

Operations

- None, bool
- basic operations
- strings
- += and friends

NoneType

- The type None has only one value: None
- Used when context requires a value, but none is really available
- **Example:** All functions must return a value. The function `print` has the *side-effect* of printing something to the standard output, but returns None
- **Example:** Initialize a variable with no value, e.g. list entries `mylist = [None, None, None]`

Python shell

```
> x = print(42)
| 42
> print(x)
| None
```

Type bool

- The type `bool` only has two values: `True` and `False`
- Logic truth tables:

<code>x or y</code>	True	False
True	True	True
False	True	False

<code>x and y</code>	True	False
True	True	False
False	False	False

<code>x</code>	<code>not x</code>
True	False
False	True

Scalar vs Non-scalar Types

- **Scalar types** (atomic/indivisible): `int`, `float`, `bool`, `None`
- **Non-scalar**: Examples `strings` and `lists`

```
"string"[3] = "i"  
[2, 5, 6, 7][2] = 6
```

Questions – What is $[7, 3, 5] [[1, 2, 3] [1]]$?

a) 1

b) 2

c) 3



d) 5

e) 7

f) Don't know


Operations on int and float

Result is float if and only if at least one argument is float, except `` with negative exponent always gives a float**

- `+`, `-`, `*` addition multiplication, e.g. $3.0 * 2 = 6.0$
- `**` and `pow(x, y)` power, e.g. $2 ** 3 = \text{pow}(2, 3) = 8$, $2 ** -2 = 0.25$
- `//` **integer division** = $\lfloor x / y \rfloor$
e.g. $15.0 // 4 = 3.0$. Note: $-8 // 3 = -3$
- `/` **division returns float**, $6 / 3 = 2.0$
- `abs(x)` absolute value
- `%` integer division remainder (modulo)
 $11 \% 3 = 2$
 $4.7 \% 0.6 = 0.500000000000000000003$

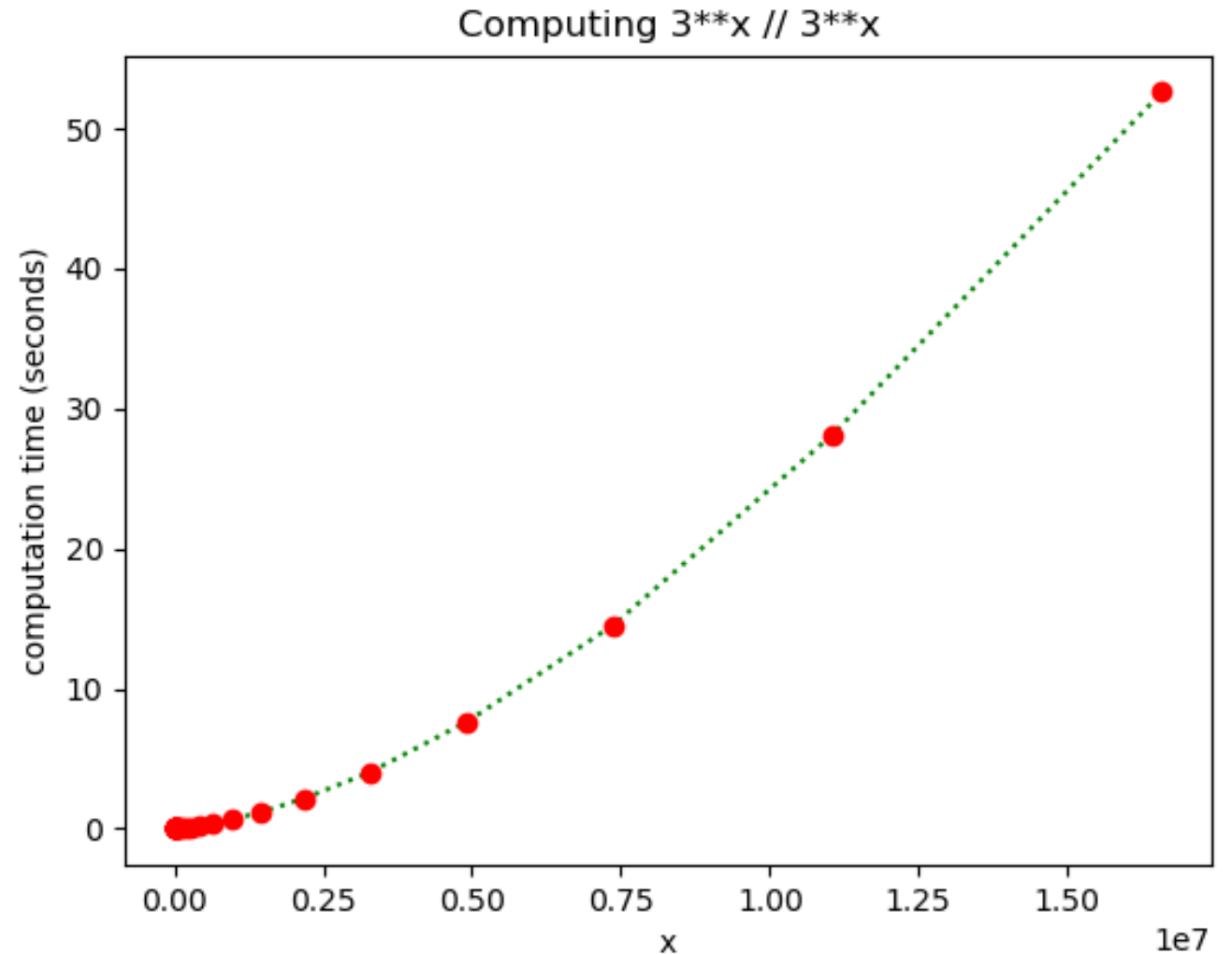
Python shell

```
> 0.4 // 0.1
| 4.0
> 0.4 / 0.1
| 4.0
> 0.3 // 0.1
| 2.0
> 0.3 / 0.1
| 2.9999999999999996
> 10**1000 / 2
| OverflowError: integer division
  result too large for a float
```



