# Programming Basics

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# Contents

# Chapter 1

# Calculations

## 1.1 Calculations using whole numbers

Evaluate the following expressions.

1.1

a. `1 / 5`
b. `2 / 6`
c. `3 / 8`
d. `4 / 5`
e. `5 / 6`

1.2

a. `1 % 5`
b. `2 % 6`
c. `3 % 8`
d. `4 % 5`
e. `5 % 6`

1.3

a. `3 / 1`
b. `7 / 2`
c. `7 / 3`
d. `5 / 4`
e. `8 / 5`

1.4

a. `3 % 1`
b. `7 % 2`
c. `7 % 3`
d. `5 % 4`
e. `8 % 5`

1.5

a. `2 / 1`
b. `6 / 2`
c. `12 / 3`
d. `8 / 4`
e. `25 / 5`

1.6

a. `2 % 1`
b. `6 % 2`
c. `12 % 3`
d. `8 % 4`
e. `25 % 5`

1.7

a. `3 / 8`
b. `4 / 2`
c. `8 / 9`
d. `1 / 2`
e. `5 / 7`

1.8

a. `3 % 8`
b. `4 % 2`
c. `8 % 9`
d. `1 % 2`
e. `5 % 7`

1.9

a. `14 / 11`
b. `16 / 14`
c. `5 / 16`
d. `20 / 12`
e. `15 / 17`

1.10

a. `14 % 11`
b. `16 % 14`
c. `5 % 16`
d. `20 % 12`
e. `15 % 17`

**Expressions** An expression is a combination of numbers and operations. Such an expression may be *evaluated* using the mathematical rules that you may already know. For example:

| expression | evaluates to |
|---|---|
| `4` | `4` |
| `5` | `5` |
| `4 + 5` | `9` |
| `4 * 5` | `20` |

Next to the more familiar operations we will explain several exceptions and particulars that come into play when doing calculations using a computer.

**Integer division** Computers treat *integers*, or whole numbers, differently from *floats*, numbers with a decimal point. In most situations you can expect similar results, but there are some differences. The first difference is division: the expression `1 / 2` surprisingly evaluates to `0`. This is because division of two integers is interpreted as asking the following question: *how often does the number 2 fit into the number 1*? In the following table, we list the results of dividing some numbers by 3.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| `x` | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| `x / 3` | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 2 |

**Modulo** An operation that you might not know is modulo, often written as `%`. This operation nicely complements the integer division; for example, in the case of an expression like `5 % 2`, we should answer the following question: *2 fits 2 times into 5, how much is then left*? The answer is `1`. In the following table, we list the the results of performing a modulo 3 for some numbers. When you compare it to the previous table, you should see that it does indeed list what is "left" after performing an integer division.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| `x` | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| `x % 3` | 0 | 1 | 2 | 0 | 1 | 2 | 0 | 1 |

**Divisibility** We call an integer *divisible* by another integer if the result of taking the modulo is `0`, or in other words: if nothing is left after the division.

## 1.2 Precedence rules

Evaluate the following expressions. Note the different rules that may apply.

1.11

a. `1 / 8 * 5`
b. `5 * 3 * 6`
c. `1 * 7 / 2`
d. `5 / 5 / 5`
e. `7 / 6 / 9`

1.12

a. `5 % 1 / 3`
b. `8 % 5 % 8`
c. `3 % 1 / 8`
d. `8 / 8 % 1`
e. `7 % 8 / 6`

1.13

a. `7 + 6 * 9`
b. `7 - 5 * 3`
c. `7 * 2 - 7`
d. `5 / 1 + 5`
e. `3 / 4 + 3`

1.14

a. `1 / 5 + 6`
b. `2 / 9 - 2`
c. `6 - 8 / 8`
d. `2 * 7 + 3`
e. `8 - 6 * 1`

1.15

a. `(2 + 3) / 4`
b. `3 / (4 - 3)`
c. `(5 - 3) * 1`
d. `6 / (1 - 7)`
e. `(1 + 8) * 8`

1.16

a. `4 * (1 - 1)`
b. `(1 - 9) / 3`
c. `4 * (9 + 1)`
d. `(1 - 3) / 9`
e. `6 * (1 - 2)`

1.17

a. `(8 - 5) % 5 % 8 - 3`
b. `1 % 9 - 3 - 4 % 9`
c. `2 - (7 / 7) - 3 / 4`
d. `8 + 2 * 6 * 8 + 3`
e. `4 % 2 - 7 % 1 - 3`

1.18

a. `5 + 1 * 9 + 9 * 4`
b. `8 * 4 - 7 * 1 - 6`
c. `8 % (9 - 6) % 3 - 3`
d. `7 % 2 - 8 % 7 - 8`
e. `2 / 7 + 3 + (2 / 2)`

1.19

a. `3 / 2 - 1 / 9 - 6`
b. `9 + (7 * 3) * 4 + 9`
c. `3 % 3 - 4 - 3 % 9`
d. `1 / 6 - 7 / (3 - 2)`
e. `8 * 7 + 6 + 2 * 4`

1.20

a. `8 % 3 - 6 % 5 - 6`
b. `5 * 9 + 8 * (4 + 6)`
c. `5 + 7 * 1 + 4 * 9`
d. `(3 - 5) * 4 - 7 * 8`
e. `5 - 2 * 8 * 6 - 5`

**Order of evaluation** When expressions contain more than a single operator, the order of evaluation becomes important. We will formulate a few rules that define what comes first when evaluating such expressions.

The main rule is that, when we are dealing with two operators of the same kind, the operations are performed *left to right*. For example:

`1 / 2 / 2` gives `0 / 2` gives `0`

Should you evaluate this expression the other way around, so from right to left, you will see that this will give you a wholly different result: `1`. So, following these rules is important, especially when division or modulo are involved.

**Operator precedence** Programming languages define a list of precedence rules for operators, in order to leave no ambiguity as to the outcome of calculations. In most cases, the rules are the same as in modern mathematics. For now, we can define the following groups for basic calculations:

1. any parts of the expression contained between parentheses come first
2. then come the arithmetic operators `*`, `/` and `%`
3. and finally the operations `+` and `-` will be performed

This list does not define what you should do if you, for example, encounter an expression containing multiplication `*` and division `/`. In such a case, where two operators are from the same group, you should default to the from-left-to-right rule.

## 1.3 Calculations using multiple kinds of numbers

Evaluate the following expressions. Also note the type of the result.

1.21

a. `1.0 - 1.5`
b. `1.0 / 1.0`
c. `1.0 + 1.5`
d. `0.5 + 0.5`
e. `1.0 * 1.0`

1.22

a. `0.5 - 1.0 * 1.5`
b. `0.5 + 0.5 * 1.5`
c. `0.5 * 1.0 + 1.0`
d. `1.5 - 0.5 * 1.0`
e. `1.0 / 0.5 + 1.5`

1.23

a. `0.5 - 0.75`
b. `1 / 2.0`
c. `0.5 / 0.25`
d. `1 - 1.5`
e. `3 * 1.5`

1.24

a. `2 - 2.0`
b. `0.5 + 0.75`
c. `1.0 / 1.0`
d. `1 * 1.5`
e. `1 + 0.5`

1.25

a. `2 - 2 + 2`
b. `2 / 4 * 3.0`
c. `0.5 * 2 / 4`
d. `1.0 - 2 / 6`
e. `1.5 * 3.0 - 3`

1.26

a. `3 + 3 - 3`
b. `1.0 - 6 + 2.0`
c. `3 + 4.5 * 9`
d. `0.5 - 2 * 3`
e. `1 - 0.5 * 1.5`

1.27

a. `2 + 3.0 + 3.0`
b. `0.5 / 1.0 + 1`
c. `1.0 * 4 * 1.0`
d. `2 - 2 + 6`
e. `1.5 + 6 / 1.5`

1.28

a. `3 - 9 + 1.5`
b. `3 - 4 * 4`
c. `1.5 + 3.0 / 6`
d. `3 * 6 / 6`
e. `1.0 * 2.0 / 4`

1.29

a. `1 + 1.5 + 3`
b. `1 - 3 - 0.5`
c. `2 + 2 + 2.0`
d. `3 - 1.5 * 4.5`
e. `2 / 2.0 + 2.0`

1.30

a. `1.0 / 2.0 * 6`
b. `2 + 2.0 + 6`
c. `2 + 2.0 + 2.0`
d. `1.5 * 6 - 6`
e. `3 + 4.5 + 9`

**Floats** Numbers with a decimal point, or *floating point numbers*, generally work as you would expect from mathematics. Notably, dividing floats like `1.0 / 2.0` gives `0.5`.

**Automatic conversion** In expressions you may encounter combinations of floats and integers. This requires a decision as to what rule to apply. Often, this is solved by doing automatic conversion: if only a single float is involved, the other number (an integer) will be converted to a float, too. The result of the operation will then also be a float.

Note that precedence rules still define what happens first: the expression `3 / 2 + 0.25` evaluates to `1.25`. First, the subexpression `3 / 2` is evaluated, giving the integer `1`. Then, `1` and `0.25` are to be added. Only then does the automatic conversion kick in, making the result a float: `1.25`.

# Chapter 2

# Logic

## 2.1 Propositions

Evaluate the following propositions to true or false.

2.1

a. `3 == 2`
b. `1 != 1`
c. `3 == 4.0`
d. `2.2 == 2`
e. `1 != 2`

2.2

a. `1.5 * 2 == 3.0`
b. `6 == 6 * 6`
c. `3.0 == 2 * 1.0`
d. `4 == 2 * 2`
e. `2 * 3.0 == 5.0`

2.3

a. `1.0 > 1.5`
b. `3 > 1.5`
c. `2 > 3.0`
d. `1 > 1.5`
e. `0.5 < 0.5`

2.4

a. `1.0 <= 0.5`
b. `1 >= 0.5`
c. `1 >= 3.0`
d. `1.5 >= 0.75`
e. `1 >= 1.5`

2.5

a. `3 == 1 / 1`
b. `0.5 * 1 == 1.0`
c. `2 + 1.0 <= 1.0`
d. `1.0 / 0.5 <= 1`
e. `1.0 >= 3 / 1.0`

2.6

a. `1.0 <= 2 - 0.5`
b. `3 >= 2 + 3`
c. `2 == 3 - 1.5`
d. `1.0 <= 0.5 - 1`
e. `1.5 - 1.0 >= 1.5`

2.7

a. `1.5 / 0.5 == 3.0`
b. `1 * 1.5 >= 3`
c. `1.5 >= 1.0 * 1`
d. `1 >= 2 - 1.0`
e. `0.5 >= 2 + 3`

2.8

a. `1.5 == 1 * 1.5`
b. `1.0 / 2 == 1.5`
c. `3 - 1 == 2`
d. `0.5 + 0.5 >= 3`
e. `1.5 == 1 + 2`

2.9

a. `2 <= 0.5 * 3`
b. `1.5 / 1.5 <= 1.5`
c. `0.5 - 1.5 == 3`
d. `0.5 - 1.0 >= 1`
e. `3 == 0.5 - 3`

2.10

a. `1.0 + 1 >= 2`
b. `1 <= 1.0 / 1.5`
c. `1.0 + 1 == 1`
d. `1 == 1.5 * 1`
e. `2 >= 3 * 3`

**Propositions are true or false** For propositions like `4 == 5` we can decide if they are *true*. The number `4` does not equal `5`, which makes this proposition not true, or *false*. There are six important ways to formulate a proposition:

| operator | meaning |
|---|---|
| `==` | equals |
| `!=` | does not equal |
| `<` | is smaller than |
| `>` | is larger than |
| `<=` | is smaller than or equal to |
| `>=` | is larger than or equal to |

Each proposition formulated using one of these operators can evaluate to one of two values: `true` or `false`. These values are called *booleans*[1]. Expressions that evaluate to `true` or `false` are called *boolean expressions*.

