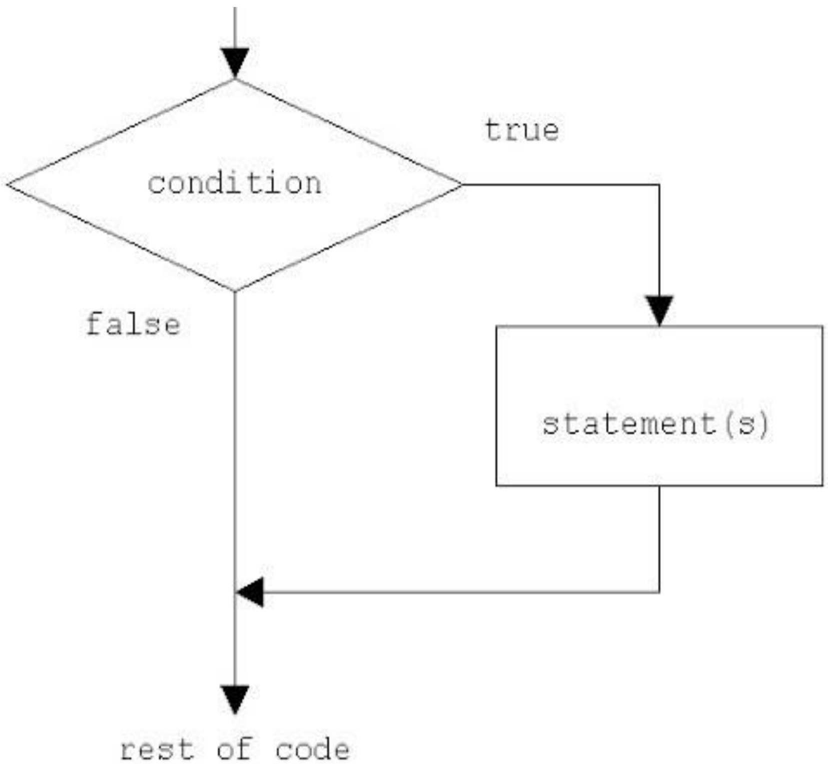
Be very careful using "==" when comparing *floats*, because float arithmetic is approximate.

```
>>> (1.1 * 3 == 3.3)
False                          # What happened?
>>> 1.1 * 3
3.3000000000000003
```

The problem: converting decimal 1.1 to binary yields a *repeating* binary expansion: $1.000110011\ldots = 1.0\overline{0011}$. That means *it can't be represented exactly* in a fixed size binary representation.

Thought for the day. Some rational numbers are repeating decimals in one base, but not in others. $1/3 = 0.33333\ldots_{10} = 0.1_3$

It's often useful to be able to perform an action *only if* some conditions is true.



General form:

```
if boolean-expression:
    statement(s)
```

Note the colon after the boolean-expression.

All of the statements controlled by the if must be indented the same amount.

```
if y != 0:
    z = (x / y)
```

If Statement Example

In file if_example.py:

```
def main():
    # A very uninteresting function to
    # illustrate if statements.
    x = int(input(" Input an integer or 0 to do nothing: "))
    if (x != 0):
        print('The number you entered was',
              x, '. Thank you!')
```

Would "`if x:`" have worked instead of "`if ( x != 0 ):`"?