Running time for $3^{**}x // 3^{**}x$

Working with larger integers takes slightly more than linear time in the number of digits



integer-division-timing.py

```
from time import time
import matplotlib.pyplot as plt

bits, compute_time = [], []

for i in range(42):
    x = 3 ** i // 2 ** i
    start = time()
    result = 3 ** x // 3 ** x      # the computation we time
    end = time()
    t = end - start
    print('i =', i, 'x =', x, 'Result =', result, 'time(sec) =', t)
    bits.append(x)
    compute_time.append(t)

plt.title('Computing 3**x // 3**x')
plt.xlabel('x')
plt.ylabel('computation time (seconds)')
plt.plot(bits, compute_time, 'g:')
plt.plot(bits, compute_time, 'ro')
plt.show()
```


module math

Many standard mathematical functions are available in the Python module “`math`”, e.g.

`sqrt`, `sin`, `cos`, `tan`, `asin`, `acos`, `atan`, `log`(natural), `log10`, `exp`, `ceil`, `floor`, ...

- To use all the functions from the `math` module use `import math`
Functions are now available as e.g. `math.sqrt(10)` and `math.ceil(7.2)`
- To import selected functions you instead write `from math import sqrt, ceil`
- The library also contains some constants, e.g.
`math.pi` = 3.141592... and `math.e` = 2.718281...
- Note: `x ** 0.5` significantly faster than `sqrt(x)`



```
Python shell
> (0.1 + 0.2) * 10
| 3.0000000000000004
> math.ceil((0.1 + 0.2) * 10)
| 4
```



Python shell

```
> import math
> math.sqrt(8)
| 2.8284271247461903
> from math import pi, sqrt
> pi
| 3.141592653589793
> sqrt(5)
| 2.23606797749979
> from math import sqrt as kvadratrod
> kvadratrod(3)
| 1.7320508075688772

> import timeit
> timeit.timeit('1e10**0.5')
| 0.021124736888936863
> timeit.timeit('sqrt(1e10)', 'from math import sqrt')
| 0.1366314052865789
> timeit.timeit('math.sqrt(1e10)', 'import math')
| 0.1946660841634582
```

Rounding up integer fractions

- Python: $\lceil x/y \rceil = -(-x // y)$

-(-13/3)		
Python	Java	C
$-(-13//3)$ = 5	$-(-13/3)$ = 4 	$-(-13/3)$ = 4 



The intermediate result x/y in
`math.ceil(x/y)`

is a float with limited precision


- Alternative computation:

$$\lceil x/y \rceil = (x + (y-1)) // y$$

Python shell

```
> from math import ceil
> from timeit import timeit

> 13 / 3
| 4.333333333333333
> 13 // 3
| 4
> -13 // 3
| -5
> -(-13 // 3)
| 5
> ceil(13 / 3)
| 5

> -(-22222222222222222222223 // 2)
| 1111111111111111111112
> ceil(22222222222222222222223 / 2)
| 111111111111111111110656 
> timeit('ceil(13 / 3)', 'from math import ceil')
| 0.2774667127609973
> timeit('-(-13 // 3)') # negation trick is fast
| 0.05231945830200857
```

floats : Overflow, inf, -inf, nan

- There exists special float values
`inf`, `-inf`, `nan`
representing “+infinity”, “-infinity” and
“not a number”
- Can be created using e.g.
`float('inf')`
or imported from the `math` module
- Some overflow operations generate an
`OverflowError`, other return `inf`
and allow calculations to continue !
- Read the [IEEE 754 standard](#) if you want to
know more details...