**Precedence rules** Like with arithmetic operations, propositional operations are subject to rules of precedence.

1. any parts of the expression contained between parentheses come first
2. then come the arithmetic operators `*` and `+` (note the rules that apply between those!)
3. and finally the operations `>`, `<`, `==`, `!=`, `>=`, `<=` will be performed

**Mixing floats and integers** Propositions can contain integers as well as floats. If an integer is compared to a floating point number, automatic conversion takes place, making the integer into a float.

[1] After George Boole, who appears to be the first to develop an algebraic system for logic in the 19th century.

## 2.2 Logic operations

Evaluate the following propositions to true or false.

2.11

a. `true && 2 >= 2`
b. `1 >= 1.0 && true`
c. `2 >= 2 && false`
d. `true && 3 <= 1`
e. `2 >= 3 && false`

2.12

a. `false || 3 >= 2`
b. `0.5 == 1.5 || true`
c. `2 <= 1.5 || false`
d. `1 <= 1.0 || true`
e. `0.5 == 1.5 || true`

2.13

a. `false && !(1.5 == 0.5)`
b. `true && !(1 <= 1.5)`
c. `!(1.0 <= 1.0) || true`
d. `!(1 >= 1) || true`
e. `false || !(1 <= 3)`

2.14

a. `1 >= 3 || !(0.5 == 0.5)`
b. `2 >= 1.0 || 2 <= 1.5`
c. `1.0 == 2 || 3 >= 1`
d. `1.5 <= 2 || !(3 >= 1.5)`
e. `0.5 == 1.0 && 1.0 >= 1.0`

2.15

a. `1.0 <= 2 && 1.0 <= 0.5`
b. `!(1 <= 1.0) && 2 <= 3`
c. `1.0 <= 2 && 2 >= 0.5`
d. `!(3 == 1.0) || 2 >= 1`
e. `3 >= 2 || 1.0 <= 3`

2.16

a. `0.5 <= 2 || !(2 >= 0.5)`
b. `2 <= 1.5 && 1 <= 3`
c. `3 >= 0.5 || 1.0 >= 0.5`
d. `1 <= 1.5 || 3 >= 1`
e. `!(1.5 == 3) || 1 <= 1`

2.17

a. `3 >= 1 || 2 <= 1`
b. `1 == 0.5 || 1.5 == 1.5`
c. `2 <= 0.5 || 1.0 >= 1`
d. `1.5 >= 3 && !(3 <= 1.5)`
e. `!(0.5 >= 0.5) || 3 <= 0.5`

2.18

a. `!(0.5 <= 2) && 1.0 >= 0.5`
b. `2 <= 1.5 && 1.0 <= 3`
c. `1.5 == 1 && !(1.5 >= 3)`
d. `!(0.5 >= 0.5) || 1 == 1.5`
e. `!(3 <= 1.5) || 2 >= 0.5`

2.19

a. `3 >= 2 || 2 >= 1.0`
b. `1.0 >= 1.0 || 1.0 >= 1.5`
c. `1.5 >= 1.5 && !(2 <= 3)`
d. `!(1.0 == 3) || 3 >= 1.0`
e. `1 >= 1.5 || 2 == 1.0`

2.20

a. `2 <= 2 && !(3 == 1)`
b. `3 >= 1.5 && 1 >= 1`
c. `1.0 <= 3 && 3 >= 1.5`
d. `!(3 <= 1.0) && 1.0 == 1.5`
e. `1.5 >= 2 || 1.5 == 1`

**Logic operations** The values `true` and `false`, or any boolean expressions, may be combined into more complex expressions using logic operations. We introduce three.

**And** This operation, written as `&&`, requires both operands (TODO) to be `true` in order to yield `true` itself. The behavior of the operator can be described using a truth table:

| expression | yields |
|---|---|
| `true && true` | `true` |
| `true && false` | `false` |
| `false && true` | `false` |
| `false && false` | `false` |

**Or** This operation is written as `||`, and requires only one of the operands to be `true` in order to yield `true`.

| expression | yields |
|---|---|
| `true \|\| true` | `true` |
| `true \|\| false` | `true` |
| `false \|\| true` | `true` |
| `false \|\| false` | `false` |

**Not** A boolean expression's value can be negated, which is expressed using an exclamation mark `!`.

| expression | yields |
|---|---|
| `!true` | `false` |
| `!false` | `true` |

**Precedence** The logic operations also have their place in the precedence hierarchy:

1. first, expressions in parentheses
2. then arithmetic operations like + en *
3. then boolean operations like >, <, ==, !=, >=, <=
4. then `!`
5. then `||`
6. and finally `&&`

(Note that unlike `*` and `/`, the **and** and **or** operations are not in the same group.)

## 2.3 Writing: conditions

In the previous sections, you have *evaluated* expressions, calculating the outcome by applying rules. Here, we ask you to write expressions yourself. This is a more creative endeavour, and it may be hard to find the "right idea". In that case, have a look at the previous sections for inspiration.

When writing such an expression, you can check it by applying the rules again. Write down your expression and try to evaluate it. You can even come up with a couple of concrete "test cases", filling in the number `n` to see if the result is what you expect.

2.21 Write an expression that tests if a number `n` is smaller than 5.

2.22 Write an expression that tests if a number `n` is between 5 and 10 (both 5 and 10 included!).

2.23 Write an expression that tests if a number `n` is divisible by 3.

2.24 Write an expression that tests if a number `n` is *even*.

2.25 Write an expression that tests if a number `n` is *odd*.

2.26 For which values does the expression `!(n > 1 && !(n > 3)) && true` yield `true`?

2.27 The expression from the previous question may be written in more simply. Do this, and check if your simplified version is indeed equivalent to the original by checking if both yield the same value when substituting different values for `n`.

# Chapter 3

# Variables

## 3.1 Variables

Evaluate the following code fragments and write down the final value for all variables.

3.1

```
dey = 3 + 0.5
luo = 1.5
```

3.2

```
gog = 1 * 3
oer = 3 * 0.5
```

3.3

```
eli = 1.0
soc = 1.0 + 3
```

3.4

```
jon = 1.0 - 2
aus = 2 * 0.5
```

3.5

```
abe = 1.5 / 1.0
sir = abe / 0.5
```

3.6

```
vow = 2 * 1.5
nub = vow + 1.0
```

3.7

```
gup = 1 / 2
ley = gup * 2
```

3.8

```
tez = 1.5 + 1
nap = tez * 3
```

3.9

```
jib = 1.0 - 3
jib = 2 + 3
```

3.10

```
aus = 2 - 2
aus = 3 - 1.5
```

3.11

```
bam = 3 / 2
bam = 1.0 + 1.0
```

3.12

```
tye = 1.5 / 1.5
tye = 1 * 1
```

3.13

```
nam = 1 + 1
sob = 1.0 - 1.0
nam = nam * 2
off = sob / 0.5
off = nam / 3
off = off + 3
```

3.14

```
kaw = 2 * 1
kaw = 1.5 * 1.0
zan = kaw / 2
zan = kaw * 1
kaw = 3 + 0.5
kaw = zan / 1.5
```

3.15

```
ora = 2 / 1.0
ora = 1 - 0.5
ora = ora + 0.5
ora = ora / 4
quo = ora - 1
ora = ora - 3
```

3.16

```
gup = 3 + 0.5
gup = 1 + 1.0
han = 2 / 2
gup = gup + 0.5
han = gup - 1
han = gup + 1.0
```

3.17

```
lod = 2 / 2
lod = 2 * 3
nid = lod / 1.0
mou = lod * 3
lod = lod - 1
gyp = 0.5 - 3
```

3.18

```
iwa = 3 - 2
you = iwa + 2
way = iwa - 0.5
iwa = way - 1
iwa = 2 / 2
iwa = iwa + 0.5
```

3.19

```
oka = 3 - 1
oka = oka * 1
fei = oka * 1
oka = oka * 1.5
oka = oka * 1
oka = oka / 0.5
```

3.20

```
fae = 1 + 0.5
fae = fae - 1.0
fae = 2 * 0.5
fae = fae - 1.5
fae = 0.5 - 2
fae = fae + 2
```

**Assignment** In the following code fragment, a *value* is assigned to a *variable*:

```
het = 2.2
```

Upon executing that line of code, a variable is created with the name `het`, and it is assigned the value `2.2`. This variable then becomes part of the *final state* after executing the code fragment. However, a code fragment can also contain multiple assignments below each other. In the following example, we assign three variables, each with their own name:

| | ike | dev | wan |
|---|---|---|---|
| `ike = 3.14` | $\boxed{3.14}$ | | |
| `dev = 3 / 4` | 3.14 | $\boxed{0}$ | |
| `wan = 0.75` | 3.14 | 0 | $\boxed{0.75}$ |

On the left we show the lines of code that are executed. On the right, we keep track of what happens when executing each line: we *trace* the code fragment. As one variable is being assigned, we draw a box around the new value. On the lines below, that value is retained, which we show by copying the value down. By doing this for all lines, we can read the final state of all variables on the last line: `ike`, `dev` and `wan`, with their accompanying values.

**Order** It's possible to assign a value to a variable for a second time (or more often). The "old" value will be *overwritten*. This makes *order* of the program important: we always process the lines from top to bottom. Take a look at the following example.

| | wei |
|---|---|
| `wei = 1` | $\cancel{\boxed{1}}$ |
| `wei = 4` | $\boxed{4}$ |

The variable `wei` is assigned a value two times, as is shown by the two boxes that are drawn around the values. But the final state only consists of a single variable named `wei`, with value `4`. The value `1` that was assigned earlier has disappeared when it was overwritten.

**Variables in expressions** Now that we have variables, we can also *use* them in calculations, referring to them by their name.

| | hat | say |
|---|---|---|
| `hat = 1` | $\boxed{1}$ | |
| `say = hat + 4` | 1 | $\boxed{5}$ |

The state after executing the final line of code consists of two variables: `hat = 1` and `say = 5`.

## 3.2 Writing: algorithms for swapping

**Swapping the values of variables** We will now see how to combine a number of assignments to develop an *algorithm*. An algorithm is a general procedure that a computer can execute. It is general because it uses a number of variables that may be assigned numbers or other data depending on the situation.