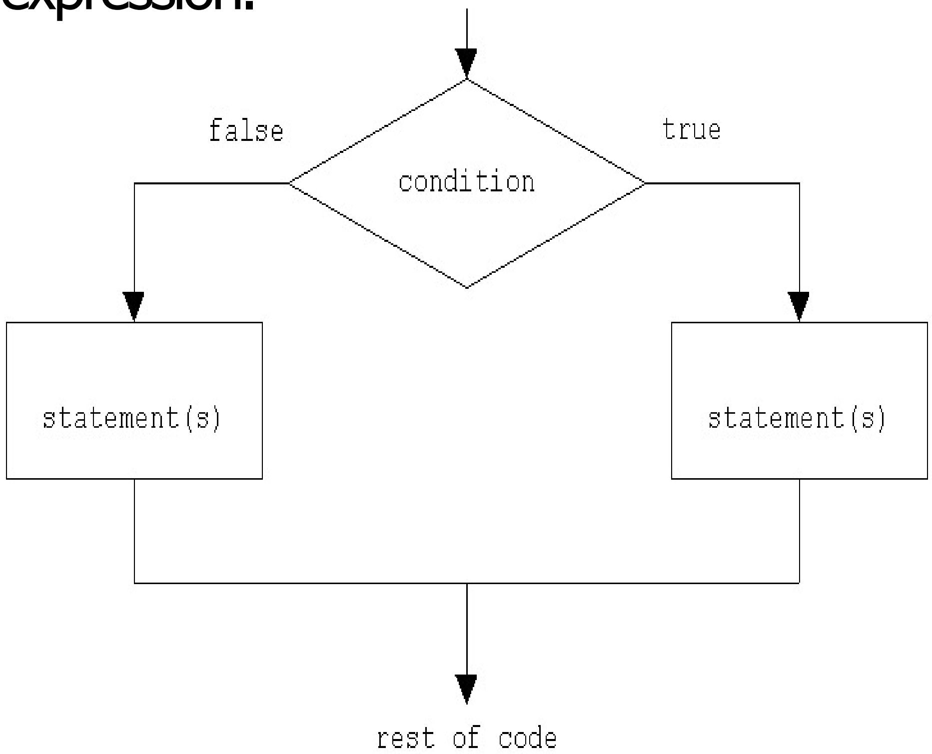
```
>>> runfile('C:/Users/scottm/PycharmProjects/As
Input an integer or 0 to do nothing: >? 10
The number you entered was 10 . Thank you!
>>> runfile('C:/Users/scottm/PycharmProjec
Input an integer or 0 to do nothing: >? 0
```

Two-way If-else Statements

A two-way **If-else** statement executes one of two actions, depending on the value of a Boolean expression.

General form:

```
if boolean-expression:
    true-case-statement(s)
else:
    false-case-statement(s)
```



Note the colons after the boolean-expression and after the `else`. All of the statements in *both* if and else branches should be indented the same amount.

If-else Statement: Example

In file compute_circle_area.py:

```python
import math


def main():
    # Estimate area of circle based on radius from user
    radius = float(input("Enter the radius of a circle: "))
    if (radius >= 0):
        area = math.pi * radius ** 2
        print('A circle with a radius of ', radius,
              'has an area of ', area)
    else:
        print('Negative radius entered: ', radius)


main()
```

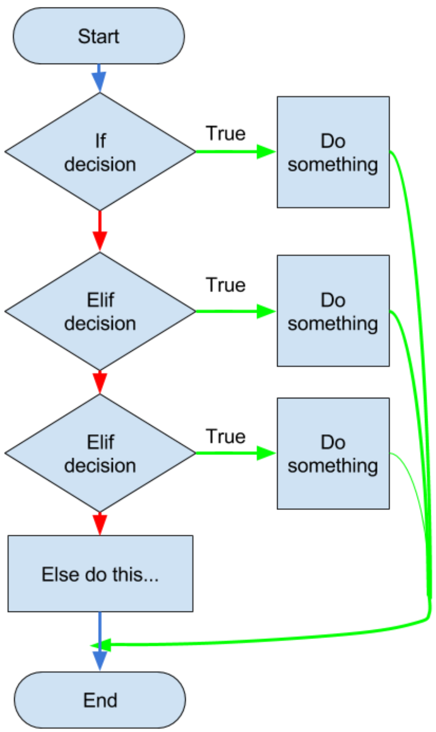
```
Enter the radius of a circle: 4.3
A circle with a radius of 4.3 has an area of 58.088048

Enter the radius of a circle: -3.75
Negative radius entered: -3.75
```

Multiway if-elif-else Statements

If you have multiple options, you can use if-elif-else statements.