Python shell

```
> 1e250 ** 2
| OverflowError:
|   (34, 'Result too large')
> 1e250 * 1e250
| inf
> -1e250 * 1e250
| -inf
> import math
> math.inf
| inf
> type(math.inf)
| <class 'float'>
> math.inf / math.inf
| nan
> type(math.nan)
| <class 'float'>
> math.nan == math.nan
| False
> float('inf') - float('inf')
| nan
```

Operations on bool

- The operations `and`, `or`, and `not` behave as expected when the arguments are `False/True`.
- The three operators also accept other types, where the following values are considered *false*:

`False, None, 0, 0.0, "", []`

(see The Python Standard Library > Built-in Types > [True Value Testing](#) for more *false* values)

- **Short-circuit evaluation**: The rightmost argument of `and` and `or` is only evaluated if the result cannot be determined from the leftmost argument alone. The result is either the leftmost or rightmost argument (see truth tables), i.e. the result is not necessarily `False/True`.

`True or 7/0` is completely valid since `7/0` will never be evaluated
(which otherwise would throw a `ZeroDivisionError` exception)

x	x or y
<i>false</i>	y
otherwise	x

x	x and y
<i>false</i>	x
otherwise	y

x	not x
<i>false</i>	True
otherwise	False

Questions – What is "abc" and 42 ?

a) False

b) True

c) "abc"



d) 42

e) TypeError

f) Don't know

Comparison operators (e.g. int, float, str)

`==` test if two objects are equal, returns bool
not to be confused with the assignment operator (`=`)

`!=` not equal

`>`


`>=`

`<`

`<=`

Python shell

```
> 3 == 7
| False
> 3 == 3.0
| True
> "-1" != -1
| True
> "abc" == "ab" + "c"
| True
> 2 <= 5
| True
> -5 > 5
| False
> 1 == 1.0
| True
> 1 == 1.00000000000000000001
| True
> 1 == 1.00000000000000000001
| False
```



Chained comparisons

- A recurring condition is often

$$x < y \text{ and } y < z$$

- If y is a more complex expression, we would like to avoid computing y twice, i.e. we often would write


```
tmp = complex expression
x < tmp and tmp < z
```

- In Python this can be written as a **chained comparisons** (which is shorthand for the above)

$$x < y < z$$

- Note: Chained comparisons do not exist in C, C++, Java, ...

Questions – What is $1 < 0 < 6/0$?

- a) True
-  b) False
- c) 0
- d) 1
- e) 6
- f) ZeroDivisionError
- g) Don't know

Binary numbers and operations

- Binary number = integer written in base 2: $101010_2 = 42_{10} = 2^1 + 2^3 + 2^5$
- Python constant prefix 0b: `0b101010` → 42
- `bin(x)` converts integer to string: `bin(49)` → "0b110001"
- `int(x, 2)` converts binary string value to integer: `int("0b110001", 2)` → 49
- Bitwise operations
 - | Bitwise OR
 - & Bitwise AND
 - ~ Bitwise NOT (~ x equals to $-x - 1$)
 - ^ Bitwise XOR
- Example: `bin(0b1010 | 0b1100)` → "0b1110"
- Hexadecimal = base 16, Python prefix 0x: `0x30` → 48, `0xA0` → 160, `0xFF` → 255
- << and >> integer bit shifting left and right, e.g. `12 >> 2` → 3, and `1 << 4` → 16

Operations on strings

- `len(str)` returns length of `str`
- `str[index]` returns `index+1`'th symbol in `str`
- `str1 + str2` returns concatenation of two strings
- `int * str` concatenates `str` with itself `int` times
- Formatting: % operator or .format() function
old Python 2 way since Python 3.0
or formatted string literals (f-strings) with prefix
since Python 3.6
letter `f` and Python expressions in `{ }`
(see pyformat.info for an introduction)

From “[What’s New In Python 3.0](#)”, 2009: A new system for built-in string formatting operations replaces the % string formatting operator. (However, *the % operator* is still supported; it *will be deprecated in Python 3.1* and removed from the language at some later time.) Read [PEP 3101](#) for the full scoop.

Python shell

```
> len("abcde")
| 5
> "abcde"[2]
| 'c'
> x, y = 2, 3
> "x = %s, y = %s" % (x, y)
| 'x = 2, y = 3'
> "x = {}, y = {}".format(x, y)
| 'x = 2, y = 3'
> "x = {1}, y = {0}".format(y, x)
| 'x = 2, y = 3'
> f'x + y = {x + y}'
| 'x + y = 5'
> f'{x + y = }' # >= Python 3.8
| 'x + y = 5'
> f'{x} / {y} = {x / y:.3}'
| '2 / 3 = 0.667'
> "abc" + "def"
| 'abcdef'
> 3 * "x--"
| 'x--x--x--'
> 0 * "abc"
| ''
```