Let's develop an algorithm to swap the values of <u>two</u> variables,

`a = 54` and `b = 29`.

As a first intuition, you might think to assign the value of `b` to `a`, and the value of `a` to `b`. An algorithm might then look like this:

```
a = b
b = a
```

Let's trace the algorithm. We take two starting values for `a` and `b`, and then we show the effect on these two variables *line by line*. Like in the previous section, we use a box to show which variable is <u>changed</u> on which line of code.

| | a | b |
|---|---|---|
| | 54 | 29 |
| a = b | $\boxed{29}$ | 29 |
| b = a | 29 | $\boxed{29}$ |

Now note that this is not the intended effect of the algorithm! Instead of swapping, the value of `a` is overwritten with **b**'s original value, and now both contain the same number.

The problem is the following: on line three (TODO numbering), we would like to assign `b` the value of `a`, but at that point, `a` has already been overwritten. From this analysis we may have an intuition for a solution: we need to make sure that on line 3, the original value of `a` is still available. To do this, we need to introduce a third variable, which can "save" the value of `a` before it is overwritten.

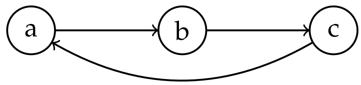
```
t = a
a = b
b = t
```

Tracing that modified program will look like this:

| | a | b | t |
|---|---|---|---|
| | 54 | 29 | |
| t = a | 54 | 29 | $\boxed{54}$ |
| a = b | $\boxed{29}$ | 29 | 54 |
| b = t | 29 | $\boxed{54}$ | 54 |

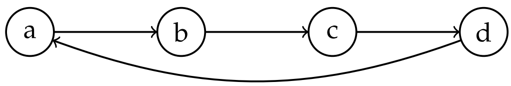
Indeed, this is the expected result for swapping!

3.21 Write an algorithm that swaps the values of three variables, as illustrated below. After executing the algorithm, the old value of `a` should be in `b`, the old value of `b` should be in `c`, and the old value of `c` should be in `a`.

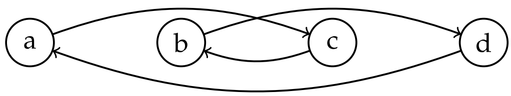



Note: you might substitute concrete numbers for `a`, `b` and `c` to think about this problem, but this is not necessary to create a generally useful algorithm.

3.22 Write an algorithm that swaps the values of four variables, as illustrated below.




3.23 Write an algorithm that swaps the values of four variables, as illustrated below.



# Chapter 4

# Conditional statements

## 4.1 Tracing conditional statements

Make a trace for each of the following code fragments. Also note the final value of the variable a.

4.1

```
a = 0
if(a == 0)
   a = 10
a = a + 1
```

4.2

```
a = -1
if(a == 0)
   a = 10
a = a + 1
```

4.3

```
a = 0
if(a < 0)
   a = 10
```

4.4

```
a = 0
if(a > 0)
   a = 10
```

4.5

```
a = 0
if(a <= 0)
   a = 10
```

4.6

```
a = 0
if(a >= 0)
   a = 10
```

4.7

```
a = 9
if(a % 3 == 0)
   a = a * 2
```

4.8

```
a = 10
if(a % 3 == 0)
   a = a * 2
```

4.9

```
a = -1
if(a < 0 || a > 10)
   a = a * 2 - 1
```

4.10

```
a = 5
if(a > 0 && a % 2 == 0)
   a = 0
```

**Conditional statements** The following code fragment contains a conditional statement, which starts with the keyword `if`. There is a requirement, or *condition*, which is `a < 10`. The statement on the following line has been indented (moved to the right) which will show that the statement is dependent on the `if`.

```
1 a = 0
2 if(a < 10)
3     a = a + 10
4 a = a - 1
```

We start the program on line 1 with the value `a = 0`. This means that on line 2, the condition `a < 10` has indeed been met. The result is that the instruction `a = a + 10` will be executed too. Line 4 is printed all the way to the left, which means that it is not a part of the conditional statement: it will be executed regardless. This means that the program finishes with the variable `a` having a value `9`.

**Tracing** Like in the previous chapter we can trace the state of the variables. A trace for the previous code fragment looks like this:

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| a | $\boxed{0}$ | 0 | $\boxed{10}$ | $\boxed{9}$ |

In the top row we print the program's line numbers. In the row below, we keep track of the variable `a`. In exactly three places, the value of `a` has a box: these are the lines where the value of the variable changed while tracing.

**Failing condition** In the code fragment below, we slightly changed the condition. In this case, at the moment of evaluating the condition, it yields `false`. Because the condition has not been met, the dependent line will be skipped. This means that the program finishes with the variable `a` having a value `-1`.

```
1 a = 0
2 if(a > 10)
3     a = a + 10
4 a = a - 1
```

And we skip line 3 in the trace:

| | 1 | 2 | 4 |
|---|---|---|---|
| a | $\boxed{0}$ | 0 | $\boxed{-1}$ |

## 4.2 Tracing with multiple variables

Make a trace for each of the following code fragments. Also note the final value of all variables.

4.11

```
a = 0
if(a != 0)
   a = 10
a = a + 1
```

4.12

```
a = 0
if(a != 0)
   a = 10
   a = a + 1
```

4.13

```
a = 3
if(a <= 10)
   a = 10
   a = a * 2
```

4.14

```
a = 3
if(a <= 10)
   a = 10
a = a * 2
```

4.15

```
a = 0
b = 9
if(a < b)
   a = b
```

4.16

```
a = 0
b = 2
if(a < 0)
   b = 8
```

4.17

```
a = 0
b = 2
if(a % 2 == 0 && b % 2 == 0)
   a = -1
b = -2
```

4.18

```
a = 0
b = 3
if(a % 2 == 0 && b % 2 == 0)
   a = -1
b = -2
```

4.19

```
a = 0
b = 2
if(a == b - 2 || a == b)
   a = 6
   b = 8
```

4.20

```
a = 4
b = -1
if(a == 0 && b < 0)
   a = -2
   b = -6
```

**Multiple dependent statements** In the next code fragment, not one but two statements are dependent on the `if` condition:

```
a = 0
if(a < 10)
    a = a + 10
    a = a * 2
```

The trace is quite like the one we did in the previous section:

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| a | $\boxed{0}$ | 0 | $\boxed{10}$ | $\boxed{20}$ |

**Multiple variables** Here we again introduce the use of multiple variables in one program. This means that more information has to be tracked while tracing the program. Take a look at this fragment:

```
a = 1
b = 0
if(a > b)
    c = a
    a = b
    b = c
```

To trace this program, we add rows for each variable that is in the program. The variables `b` and `c` are not initialized until later, which is why some of the values are blank.

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| a | $\boxed{1}$ | 1 | 1 | 1 | $\boxed{0}$ | 0 |
| b | | $\boxed{0}$ | 0 | 0 | 0 | $\boxed{1}$ |
| c | | | | $\boxed{1}$ | 1 | 1 |

## 4.3 Specifying cases

Make a trace for each of the following code fragments. Also note the final value of all variables.

4.21

```
a = 0
if(a == 0)
   a = 10
else
   a = -10
```

4.22

```
a = 1
if(a == 0)
   a = 10
else
   a = -10
```

4.23

```
a = -1
if(a < 0)
   a = 7
else if (a > 2)
   a = 8
else
   a = 9
```

4.24

```
a = 1
if(a < 0)
   a = 7
else if (a > 2)
   a = 8
else
   a = 9
```

4.25

```
a = 3
if(a < 0)
   a = 7
else if (a > 2)
   a = 8
else
   a = 9
```

4.26

```
a = -1
if(a < 0)
   a = 7
else if (a < 2)
   a = 8
else
   a = 9
```

4.27

```
a = 1
if(a < 0)
   a = 7
else if (a < 2)
   a = 8
else
   a = 9
```

4.28

```
a = 3
if(a < 0)
   a = 7
else if (a < 2)
   a = 8
else
   a = 9
```

**When the condition fails** Below an `if` statement you might find an `else` statement. The two statements are then connected, and the `else` statement defines what should happen in case the condition in the `if` statement yields `false`.

```
1 a = 1
2 if(a < 0)
3     a = a + 10
4 else
5     a = a - 10
```

Tracing the program above would look like this:

| | 1 | 2 | 4 | 5 |
|---|---|---|---|---|
| a | $\boxed{1}$ | 1 | 1 | -9 |

In summary, an `if-else` combination always describes two possibilities: what should happen in case the condition is met (`a < 0`), and what should happen in case the condition is not met, `a` having a value that meets the opposite condition `a >= 0`.

**Connecting multiple conditions** To describe even more than two options, `if` statements can be augmented by adding `else if` statements. In the next fragment, we specify three options: `a < 0`, `a > 0` and otherwise `a = 0`. For each of the three cases, a single dependent instruction is specified, which will only be executed as that specific condition is met. All other cases are then skipped.

```
1 a = 3
2 if(a < 0)
3     a = -1
4 else if(a > 0)
5     a = 1
6 else
7     a = 100
```

The program starts with `a` being the integer `3`, and the trace looks like this:

| | 1 | 2 | 4 | 5 |
|---|---|---|---|---|
| a | $\boxed{3}$ | 3 | 3 | $\boxed{1}$ |

By using even more `else if` statements, you can specify further options. The `else` statement always comes last, because it describes "any other possibility".

# Chapter 5

# Repetition using `while`

## 5.1 Tracing while-loops

Evaluate the following code fragments and write down the final value for all variables. Make a trace-table if needed.

5.1

```
a = 0
while(a < 3)
   a = a + 1
a = a * 2
```

5.2

```
a = -1
while(a < 4)
   a = a + 2
a = a * 3
```

5.3

```
a = 0
while(a <= 6)
   a = a + 2
a = a * 2
```

5.4

```
a = 2
while(a < 8)
   a = a + 2
```

5.5

```
a = 16
while(a > 1)
   a = a / 2
```

5.6

```
a = 2
while(a < 200)
   a = a * a
```

5.7

```
a = 8
while(a < 18)
   a = a / 2 + a
```

5.8

```
a = 0
while(a <= 15)
   a = a * 2 + 1
```

5.9

```
a = 0
while(a >= -15)
   a = a * 2 - 1
```

5.10

```
a = 1
while(a < 16)
   a = a * -2
```

**Looping** In the following fragment a variable is changed using a `while`-loop.

```
1 a = 0
2 while(a < 2)
3     a = a + 1
4 a = a / 2
```

On line 1, the variable `a` is initialized with the integer `0`. On the next line, we see the `while` keyword, and then between parentheses a condition `(a < 2)`. Now, *as long as* the condition yields `true`, any statements within the loop will be repeated. In this case, only line 3 is in the loop, but more statements might be included. It's important to realize that the condition is evaluated once per loop: on line 2, each time a decision is made if the loop can be executed again.