General Form:

```
if boolean-expression1:
    statement(s)
elif boolean-expression2:
    statement(s)
elif boolean-expression3:
    ...
else:                    # optional
    statement(s)
```



You can have any number of `elif` branches with their conditions. The else branch is optional.

Sample Program: Calculate US Federal Income Tax

Simplified US Federal Income Tax Table

Source: https://www.nerdwallet.com/article/taxes/federal-income-tax-brackets

Single filers

Tax rate	Taxable income bracket	Tax owed
10%	$0 to $9,875	10% of taxable income
12%	$9,876 to $40,125	$987.50 plus 12% of the amount over $9,875
22%	$40,126 to $85,525	$4,617.50 plus 22% of the amount over $40,125
24%	$85,526 to $163,300	$14,605.50 plus 24% of the amount over $85,525
32%	$163,301 to $207,350	$33,271.50 plus 32% of the amount over $163,300

income_tax.py

```python
# Ask user for income and calculate US Federal income tax for 2021.
# Tax rates and income bracket data from
# https://www.nerdwallet.com/article/taxes/federal-income-tax-brackets
def main():
    income = int(input('Enter 2021 income: '))
    print()
    if income <= 9_875:
        tax = income * 0.1
        bracket = "10%"
    elif income <= 40_125:
        tax = 987.5 + (income - 9_875) * 0.12
        bracket = "12%"
    elif income <= 85_525:
        tax  = 4_617.50 + (income - 40_125) * 0.22
        bracket = "22%"
    elif income <= 163_300:
        tax = 14_605.50 + (income - 85_525) * 0.24
        bracket = "24%"
    else:
        tax = 33_271.50 + (income - 163_300) * 0.32
        bracket = "32%"

    print('An income of', income, 'places you in the',
          bracket, 'income bracket.')
    print('The US Federal tax on an income of', income,
          'is', tax)
```

Break

Maybe take a break?

Logical Operators

Python has **logical operators** (and, or, not) that can be used to make compound Boolean expressions.

not : logical negation

and : logical conjunction

or : logical disjunction

Operators **and** and **or** are always evaluated using *short circuit evaluation*.

$$(\ x \ \% \, 100 \ == \ 0 \ ) \ \text{and not} \ (\ x \ \% \, 400 \ == \ 0 \ )$$

Truth Tables

And: $(\mathrm{A\ and\ B})$ is True whenever both A is True and B is True.

A	B	A and B
False	False	False
False	True	False
True	False	False
True	True	True

Not: $\mathrm{not\ A}$ is True whenever A is False.

A	not A
False	True
True	False

Or: $(\mathrm{A\ or\ B})$ is True whenever either A is True or B is True.

A	B	A or B
False	False	False
False	True	True
True	False	True
True	True	True

Remember that “is True” really means “is not False, the empty string, 0, or None.”

Short Circuit Evaluation

Notice that (A and B) is False, if A is False; it doesn't matter what B is.
So there's no need to evaluate B, if A is False!

Also, (A or B) is True, if A is True; it doesn't matter what B is.
So there's no need to evaluate B, if A is True!

```
>>> x = 13
>>> y = 0
>>> legal = (y == 0 or x / y > 0)
>>> print(legal)
True
```

Python doesn't evaluate B if evaluating A is sufficient to determine the value of the expression. *That's important sometimes.*
This is called *short circuiting* the evaluation.
Stopping early when answer it know.

Boolean Operators

In a Boolean context, Python doesn't always return True or False, just something equivalent. What's going on in the following?

```
>>> "" and 14
''                           # equivalent to False
>>> bool("" and 14)
False                        # coerced to False
>>> 0 and "abc"
0                            # equivalent to False
>>> bool(0 and "abc")
False                        # coerced to False
>>> not(0.0)
True                         # same as not( False )
>>> not(1000)
False                        # same as not( True )
>>> 14 and ""
''                           # equivalent to False
>>> 0 or "abc"               # same as False or True
'abc'                        # equivalent to True
>>> bool(0 or 'abc')         # coerced to True
True
```

Leap Years

Here's a concise way to do a Leap Year computation:

```
# Determine if year entered is a leap year or not.
def main():
    year = int(input('Enter a year: '))
    is_leap_year = ((year % 4 == 0)
                    and (not (year % 100 == 0) or (year % 400 == 0)))

    if is_leap_year:
        print(year, "is a leap year.")
    else:
        print(year, 'is not a leap year.')


main()
```

Note the use of outer parenthesis on the assignment to is_leap_year to avoid the use of the continuation character, "\".