% formatting (inherited from C's `sprint()` function) was supposed to be on the way out - but is still going strong in Python 3.13

Python does not automatic convert to string



- A `str` can not be concatenated with an `int`
- The `int` must first be converted to a `str` using `str(int value)`

works in Java
and Javascript

Python shell

```
> 'abc' + 42
| TypeError: can only concatenate str (not "int") to str
> 'abc' + str(42)
| 'abc42'
```

- In some languages, like Java and Javascript, the conversion to string happens automatically (just a language design choice)

... more string functions


- `str[-index]` returns the symbol *i* positions from the right, the rightmost `str[-1]`
- `str[from:to]` substring starting at index *from* and ending at index *to*-1
- `str[from:-to]` substring starting at *form* and last at index `len(str) - to - 1`
- `str[from:to:step]` only take every *step*'th symbol in `str[from:to]`
 - *from* or/and *to* can be omitted and defaults to the beginning/end of string
- `chr(x)` returns a string of length 1 containing the *x*'th Unicode character
- `ord(str)` for a string of length 1, returns the Unicode number of the symbol
- `str.lower()` returns string in lower case
- `str.split()` split string into list of words, e.g.
`"we love python".split() = ['we', 'love', 'python']`

Python shell

```
> s = 'this is a string'
> s.capitalize()
| 'This is a string'
> s.title()
| 'This Is A String'
> s.upper()
| 'THIS IS A STRING'
> s.title().swapcase()
| 'tHIS iS a sTRING'
> s.removeprefix('this is ')
| 'a string'
> s.removesuffix(' string')
| 'this is a'
> s.replace('is', 'IS')
| 'thIS IS a string'
> s.ljust(30)
| 'this is a string          '
> s.center(30)
| '      this is a string      '
> s.rjust(30, '.')
| '.....this is a string'
> s.count('i')
| 3
> '12345'.zfill(8)
| '00012345'
```

Questions – What is `s[2:42:3]`?

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
s = 'abw~~w~~dexy__lwt~~o~~pavghevt_xyp~~x~~xyattx_hxwoadnxxx'

- a) 'wwdexy__lwtopavghevt_xypxxyattx_hxwoadn'
-  b) 'we_love_python'
- c) 'we_love_java'
- d) Don't know

Strings are immutable

- Strings are non-scalar, i.e. for `s = "abcdef"`, `s[3]` will return `"d"`
- Strings are **immutable** and cannot be changed once created.
I.e. the following natural update **is not possible** (but is e.g. allowed in C)

`s[3] = "x"`

- To replace the `"d"` with `"x"` in `s`, instead create the new string

`s = s[:3] + "x" + s[4:]`

Operators

Precedence rules & Associativity

Example: * has higher precedence than +

$$2 + 3 * 4 \equiv 2 + (3 * 4) \rightarrow 14 \quad \text{and} \quad (2 + 3) * 4 \rightarrow 20$$

All operators in same group are evaluated left-to-right

$$2 + 3 - 4 - 5 \equiv ((2 + 3) - 4) - 5 \rightarrow -4$$

except for **, that is evaluated right-to-left

$$2 ** 2 ** 3 \equiv 2 ** (2 ** 3) \rightarrow 256$$

Rule: Use **parenthesis** whenever in doubt of precedence!

Precedence (low to high)		
or		
and		
not x		
in	not in	
is	is not	
==	<	<=
!=	>	>=
^		
&		
<<		>>
+		-
*		@
/	//	%
+x	-x	~x
**		

Long expressions

- Long expressions can be broken over several lines by putting parenthesis around it
- The PEP8 guidelines recommend to limit **all** lines to a maximum of 79 characters

```
Python shell
> (1
    + 2 +
    3)
| 6
```

`+=` and friends

- Recurring statement is

`x = x + value`

- In Python (and many other languages) this can be written as

`x += value`

- This also applies to other operators like

`+= -= *= /= //= **=`
`|= &= ^= <<= >>=`

Python shell

```
> x = 5
> x *= 3
> x
| 15
> a = 'abc'
> a *= 3
> a
| 'abcabcabc'
```

`:=` assignment expressions (the “Walrus Operator”)

New in
Python 3.8


- Syntax

`name := expression`

- Evaluates to the value of `expression`, with the side effect of assigning result to `name`
- Useful for naming intermediate results/repeating subexpressions for later reuse
- See [PEP 572](#) for further details and restrictions of usage

Python shell

```
> (x := 2 * 3) + 2 * x
| 18
> print(1 + (x := 2 * 3), 2 + x)
| 7 8
> x := 7
| SyntaxError
> (x := 7) # valid, but not recommended
> while line := input():
|     print(line.upper())
> abc
| ABC
```

-  In some languages, e.g. Java, C and C++, “=” also plays the role of “:=”, implying “if (x=y)” and “if (x==y)” mean quite different things (common typo)