**Tracing loops** Like with sequences of assignment statements, we can trace the execution of loops. The technique is a little bit different, because the loop may be executed multiple times. For the previous fragment, the trace looks like this:

| regel | 1 | 2 | 3 | 2 | 3 | 2 | 4 |
|---|---|---|---|---|---|---|---|
| var a | $\boxed{0}$ | 0 | $\boxed{1}$ | 1 | $\boxed{2}$ | 2 | $\boxed{1}$ |
| a < 2 | | true | | true | | $\boxed{\texttt{false}}$ | |

Atop the table are the line numbers for each line that we encounter, from left to right. Below that, we include lines for each variable or expression that we would like to trace. Like before, we write down a value for each variable as it is initialized, and we draw a box around each variable whenever it changes.

We included the condition for the `while`-loop as part of the trace. We only write the condition on line 2, because it is only calculated and checked on that line. The condition yields a boolean value, so the possible values are `true` and `false`.

In this case, the condition is checked three times. The first two times it yields `true`, so line 3 is run right after. The third time it yields `false`, after which the rest of the program is run — in this case only line 4.

## 5.2 Complex conditions

Evaluate the following code fragments and write down the final value for all variables. Make a trace-table if needed.

5.11

```
a = 4
while(a == 4)
    a = a + 1
```

5.12

```
a = 4
while(a == 4 || a == 5)
    a = a + 1
```

5.13

```
a = 0
while(a + 1 < 4)
    a = a + 1
```

5.14

```
a = 0
while(a != 4)
    a = a + 2
```

5.15

```
a = 1
while(a != 5)
    a = a + 2
```

5.16

```
a = 0
while(a != 4 && a < 8)
    a = a + 2
```

5.17

```
a = 1
while(a != 4 && a < 8)
    a = a + 2
```

5.18

```
a = 4
while(a + 1 != a * 2)
    a = a - 1
```

5.19

```
a = 16
while(a < -2 || a > 2)
    a = a / -2
```

5.20

```
a = 32
while(a < -2 || a > 2)
    a = a / -2
```

**More complex conditions** In this paragraph we reintroduce more complex conditions that are combinations of propositions with logical connectors. Below you'll find a summary of the rules that apply.

### Propositions

| **operation** | **meaning** |
|---|---|
| `==` | equals |
| `!=` | does not equal |
| `<` | is smaller than |
| `>` | is larger than |
| `<=` | is smaller than or equal to |
| `>=` | is larger than or equal to |

### Logische combinaties

| expression | yields |
|---|---|
| `true && true` | `true` |
| `true && false` | `false` |
| `false && true` | `false` |
| `false && false` | `false` |

| expression | yields |
|---|---|
| `true \|\| true` | `true` |
| `true \|\| false` | `true` |
| `false \|\| true` | `true` |
| `false \|\| false` | `false` |

### Ontkenning

| expression | yields |
|---|---|
| `!true` | `false` |
| `!false` | `true` |

The rules of precedence also apply like earlier.

## 5.3 Multiple variables

Evaluate the following code fragments and write down the final value for all variables. Make a trace-table if needed.

5.21

```
a = 0
b = 0
while(a < 2)
   b = b + 2
   a = a + 1
```

5.22

```
a = 0
b = 0
while(a < 2)
   a = a + 1
   b = a * 2
```

5.23

```
a = 0
b = 0
while(a < 2)
   a = a + 1
   b = a - 2
```

5.24

```
a = 0
b = 1
while(a > -2)
   a = a - 1
   b = b * 2
```

5.25

```
a = 2
b = 1
while(a >= b)
   a = a + 1
   b = b * 2
```

5.26

```
a = 0
b = 0
while(a <= 8)
   a = b * 2
   b = b + 1
```

5.27

```
a = 0
b = 0
while(a < 6 && b < 2)
   a = a + 2
   b = b++
```

5.28

```
a = 0
b = 0
while(a < 6 || b < 2)
   a = a + 2
   b = b++
```

**Tracing multiple variables with loops** Consider the following code fragment:

```
1 a = 0
2 b = 0
3 while(a < 2)
4     a = a + 1
5     b = b + 1
6 a = 42
```

The accompanying trace looks like this;

| | 1 | 2 | 3 | 4 | 5 | 3 | 4 | 5 | 3 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| var a | $\boxed{0}$ | 0 | 0 | $\boxed{1}$ | 1 | 1 | $\boxed{2}$ | 2 | 2 | $\boxed{42}$ |
| var b | | $\boxed{0}$ | 0 | 0 | $\boxed{1}$ | 1 | 1 | $\boxed{2}$ | 2 | 2 |
| a < 2 | | | true | | | true | | | $\boxed{\texttt{false}}$ | |

**Incrementing** Loops often use a **counter**, a variable that is incremented by 1 in each loop step. Many programming languages have a special operator to do this: `++`. The statement `i++` is equivalent to `i = i + 1`. Decrementing also has a shortcut: `i--`. This command performs the same operator as `i = i - 1`.

## Chapter 6

# Repetition using `for`

## 6.1 Counting loops

Write down what is printed when running each of the following code fragments.

6.1

```
i = 0
while(i < 3)
   print(i)
   i++
```

6.2

```
i = 12
while(i < 15)
   print(i)
   i++
```

6.3

```
i = 3
while(i >= 0)
   print(i)
   i--
```

6.4

```
i = 14
while(i > 10)
   print(i)
   i--
```

6.5

```
for(i = 0; i < 3; i++)
   print(i)
```

6.6

```
for(i = 3; i >= 0; i--)
   print(i)
```

6.7

```
i = 12
for(; i < 15 ; i++)
   print(i)
```

6.8

```
i = 14
for(; i > 10; i--)
   print(i)
```

6.9

```
for(i = 14; i >= 10; )
   i--
   print(i)
```

6.10

```
for(i = 8; i <= 10;)
   i++
   print(i)
```

6.11

```
for(i = 14; i >= 8; i = i - 2)
   print(i)
```

6.12

```
for(i = 0; i < 10; i = i + 2)
   print(i)
```

**For-loops** Onderstaand codefragment print de getallen 0 t/m 9 met een `while`-loop.

```
i = 0
while(i < 10)
    print(i)
    i++
```

Zoals je misschien is opgevallen bevatten veel loop-constructies min of meer dezelfde ingredienten: Een **initialisatie** (`i = 0`), een **conditie** (`i < 10`), en een **update** (`i++`). Omdat dit patroon zo veel voorkomt, hebben de meeste programmeertalen hier een speciale constructie voor: de `for`-loop. Het onderstaande stukje code laat precies hetzelfde programma zien, maar dan geschreven als een `for`-loop.

```
1 for(i = 0; i < 10; i++)
2    print(i)
```

De `for`-loop bevat dezelfde drie ingredienten als de `while`-loop: De initialisatie (`i = 0`), de conditie (`i < 10`), en de update (`i++`). De initialisatie (`i = 0`), wordt alleen de eerste keer uitgevoerd. De conditie (`i < 10`) wordt elke keer voor het begin van de iteratie uitgevoerd. De update (`i++`) wordt elke keer *aan het einde* van de iteratie uitgevoerd. Dus, de volgorde van executie in dit voorbeeld:

- regel 1, `i = 0` (initialisatie)
- regel 1, `i < 10` (conditie)
- regel 2, `print(i)`
- regel 1, `i++` (update)
- regel 1, `i < 10` (conditie)
- regel 2, `print(i)`
- etc.

Het lastige hierbij is dat regel 1 van de `for`-loop dus eigenlijk 3 verschillende commando's heeft, die ook op verschillende momenten worden uitgevoerd. De makkelijktse manier om te zien hoe een `for`-loop wordt uitgevoerd is door hem te vertalen naar een `while`-loop:

```
                                              <init>
for(<init>; <conditie>; <update>)             while(<conditie>)
    <inhoud van loop>                             <inhoud van loop>
                                                  <update>
```

## 6.2 Tracing for-loops

Evaluate the following code fragments and write down the final value for all variables. Make a trace-table if needed.

6.13

```
for(i = 0; i < 3; i++)
   a = i * 2
```

6.14

```
for(i = 3; i >= 0; i--)
   a = i * 2
```

6.15

```
for(i = 3; i >= 0; i = i - 1)
   a = i * 2
```

6.16

```
a = 16
for(i = 0; i < 3; i = i + 1)
   a = a / 2
```

6.17

```
a = 16
for(i = 0; i <= 2; i = i + 1)
   a = a / 2
```

6.18

```
a = 1
for(i = 2; i <= 8; i = i * 2)
   a = a + 1
```

6.19

```
a = 0
for(i = 1; a < 3; i = i * 2)
   a = a + 1
```

6.20

```
for(i = 0; i < 6; i = i + 1)
   i = i + 1
```

**For-loops traceren** In het volgende stuk code wordt de waarde van een variabele veranderd binnen een `for`-loop:

```
1  a = -10
2  for(i = 0; i < 2; i++)
3      a = i * 2
4  a = a + 6
```

Als we dit fragment willen traceren hebben we een probleem. Regel 2 bestaat eigenlijk uit meerdere opdrachten: initialisatie (`i = 0`), conditie (`i < 2`) en update (`i++`). We kunnen dit expliciet opnemen in de trace:

| regel | 1 | 2 (i = 0) | 2 (i < 2) | 3 | 2 (i++) | 2 (i < 2) | 3 | 2 (i++) | 2 (i < 2) | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| var i | | $\boxed{0}$ | 0 | 0 | $\boxed{1}$ | 1 | 1 | $\boxed{2}$ | 2 | |
| var a | $\boxed{-10}$ | -10 | -10 | $\boxed{0}$ | 0 | 0 | $\boxed{2}$ | 2 | 2 | $\boxed{8}$ |
| i < 2 | | | true | | | true | | | $\boxed{\texttt{false}}$ | |

We hebben in dit voorbeeld voor de duidelijkheid de betreffende commando's onder de labels van de `for`-loop gezet en de waarheidswaarden van conditie expliciet gemaakt. Je kan dit natuurlijk ook wat beknopter opschrijven:

| regel | 1 | 2 | 2 | 3 | 2 | 2 | 3 | 2 | 2 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|
| var i | | $\boxed{0}$ | 0 | 0 | $\boxed{1}$ | 1 | 1 | $\boxed{2}$ | 2 | |
| var a | $\boxed{-10}$ | -10 | -10 | $\boxed{0}$ | 0 | 0 | $\boxed{2}$ | 2 | 2 | $\boxed{8}$ |

## 6.3 For and while loops

Rewrite these `for`-loops as `while`-loops.

6.21

```
b = 8
for(a = 5; a > 3; a = a - 1)
   b = b / 2
```

6.22

```
for(e = 0; e < 4; e = e + 1)
   print(e)
```

6.23

```
for(i = 4; i >= 0; i = i - 1)
   print(i)
```

6.24

```
b = 0
for(i = 0; i < 4; i = i + 2)
   b = i * 2
```

Rewrite these `while`-loops as `for`-loops.