Leap Years Revisited

```
>python LeapYear2.py
Enter a year: 2000
Year 2000 is a leap year.
>python LeapYear2.py
Enter a year: 1900
Year 1900 is not a leap year.
>python LeapYear2.py
Enter a year: 2004
Year 2004 is a leap year.
>python LeapYear2.py
Enter a year: 2005
Year 2005 is not a leap year.
```

Conditional Expressions

A Python **conditional expression** returns one of two values based on a condition.

Consider the following code:

```
# Set parity according to num
if (num % 2 == 0):
    parity = "even"
else:
    parity = "odd"
```

This sets variable `parity` to one of two values, “even” or “odd”.

An alternative is:

```
parity = "even" if ( num % 2 == 0 ) else "odd"
```

Conditional Expression

General form:

```
expr-1 if boolean-expr else expr-2
```

It means to return `expr-1` if `boolean-expr` evaluates to True, and to return `expr-2` otherwise.

```
# find maximum of x and y
max = x if (x >= y) else y
```

Conditional Expression

Use of conditional expressions can simplify your code.

In file test_sort.py:

```
# Determine if 3 numbers are in sorted ascending order.
def main():
    x = float(input("Enter first number: "))
    y = float(input("Enter second number: "))
    z = float(input("Enter second number: "))
    print('Ascending' if (x <= y) and (y <= z)
              else 'Not Ascending')


main()
```

```
Enter first number: 12
Enter second number: 57
Enter second number: 109
Ascending
```

```
Enter first number: -26.6
Enter second number: 0.72
Enter second number: -12.75
Not Ascending
```

Operator Precedence

Arithmetic expressions in Python attempt to match widely used mathematical rules of precedence. Thus,

$$3 + 4 * (5 + 2)$$

is interpreted as representing:

$$(3 + (4 * (5 + 2))).$$

That is, we perform the operation within parenthesis first, then the multiplication, and finally the addition.

To make this happen we *precedence rules* are enforced.

Precedence

The following are the precedence rules for Python, with items higher in the chart having higher precedence.

Operator	Meaning
+, -	Unary plus, minus, like - 3, +12
**	Exponentiation
not	logical negation
*, /, //, %	Multiplication, division, integer division, modulus
+, -	Binary plus, minus
<, <=, >, >=	Comparison
==, !=	Equal, not equal
and	Conjunction
or	Disjunction

Precedence Examples

```
>>> -3 * 4
-12
>>> - 3 + - 4
-7
>>> 3 + 2 ** 4
19
>>> 4 + 6 < 11 and 3 - 10 < 0
True
>>> 4 < 5 <= 17          # notice special syntax
True
>>> 4 + 5 < 2 + 7
False
>>> 4 + (5 < 2) + 7    # this surprised me!
11
```

Most of the time, the precedence follows what you would expect.

Precedence

Operators on the same line have equal precedence.

Operator	Meaning
`+, -`	Binary plus, minus
`*, /, //, %`	Multiplication, division, integer division, remainder

Evaluate them left to right.

All binary operators are *left associative*. Example: `x + y - z + w` means `((x + y) - z) + w`.

Note that assignment is *right associative*.

```
x = y = z = 1     # assign z first
```

Use Parentheses to Override Precedence

Use parenthesis to override precedence or to make the evaluation clearer.

```
>>> 10 - 8 + 5              # an expression
7
>>> (10 - 8) + 5            # what precedence will do
7
>>> 10 - (8 + 5)            # override precedence
-3
>>> 5 - 3 * 4 / 2           # not particularly clear
-1.0
>>> 5 - ((3 * 4) / 2)       # better
-1.0
```

Work to make your code easy to read!