6.25

```
a = 1
while(a < 6)
   print(a)
   a = a + 2
```

6.26

```
a = 8
b = 0
while(a > 1)
   b = b + 1
   a = a / 2
```

6.27

```
a = 8
b = 0
while(b < 3)
   a = a / 2
   b = b + 1
```

6.28

```
a = 8
b = 0
while(a > 1 || b <= 3)
   b = b + 1
   a = a / 2
   print(a)
```

**Herschrijven** Dit is de vergelijking van `for`- en `while`-loops die je al gezien hebt:

```
for(<init>; <conditie>; <update>)
    <inhoud van loop>
```

```
<init>
while(<conditie>)
    <inhoud van loop>
    <update>
```

Die kun je gebruiken om `for`-loops naar `while`-loops om te zetten en andersom. Als je dit doet, kun je beide versies traceren en de uitkomst vergelijken. Zo weet je dat het omzetten precies is gelukt.

# Chapter 7

# Algorithms: sequences

## 7.1 Sequences

7.1 Schrijf een algoritme dat de eerste `10` waarden van de volgende reeks print.

```
0 2 4 6 8 10 ...
```

7.2 Schrijf een algoritme dat de eerste `12` waarden van de volgende reeks print.

```
1 3 5 7 9 11 ...
```

7.3 Schrijf een algoritme dat de eerste `7` waarden van de volgende reeks print.

```
4 5 6 7 8 9 ...
```

7.4 Schrijf een algoritme dat de eerste `9` waarden van de volgende reeks print.

```
4 8 12 14 16 ...
```

7.5 Schrijf een algoritme dat de eerste `10` waarden van de volgende reeks print.

```
0 1 4 9 16 25 36 ...
```

7.6 Schrijf een algoritme dat de eerste `15` waarden van de volgende reeks print.

```
1 2 5 10 17 26 37 ...
```

7.7 Schrijf een algoritme dat de eerste `9` waarden van de volgende reeks print.

```
5 4 3 2 1 0 -1 -2 -3 ...
```

**Standaard-reeksen** Met een loop kun je reeksen getallen printen. Met de volgende `for`-loop printen we de getallen 0 tot en met 9:

```
for(i = 0; i < 10; i++)
    print(i)
```

```
0, 1, 2, 3, 4, 5, 6, 7, 8, 9
```

Om andere reeksen te printen moet je achterhalen wat de regelmaat in de reeks is. Vaak kun je je loop dan baseren op het voorbeeld hierboven. Wil je bijvoorbeeld tien getallen uit de reeks $0, 4, 8, 12, 16, ...$ printen, dan zou je kunnen opmerken dat elk van die getallen steeds vier keer zo groot is als het getal uit de reeks hierboven. Dus kunnen we ons programma zo aanpassen:

```
for(i = 0; i < 10; i++)
    print(i * 4)
```

```
0, 4, 8, 12, 16, 20, 24, 28, 32, 36
```

Voor de reeks $1, 2, 3, 4, ...$ kunnen we het volgende programma gebruiken. Vergelijk het weer met het eerste programma hierboven:

```
for(i = 0; i < 10; i++)
    print(i + 1)
```

```
1, 2, 3, 4, 5, 6, 7, 8, 9, 10
```

**Aantal stappen** Je kunt de lengte van de reeks variëren door de conditie van de loop zelf aan te passen. Met `i < 10` printen we 10 getallen, maar dat kan net zo goed een ander aantal zijn.

**Traceren** Om te controleren of de programma's kloppen, kun je een trace maken. Je hoeft waarschijnlijk niet de hele loop uit te schrijven; een aantal stappen is genoeg, zolang je kunt verifiëren dat de eerste paar getallen precies kloppen.

## 7.2 More complex sequences

7.8 Schrijf een algoritme dat de eerste `12` waarden van de volgende reeks print.

`1 2 4 8 16 ...`

7.9 Schrijf een algoritme dat de eerste `7` waarden van de volgende reeks print.

`1 3 9 27 81 ...`

7.10 Schrijf een algoritme dat de eerste `10` waarden van de volgende reeks print.

`2 4 6 8 10 ...`

7.11 Schrijf een algoritme dat de eerste `9` waarden van de volgende reeks print.

`16 8 4 2 1 0 0 ...`

7.12 Schrijf een algoritme dat de eerste `10` waarden van de volgende reeks print.

`1000 100 10 1 0 0 ...`

7.13 Schrijf een algoritme dat de eerste `7` waarden van de volgende reeks print.

`21 10 5 2 1 0 0 ...`

7.14 Schrijf een algoritme dat de eerste `9` waarden van de volgende reeks print.

`5 4 3 2 1 0 -1 -2 -3 ...`

**Standaard-reeksen** De volgende reeks is niet zomaar af te leiden uit de reeksen in het vorige hoofdstuk:

```
1 2 4 8 16 32 ...
```

Elk getal van de reeks is het voorgaande getal, keer 2. Om de reeks te genereren, introduceren we daarom een aparte variabele `getal`, waarin we de tussenstand van de berekening bijhouden. De tussenstand vermenigvuldigen we steeds met 2, en dan printen we het resultaat:

```
getal = 1
for(i = 0; i < 10; i++)
    print(getal)
    getal = getal * 2
```

Vergeet niet je uitwerkingen te traceren.

## 7.3 Filtering sequences

7.15 Schrijf een algoritme dat de eerste `14` waarden van de volgende reeks print.

```
1 2 * 4 5 * 7 8 * 10 ...
```

7.16 Schrijf een algoritme dat de eerste `12` waarden van de volgende reeks print.

```
1 2 3!  4 5 6!  7 8 9!  10 ...
```

7.17 Schrijf een algoritme dat de laatste `12` waarden van de volgende reeks print.

```
...  0 16 14 0 10 8 0 4 2 0
```

7.18 Schrijf een algoritme dat de eerste `12` waarden van de volgende reeks print.

```
1 2 # 8 16 # 64 128 # 512 ...
```

7.19 Schrijf een algoritme dat de eerste `12` waarden van de volgende reeks print.

```
1 2 2 8 16 5 64 128 8 512 ...
```

**Filter** Neem de volgende reeks:

```
* 2 4 * 8 10 * 14 16 * ...
```

De reeks lijkt erg op de eenvoudige standaardreeks, maar elk getal dat deelbaar is door 3, is vervangen door een `*`. Om deze reeks te genereren, gebruiken we een `if-else`:

```
for(i = 0; i < 10; i++)
    getal = i * 2
    if(getal % 3 == 0)
        print("*")
    else
        print(getal)
```

# Chapter 8

# Strings

## 8.1 Indexing into strings

Write down what is printed when running each of the following code fragments.

8.1

```
s = "Hello, world!"
print(s[0])
```

8.2

```
s = "Hello, world!"
print(s[4])
```

8.3

```
s = "Hello, world!"
print(s[5])
```

8.4

```
s = "Hello, world!"
print(s[6])
```

8.5

```
s = "Hello, world!"
print(s[11])
```

8.6

```
s = "Hello, world!"
print(s[10 + 1])
```

8.7

```
s = "Leibniz"
a = 2
print(s[a])
```

8.8

```
s = "von Neumann"
x = 5
print(s[x])
```

8.9

```
s = "Fourier"
foo = 3 * 2
print(s[foo])
```

8.10

```
s = "Fourier"
muz = 3
print(s[muz * 2])
```

8.11

```
s = "Riemann"
fol = 5
print(s[fol / 2])
```

8.12

```
s = "Laplace"
dal = 2
print(s[5 / dal + 1])
```

8.13

```
s = "Hamilton"
alb = length(s) - 1
print(s[alb * 2])
```

8.14

```
s = "Kolmogorov"
kul = length(s) - 2
print(s[kul / 2])
```

8.15

```
s = "Bernoulli"
lop = length(s)/2
print(s[lop])
```

8.16

```
s = "Wrap"
len = length(s)
print(s[2 % len])
```

8.17

```
s = "Wrap"
len = length(s)
print(s[3 % len])
```

8.18

```
s = "Wrap"
len = length(s)
print(s[4 % len])
```

**Strings** Een string bestaat uit losse *tekens* of *characters*. We definiëren een string `s` die bestaat uit 13 tekens:

```
s = "Hello, world!"
```

De tekens in zo'n string hebben een *positie* of *index*. Daarbij wordt altijd vanaf 0 geteld:

| teken | H | e | l | l | o | , |   | w | o | r | l | d | ! |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| index | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |

**Indexering** We kunnen de losse tekens van een string ophalen door te indexeren:

```
s = "Hello, world!"
print(s[1])
```
```
e
```

Dit stukje code print het onderdeel van de string `"Hello, world!"` dat zich bevindt op plaats 1. Omdat we vanaf 0 tellen, is dit de letter `e`, zoals in de tabel hierboven.

**Variabelen als index** We kunnen natuurlijk ook prima variabelen of expressies gebruiken als index van een string:

```
s = "Hello, world!"
i = 7
print(s[(i - 1) / 2]
```
```
l
```

**Grenzen** Lezen of schrijven buiten de grenzen van een string levert een *out of bounds*-fout op of een *segmentation fault*. Bijvoorbeeld bij het opvragen van de waarde op positie 10 van de string `"Error"`. Hou de grenzen dus goed in de gaten!

## 8.2 Repetition and strings

Write down what is printed when running each of the following code fragments. Make a trace-table if needed.

8.19

```
s = "Hello, world!"
i = 0
len = length(s)
while(i < len)
   print(s[i])
   i = i + 1
```

8.20

```
s = "Hello, world!"
i = 0
len = length(s)
while(i < len)
   print(s[i])
   i = i + 2
```

8.21

```
s = "Hello, world!"
i = length(s) - 1
while(i >= 0)
   print(s[i])
   i = i - 1
```

8.22

```
s = "Hello, world!"
l = length(s)
for(i = 0; i < l; i = i + 1)
   print(s[i])
```

8.23

```
s = "guret"
l = length(s)
for(i = l - 1; i >= 0; i = i - 1)
   print(s[i])
```

8.24

```
s = "!yenskle!s"
l = length(s)
for(i = 1; i < l; i = i * 2)
   print(s[i])
```

8.25

```
s = "ok craab  borg"
for(i = 13; i >= 0; i = i - 2)
   print(s[i])
```

8.26

```
s = "inn dreaxx"
for(i = 0; i < 5; i = i + 1)
   print(s[i * 2])
```

8.27

```
s = "args"
for(i = 0; i < 6; i = i + 1)
   print(s[i / 2])
```

8.28

```
s = "hi!"
len = length(s)
for(i = 0; i < 6; i = i + 1)
   print(s[i % len])
```

8.29

```
s = "h!i"
len = length(s)
for(i = 0; i < 12; i = i + 2)
   print(s[i % len])
```

**Herhaling en strings** Je kan strings natuurlijk ook combineren met loops.

```
1 s = "Hsopil"
2 i = 0
3 len = length(s)
4 while(i < len)
5     print(s[i])
6     i = i + 2
```

Op regel 3 wordt het commando `length` gebruikt om de lengte van de string `s` te bepalen (in dit geval 6). Vrijwel alle programmeertalen hebben zo een ingebouwde opdracht.

Als we willen weten wat er geprint wordt tijdens het uitvoeren van deze code kunnen we, net als in eerdere hoofdstukken, een trace maken. Voor dat we dat doen, is het handig om eerste een tabel te maken met de indices van string `s`:

| index | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| karakter | H | s | o | p | i | l |

**Trace** In de trace willen we bijhouden wat de waarde van de variabele `i` is en wat er geprint wordt. Voor het gemak houden we ook de waarde van `s[i]` bij. Om de trace een beetje compact te houden laten we de waardes van de variabelen `s = "Hsopil"` en `len = 6` buiten beschouwing. Deze veranderen toch niet gedurende de loop.

| regel | 1 | 2 | 3 | 4 | 5 | 6 | 4 | 5 | 6 | 4 | 5 | 6 | 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| var i | | $\boxed{0}$ | 0 | 0 | 0 | $\boxed{2}$ | 2 | 2 | $\boxed{4}$ | 4 | 4 | $\boxed{6}$ | 6 |
| s[i] | | H | H | H | H | o | o | o | i | i | i | | |
| print | | | | | H | | | o | | | i | | |

Deze code print dus de text `Hoi` naar het scherm.

## 8.3 More repetition with strings

Write down what is printed when running each of the following code fragments. Make a trace-table if needed.

8.30

```
s1 = "Hlo ol"
s2 = "el,wrd"
i = 0
while(i < 6)
   print(s1[i])
   print(s2[i])
   i = i + 1
```

8.31

```
s1 = "asedm"
s2 = "!artm"
i = 0
while(i < 5)
   print(s1[i])
   print(s2[5 - i])
   i = i + 1
```

8.32

```
i = 0
s = "srblcabe"
while(i < 4)
   print(s[i])
   print(s[i + 4])
   i = i + 1
```

8.33

```
s1 = "ab"
s2 = "123"
j = 1
for(i = 0; i < 2; i = i + 1)
   print(s1[i])
   print(s2[j])
   j = j + 1
```

8.34

```
s1 = "ab"
s2 = "123"
for(i = 0; i < 3; i = i + 1)
   print(s1[i / 2])
   print(s2[i])
```

8.35

```
s = "args"
for(i = 0; i < 6; i = i + 1)
   print(s[i / 3])
```

8.36

```
s = "hi!"
for(i = 0; s[i] != '!'; i = i + 1)
   print(s[i])
```

# Chapter 9

# Arrays

## 9.1 Arrays

Write down what is printed when running each of the following code fragments. Make a trace-table if needed.

9.1

```
rop = [8, 5, 4]
print(rop[1])
```

9.2

```
fifi = [0.1, 3.1, 2.1]
print(fifi[2])
```

9.3

```
bol = [’x’, ’b’, ’g’]
print(bol[0])
```

9.4

```
p = [16, 2, 0]
print(p[2 - 1])
```

9.5

```
aaa = [4, 2, 0]
print(aaa[10 % 3])
```

9.6

```
yup = [0.4, 0.3, 0.1]
print(yup[1 * 2])
```

9.7

```
uil = [8, 2, 0]
print(uil[2] - 1)
```

9.8

```
lala = [4, 10, 0]
print(lala[1] % 3)
```

9.9

```
tir = [0.4, 0.3, 0.1]
print(tir[1] * 2)
```

9.10

```
ala = [1, 2, 0]
i = 2
print(ala[i])
```

9.11

```
jul = [4.0, 2.5, 8.1]
a = 1
print(jul[a + 1])
```

9.12

```
j = [1.5, 1.2, 3.1]
vi = 2
print(j[vi] * 2)
```

9.13

```
u = [10, 14, 6]
t = 2
print(u[(t + 5) % 3])
```

9.14

```
hi = [4, 3, 2]
x = 1
print(hi[x * 2] + 2)
```

9.15

```
f = [14, 12]
l = 2
print(f[l + 11 % 2] % 6)
```

9.16

```
l = [13, 11]
i = 0
print(l[i] - l[i + 1])
```

9.17

```
lom = [11, 12, 13]
i = lom[0] % 3
print(lom[i] - 10)
```

9.18

```
s = "Wrap"
len = length(s)
print(s[4 % len])
```

**Arrays** In het volgende codefragment wordt een array van integers gedefiniëerd:

| | | |
|---|---|---|
| `ooy = [5, 6, 7]` | $\rightarrow$ | *array van integers* |
| `print(ooy[0])` | $\rightarrow$ | *print '5'* |
| `print(ooy[1])` | $\rightarrow$ | *print '6'* |
| `print(ooy[2])` | $\rightarrow$ | *print '7'* |

De eerste regel maakt een array met de getallen `5`, `6` en `7` en kent deze toe aan de variabele `ooy`. De regels eronder printen vervolgens de individuele elementen uit deze array. Let op, net als bij strings beginnen de indices van arrays met tellen bij `0`.

**Types** Zoals je ziet, lijken arrays erg op strings. Dat is ook niet zo gek, een string is niets anders dan een array van karakters. Het grote verschil is dat we in een array getallen kunnen opslaan. We kunnen dus een array van integers of floating point getallen maken. De voorbeelden hieronder laten verschillende type arrays zien.

| | | |
|---|---|---|
| `ooy = [5, 6, 7]` | $\rightarrow$ | *array van integers* |
| `lia = [5.0, 6.0, 7.0]` | $\rightarrow$ | *array van floats* |
| `aps = ['e', 'f', 'g']` | $\rightarrow$ | *array van karakters (in veel talen equivalent aan een string)* |

**Indices** Je kan natuurlijk gewoon variabelen gebruiken voor de indices:

```
elk = [1, 2, 3]
i = 1
print(elk[i])
```

print: 2

En, net als met strings, is het mogelijk om hele berekeningen te gebruiken als index:

```
das = [1, 2, 3]
i = 1
print(das[(i + 1) / 2])
```

print: 2

## 9.2 Mutating arrays

Evaluate the following code fragments and write down the final value for all variables.

9.19

```
lop = [10, 20, 30]
lop[1] = 5
```

9.20

```
kol = ['a', 'o', 'i']
kol[0] = 'h'
```

9.21

```
fof = [0.1, 0.2, 0.3]
fof[2] = 1.0
```

9.22

```
dido = [20, 15, 10]
i = 0
dido[i] = 2
```

9.23

```
l = [5, 1, 2]
hil = 2
l[hil] = hil
```

9.24

```
l = [0.1, 0.2, 0.3]
hihi = 10 / 5
l[hihi / 2] = 1.0
```

9.25

```
yoyo = [2.0, 1.5, 1.0]
i = 0
yoyo[i] = yoyo[i + 1]
```

9.26

```
yoyo = [2.0, 1.5, 1.0]
i = 0
yoyo[i + 1] = yoyo[i]
```

9.27

```
yoyo = [2.0, 1.5, 1.0]
yoyo[0] = yoyo[1]
yoyo[1] = yoyo[2]
```

9.28

```
hipp = [42, 3, 101]
y = 1
hipp[y] = hipp[y] + 1
```

9.29

```
fle = [7, 6, 5]
s = 2
fle[s] = fle[s] * 2
```

9.30

```
k = [3.4, 2.0, 0.6]
m = 1
k[m - 1] = k[m + 1] / 2
```

9.31

```
r = [0, 0, 0, 0]
p = r[0]
r[p + 1] = r[p] + 1
```

9.32

```
zi = ['a', 'b', 'c']
p = 2
zi[(p + 1) % 3] = 's'
```

9.33

```
b = [false, true, false]
l = 0
b[l + 2] = b[0] || b[1]
```

9.34

```
rol = [1, 2, 3, 4]
o = 3
rol[o] = rol[o] % 4
```

9.35

```
j = [0, -1, -2]
v = j[1] + 2
j[v] = j[v] * 2
```

9.36

```
r = [4, 2, 0]
r[r[0] / 2] =
   r[r[2 / 2] / 2] / 2
```

**Aanpassen** Arrays zijn modificeerbaar. Dat wil zeggen dat als we eenmaal een array hebben gemaakt, we later nog aanpassingen kunnen doen. Neem het volgende voorbeeld:

```
lan = [0, 0, 0]
lan[1] = 5
```

Eerst maken we een array met drie nullen. Daarna maken we van het eerste element van de array een `5`. Na het uitvoeren van dit codefragment is array `lan` → `[0, 5, 0]`.

## 9.3 Repetition and arrays

Write down what is printed when running each of the following code fragments.

9.37

```
klo = [1, 2, 3, 4, 5]
l = length(klo)
for(i = 0; i < l; i = i + 1)
   print(klo[i])
```

9.38

```
vlo = [1, 2, 3, 4, 5]
l = length(vlo)
for(i = l - 1; i >= 0; i = i - 1)
   print(vlo[i])
```

9.39

```
tik = [1, 2, 3, 4, 5]
i = 0
while(tik[i] < 4)
   print(tik[i])
   i = i + 1
```

9.40

```
hal = [10, 20, 30]
i = 2
while(hal[i] / 10 > 1)
   print(i)
   i = i - 1
```

Evaluate the following code fragments and write down the final value for all variables.

9.41

```
lap = ['a', 'b', 'c', 'd', 'e']
l = length(lap)
for(i = l - 1; i >= 0; i = i - 1)
   lap[i] = 'x'
```

9.42

```
gop = [4, 2, 5, 1, 8]
l = length(gop)
for(i = 0; i < l - 1; i = i + 1)
   gop[i] = gop[i + 1]
```

9.43

```
gop = [4, 2, 5, 1, 8]
l = length(gop)
for(i = 0; i < l - 1; i = i + 1)
   gop[i] = gop[i] + 1
```

9.44

```
gop = [4, 2, 5, 1, 8]
l = length(gop)
for(i = 0; i < l - 1; i = i + 1)
   gop[i + 1] = gop[i]
```

**Herhaling** In de praktijk komen arrays veel voor in combinatie met loops.

```
eus = [0, 0, 0, 0]
for(i = 0; i < length(eus); i++)
    eus[i] = i * 2
```

Na het uitvoeren van dit codefragment bevat array `eus` de waardes `0`, `2`, `4` en `6`. Deze code maakt gebruik van het commando `length()` om de lengte van de array te bepalen. Let erop dat niet alle programmeertalen zo'n commando hebben (bijvoorbeeld de programmeertaal C). In zulke gevallen zal je als programmeur zelf de lengte van een array moeten bijhouden.

# Chapter 10

# Functions

## 10.1 Functions that print

Write down what is printed when running each of the following code fragments.

10.1

```
void baz():
   print("fly")
baz()
```

10.2

```
void bar():
   print("jump")
```

10.3

```
void foo():
   print("fly")
void bar():
   print("jump")
foo()
bar()
bar()
```

10.4

```
void baz():
   print("jump")
void foo():
   print("bicycle")
baz()
```

10.5

```
void foo():
   print("pie")
void baz():
   foo()
   print("bicycle")
foo()
baz()
```

10.6

```
void baz():
   bar()
   print("rainbow")
void bar():
   print("fly")
baz()
```

10.7

```
void foo():
   baz()
   print("cake")
void baz():
   print("jump")
baz()
```

10.8

```
void bar():
   print("bicycle")
void baz():
   print("jump")
   bar()
baz()
```

**Functiedefinitie** Bij functies onderscheiden we de *definitie*, waarin wordt beschreven wat de functie moet doen, van de *aanroep*, die vertelt dat de functie daadwerkelijk moet worden uitgevoerd. Dat betekent meteen dat als we een functie definiëren de functie niet direct wordt uitgevoerd. Een functiedefinitie ziet er in dit boek als volgt uit:

```
<type> <naam van functie>():
  <inhoud van functie>
```

Voorlopig zullen we `void` invullen als `<type>`. In de praktijk is dat een functie die een opdracht uitvoert (zoals `print`). Een voorbeeld van een functie die iets doet:

```
void ding_printer():
  print("iets")
```

**Functieaanroep** Van zichzelf doet een definitie niet anders dan een functie definiëren onder een gestelde naam. Het aanroepen van de functie gebeurt dan als volgt:

```
<naam van functie>()
```

**Traceren** Functieaanroepen kun je traceren. We starten bij de allereerste regel die geen functiedefinitie is, maar een aanroep, en van daar stappen we naar de functie die wordt aangeroepen. Om duidelijk te maken welke functies er zijn, hebben we de definities gemarkeerd met een streep in de kantlijn:

```
 void baz():
 2 bar()
 4 print("rainbow")
 void bar():
 3 print("fly")
1 baz()
```

Zo zie je in welke volgorde de twee `print`-statements worden uitgevoerd.

## 10.2 Parameters

Write down what is printed when running each of the following code fragments.

10.9

```
void hay(x):
   print(x)
hay("fly")
```

10.10

```
void dal(y):
   print(y)
dal("jump")
```

10.11

```
void eau(x, y):
   print(x / y)
eau(10, 12)
```

10.12

```
void pow(y, x):
   print(x / y)
pow(10, 12)
```

10.13

```
void gam(x, z):
   print(z / x)
gam(10, 12)
```

10.14

```
void zek(x, z):
   print(x / z)
zek(12, 10)
```

10.15

```
void eid(x, y, z):
   print(z / x)
eid(10, 11, 12)
```

10.16

```
void ash(y, x, z):
   print(x / z)
ash(12, 11, 10)
```

10.17

```
void bar(z, y, x):
   print(y / x * z)
bar(10, 11, 12)
```

10.18

```
void duo(x, z, y):
   print(y / z)
duo(12, 11, 10)
```

10.19

```
void oca(y, z, x):
   print(x / y)
oca(10, 11, 12)
```

10.20

```
void tug(z, x, y):
   print(x / z * y)
tug(12, 11, 10)
```

**Parameters** Functies hebben vaak parameters. Bij het aanroepen van de functie worden *concrete* waarden ingevuld voor deze parameters. Vanuit het perspectief van de functie, krijgen deze waarden namen die gespecificeerd staan in de *parameterlijst*. Zo hebben we deze definities:

```
void datum_1(dag, maand):
  print(dag)
  print(maand)
```

```
void datum_2(maand, dag):
  print(dag)
  print(maand)
```

In het eerste geval hebben we de parameters `dag` en `maand`. In het tweede geval `maand` en `dag`, in de omgekeerde volgorde. Deze volgorde heeft effect op hoe de meegegeven parameters behandeld worden. We roepen de functies aan in deze voorbeelden:

```
datum_1(21, 6)
```

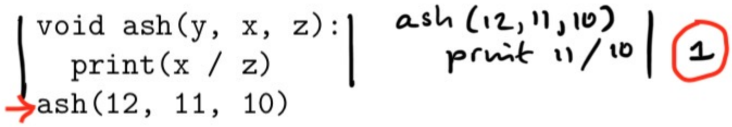
```
datum_2(6, 21)
```

De uitvoer is dan:

```
21
6
```

```
21
6
```

**Traceren** Het volgen van alle waarden bij een functie met parameters kan snel ingewikkeld worden. Daarom is het ook nu handig te traceren. Allereerst strepen we de functies aan (in dit geval ééntje). Dan markeren we de startregel met een pijltje.




Op de startregel staat een functieaanroep. Deze aanroep nemen we over rechts van de functiedefinitie. De functiedefinitie nemen we ook over, maar we vullen alle waarden zo **concreet** mogelijk in. De parameters `y`, `x` en `z` hebben in de concrete versie waarden gekregen, dus vullen we die ook in op de `print`-regel.

Tot slot blijft er nog een berekening over in het `print`-statement. Als we die evalueren, krijgen we het getal dat er geprint zal worden.

## 10.3 Calling functions with variables

Write down what is printed when running each of the following code fragments.

10.21

```
void foo(x):
   print(x)
inv = "fly"
foo(inv)
```

10.22

```
void bar(name):
   print(name)
foo = "skip"
bar("jump")
```

10.23

```
var = "bear"
void una(var):
   print(var)
una(var)
```

10.24

```
name = "pieter"
void greet(name):
   print("hello")
greet(name)
```

10.25

```
x = 3
y = 5
void foo(a, b):
   print(a / b)
foo(x, y)
```

10.26

```
x = 3
y = 5
void baz(y, x):
   print(x / y)
baz(x, y)
```

10.27

```
x = 10
void bar(x, z):
   print(z / x)
bar(x, 12)
```

10.28

```
var1 = 2
void dra(var1, var2):
   print(var1 + var2)
dra(var1, 8)
```

10.29

```
x = "fly"
var2 = "skip"
void shout(var1, var2):
   print(var1 + var2)
shout(x, "jump")
```

10.30

```
x = 3
a = 2
void magic(a, b):
   print(a - b)
magic(x, a)
```

**Aanroepen met variabelen** Functies kunnen ook worden aangeroepen met variabelen als concrete waarden voor de parameters. Zo hebben we bijvoorbeeld de volgende functie:

```
void twice(text):
  print(text)
  print(text)
```

Als we deze functie als volgt aanroepen:

```
fruits = "pineapple blueberry"
twice(fruits)
```

dan krijg je twee keer de tekst `pineapple blueberry` op je scherm geprint. De waarde van de variabele `fruits`, dat is de string `"pineapple blueberry"`, wordt namelijk meegegeven aan de functie `twice`. Op de regel met `twice(fruits)` wordt de huidige waarde van fruits ingevuld. Dit kan je je voorstellen alsof de regel veranderd wordt naar `twice("pineapple blueberry")`. Binnen de functie `twice` wordt de string `"pineapple blueberry"` toegewezen aan `text`. Daarna wordt die waarde geprint.

Ook bij het aanroepen van functies met variabelen maakt de volgorde van de parameters uit:

```
x = 10
y = 40
void minus(x, y):
  print(x - y)
minus(y, x)
```

Omdat de waardes van de variabelen worden meegegeven aan de functie wordt hier `30` geprint en niet `-30`. Je kan de regel `minus(y, x)` vervangen door `minus(40, 10)`, ofwel de waardes van de variabelen `x` en `y` op dat moment. Binnen de functie wordt de waarde `40` aan de variabele `x` en de waarde `10` aan de variabele `y` toegewezen. Dan wordt er `print(x - y)` uitgevoerd, ofwel `print(40 - 10)`.

**Traceren** We voegen nu expliciet een element aan de trace toe: het vervangen van de waarden in de functieaanroep. Bij de startregel strepen we de variabelenamen door, en vervangen deze door de waarden die eerder toegekend zijn. (Hierbij letten we nog helemaal *niet* op de functiedefinitie!)

```
x = 3
y = 5
void baz(y, x):
  print(x / y)
```

baz(~~x~~3, ~~y~~5)

baz(3,5):
  print 5/3

1

Nu de concrete waarden ingevuld zijn, kunnen we de trace verder opschrijven zoals in de vorige paragraaf.

# Chapter 11

# Functions that calculate

## 11.1 Functions that return something

Write down what is printed when running each of the following code fragments.

11.1

```
string foo(x):
   return x
print(foo("hard"))
```

11.2

```
string bar(name):
   return "jump"
print(bar("hi"))
```

11.3

```
int foo(x, y):
   return x / y
print(foo(10, 12))
```

11.4

```
int baz(y, x):
   return x / y
print(baz(10, 12))
```

11.5

```
amd = 4
float oei(dam, mad):
   return dam * mad + amd
sim = oei(amd, amd)
print(sim)
```

11.6

```
x = 1
int una(x):
   return x + 1
int zab(y):
   return y - 1
print(zab(2) + una(x))
```

11.7

```
string mak(x, y, z):
   return y
mis = "cal"
res = mak("sol", mis, "toa")
print(res)
```

11.8

```
void una(x, z):
   print(x / z)
int kam(y):
   return y * 3
print(una(kam(4), 10))
```

**Retourneren** *Retourneren* is een ander woord voor *teruggeven*. Het is mogelijk voor functies om een waarde terug te geven naar vanwaar de functie wordt uitgevoerd. Dit doe je met het commando `return`. De waarde die hier teruggegeven wordt noemen we ook wel het *resultaat* van de functie. Het resultaat van de functie vervangt als het ware de functieaanroep zelf. Dit werkt net als het gebruik van variabelen; die worden vervangen door hun waardes.

**Types** Helemaal in het begin van dit hoofdstuk lieten we het volgende zien:

```
<type> <naam van functie>():
  <inhoud van functie>
```

Tot nog toe hebben we alleen `void` in de plaats van `<type>` gebruikt. `void` staat voor `niets` en dit betekent dat onze functie niets teruggeeft. Dan hoef je dus ook geen `return` commando te geven. Als je wel iets wil teruggeven moet je het specifieke `type` aanduiden. In onze voorbeelden zullen we alleen de types `int`, `float`, en `string` gebruiken.

**Traceren** Functies die iets uitrekenen traceren we op vrijwel dezelfde manier als voorheen. Daar komt bij dat er iets *terug*gaat van de functie naar de startregel. In het volgende voorbeeld zie je dat de functie het getal 3 uitrekent en `returnt`. Dit kunnen we uiteindelijk invullen in de `print`.

```
| int das(x):           | das(12):
|   return x / 4       |   return 12/4 | 3
→print(das(12))        | print(3)
```

## 11.2 Functies that call other functions

Write down what is printed when running each of the following code fragments.

11.9

```
int gus(z, y)
   return dim(z, y) / 2
int yap(z, x)
   return gus(x, z) - 3
int dim(y, x)
   return x + 4
x = 6
y = 4
print(yap(x, y))
```

11.10

```
int uru(x, y)
   return 2 * y
int sal(z, y)
   return 4 / uru(y, z)
int hit(z, x)
   return 2 + sal(z, x)
y = 5
x = 6
print(hit(x, y))
```

11.11

```
int dip(y, x)
   return y * 4
int mux(y, z)
   return 5 / dip(y, z)
int bad(x, z)
   return mux(z, x) + 3
y = 4
x = 5
print(bad(x, y))
```

11.12

```
int loo(y, z)
   return z / 3
int aam(z, y)
   return loo(y, z) * 6
int wah(y, z, x)
   return aam(y, z) - 2
z = 2
x = 5
y = 4
print(wah(x, y, z))
```

11.13

```
int nae(z, y)
   return 2 * y
int bus(x, z)
   return nae(z, x) + 3
int ann(z, y, x)
   return bus(y, z) / 2

y = 5
x = 3
z = 6
print(ann(x, y, z))
```

**Traceren** Als er sprake is van meerdere functies die iets uitrekenen, dan kan het traceren er als volgt uitzien.

| | | | |
|---|---|---|---|
| `int fli(x):`<br>`  return 2 + x` | 4 fli(5):<br>return 2+5 | 5 7 | |
| `int fla(y):`<br>`  return 10 - fli(y)` | 3 fla(5):<br>return 10-fli(5) | 6 10-7 | 7 3 |
| `int flo(z):`<br>`  return 2 * fla(z)` | 2 flo(5):<br>return 2* fla(5) | 8 2*3 | 9 6 |
| → 1 `print(flo(5))` | 10 print(6) | | |

Met cijfers is aangegeven in welke volgorde de trace ingevuld wordt.

# Answers

## Exercises

| 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 1.10 |
|---|---|---|---|---|---|---|---|---|---|
| a. 0 | a. 1 | a. 3 | a. 0 | a. 2 | a. 0 | a. 0 | a. 3 | a. 1 | a. 3 |
| b. 0 | b. 2 | b. 3 | b. 1 | b. 3 | b. 0 | b. 2 | b. 0 | b. 1 | b. 2 |
| c. 0 | c. 3 | c. 2 | c. 1 | c. 4 | c. 0 | c. 0 | c. 8 | c. 0 | c. 5 |
| d. 0 | d. 4 | d. 1 | d. 1 | d. 2 | d. 0 | d. 0 | d. 1 | d. 1 | d. 8 |
| e. 0 | e. 5 | e. 1 | e. 3 | e. 5 | e. 0 | e. 0 | e. 5 | e. 0 | e. 15 |

| 1.11 | 1.12 | 1.13 | 1.14 | 1.15 | 1.16 | 1.17 | 1.18 | 1.19 | 1.20 |
|---|---|---|---|---|---|---|---|---|---|
| a. 0 | a. 0 | a. 61 | a. 6 | a. 1 | a. 0 | a. 0 | a. 50 | a. -5 | a. -5 |
| b. 90 | b. 3 | b. -8 | b. -2 | b. 3 | b. -2 | b. -6 | b. 19 | b. 102 | b. 125 |
| c. 3 | c. 0 | c. 7 | c. 5 | c. 2 | c. 40 | c. 1 | c. -1 | c. -7 | c. 48 |
| d. 0 | d. 0 | d. 10 | d. 17 | d. -1 | d. 0 | d. 107 | d. -8 | d. -7 | d. -64 |
| e. 0 | e. 1 | e. 3 | e. 2 | e. 72 | e. -6 | e. -3 | e. 4 | e. 70 | e. -96 |

| 1.21 | 1.22 | 1.23 | 1.24 | 1.25 |
|---|---|---|---|---|
| a. -0.5 | a. -1.0 | a. -0.25 | a. 0.0 | a. 2 |
| b. 1.0 | b. 1.25 | b. 0.5 | b. 1.25 | b. 0.0 |
| c. 2.5 | c. 1.5 | c. 2.0 | c. 1.0 | c. 0.25 |
| d. 1.0 | d. 1.0 | d. -0.5 | d. 1.5 | d. 1.0 |
| e. 1.0 | e. 3.5 | e. 4.5 | e. 1.5 | e. 1.5 |

| 1.26 | 1.27 | 1.28 | 1.29 | 1.30 |
|---|---|---|---|---|
| a. 3 | a. 8.0 | a. -4.5 | a. 5.5 | a. 3.0 |
| b. -3.0 | b. 1.5 | b. -13 | b. -2.5 | b. 10.0 |
| c. 43.5 | c. 4.0 | c. 2.0 | c. 6.0 | c. 6.0 |
| d. -5.5 | d. 6 | d. 3 | d. -3.75 | d. 3.0 |
| e. 0.25 | e. 5.5 | e. 0.5 | e. 3.0 | e. 16.5 |

| 2.1 | 2.2 | 2.3 | 2.4 | 2.5 |
|---|---|---|---|---|
| a. `FALSE` | a. `TRUE` | a. `FALSE` | a. `FALSE` | a. `FALSE` |
| b. `FALSE` | b. `FALSE` | b. `TRUE` | b. `TRUE` | b. `FALSE` |
| c. `FALSE` | c. `FALSE` | c. `FALSE` | c. `FALSE` | c. `FALSE` |
| d. `FALSE` | d. `TRUE` | d. `FALSE` | d. `TRUE` | d. `FALSE` |
| e. `TRUE` | e. `FALSE` | e. `FALSE` | e. `FALSE` | e. `FALSE` |

| 2.6 | 2.7 | 2.8 | 2.9 | 2.10 |
|---|---|---|---|---|
| a. `TRUE` | a. `TRUE` | a. `TRUE` | a. `FALSE` | a. `TRUE` |
| b. `FALSE` | b. `FALSE` | b. `FALSE` | b. `TRUE` | b. `FALSE` |
| c. `FALSE` | c. `TRUE` | c. `TRUE` | c. `FALSE` | c. `FALSE` |
| d. `FALSE` | d. `TRUE` | d. `FALSE` | d. `FALSE` | d. `FALSE` |
| e. `FALSE` | e. `FALSE` | e. `FALSE` | e. `FALSE` | e. `FALSE` |

| 2.11 | 2.12 | 2.13 | 2.14 | 2.15 |
|---|---|---|---|---|
| a. `TRUE` | a. `TRUE` | a. `FALSE` | a. `FALSE` | a. `FALSE` |
| b. `TRUE` | b. `TRUE` | b. `FALSE` | b. `TRUE` | b. `FALSE` |
| c. `FALSE` | c. `FALSE` | c. `TRUE` | c. `TRUE` | c. `TRUE` |
| d. `FALSE` | d. `TRUE` | d. `TRUE` | d. `TRUE` | d. `TRUE` |
| e. `FALSE` | e. `TRUE` | e. `FALSE` | e. `FALSE` | e. `TRUE` |

| 2.16 | 2.17 | 2.18 | 2.19 | 2.20 |
|---|---|---|---|---|
| a. `TRUE` | a. `TRUE` | a. `FALSE` | a. `TRUE` | a. `TRUE` |
| b. `FALSE` | b. `TRUE` | b. `FALSE` | b. `TRUE` | b. `TRUE` |
| c. `TRUE` | c. `TRUE` | c. `FALSE` | c. `FALSE` | c. `TRUE` |
| d. `TRUE` | d. `FALSE` | d. `FALSE` | d. `TRUE` | d. `FALSE` |
| e. `TRUE` | e. `FALSE` | e. `TRUE` | e. `FALSE` | e. `FALSE` |

| 3.1 | 3.2 | 3.3 | 3.4 | 3.5 |
|---|---|---|---|---|
| `dey = 3.5` | `gog = 3` | `eli = 1.0` | `jon = -1.0` | `abe = 1.5` |
| `luo = 1.5` | `oer = 1.5` | `soc = 4.0` | `aus = 1.0` | `sir = 3.0` |

| 3.6 | 3.7 | 3.8 | 3.9 | 3.10 |
|---|---|---|---|---|
| `vow = 3.0` | `gup = 0` | `tez = 2.5` | `jib = 5` | `aus = 1.5` |
| `nub = 4.0` | `ley = 0` | `nap = 7.5` | | |

| 3.11 | 3.12 | 3.13 | 3.14 | 3.15 |
|---|---|---|---|---|
| `bam = 2.0` | `tye = 1` | `nam = 4`<br>`sob = 0.0`<br>`off = 4` | `kaw = 1.0`<br>`zan = 1.5` | `quo = -0.75`<br>`ora = -2.75` |

| 3.16 | 3.17 | 3.18 | 3.19 | 3.20 |
|---|---|---|---|---|
| `gup = 2.5`<br>`han = 3.5` | `lod = 5`<br>`nid = 6.0`<br>`mou = 18`<br>`gyp = -2.5` | `you = 3`<br>`way = 0.5`<br>`iwa = 1.5` | `fei = 2`<br>`oka = 6.0` | `fae = 0.5` |

| 4.1 | 4.2 | 4.3 | 4.4 | 4.5 |
|---|---|---|---|---|
| `a = 11` | `a = 0` | `a = 0` | `a = 0` | `a = 10` |

| 4.6 | 4.7 | 4.8 | 4.9 | 4.10 |
|---|---|---|---|---|
| `a = 10` | `a = 18` | `a = 10` | `a = -3` | `a = 5` |

| 4.11 | 4.12 | 4.13 | 4.14 | 4.15 |
|---|---|---|---|---|
| `a = 1` | `a = 0` | `a = 20` | `a = 20` | `a = 9`<br>`b = 9` |

| 4.16 | 4.17 | 4.18 | 4.19 | 4.20 |
|---|---|---|---|---|
| `a = 0`<br>`b = 2` | `a = -1`<br>`b = -2` | `a = 0`<br>`b = -2` | `a = 6`<br>`b = 8` | `a = 4`<br>`b = -1` |

| 4.21 | 4.22 | 4.23 | 4.24 | 4.25 | 4.26 | 4.27 | 4.28 |
|---|---|---|---|---|---|---|---|
| `a = 10` | `a = -10` | `a = 7` | `a = 9` | `a = 8` | `a = 7` | `a = 8` | `a = 9` |

| 5.1 | 5.2 | 5.3 | 5.4 | 5.5 |
|---|---|---|---|---|
| `a = 6` | `a = 15` | `a = 16` | `a = 8` | `a = 1` |

| 5.6 | 5.7 | 5.8 | 5.9 | 5.10 |
|---|---|---|---|---|
| `a = 256` | `a = 18` | `a = 31` | `a = -31` | `a = 16` |

| 5.11 | 5.12 | 5.13 | 5.14 | 5.15 |
|---|---|---|---|---|
| `a = 5` | `a = 6` | `a = 3` | `a = 4` | `a = 5` |

| 5.16 | 5.17 | 5.18 | 5.19 | 5.20 |
|---|---|---|---|---|
| `a = 4` | `a = 9` | `a = 1` | `a = -2` | `a = 2` |

| 5.21 | 5.22 | 5.23 | 5.24 | 5.25 | 5.26 | 5.27 | 5.28 |
|---|---|---|---|---|---|---|---|
| `a = 2`<br>`b = 4` | `a = 2`<br>`b = 4` | `a = 2`<br>`b = 0` | `a = -2`<br>`b = 4` | `a = 5`<br>`b = 8` | `a = 10`<br>`b = 6` | `a = 4`<br>`b = 2` | `a = 6`<br>`b = 3` |

| 6.1 | 6.2 | 6.3 | 6.4 |
|---|---|---|---|
| `0 1 2` | `12 13 14` | `3 2 1 0` | `14 13 12 11` |

| 6.5 | 6.6 | 6.7 | 6.8 |
|---|---|---|---|
| `0 1 2` | `3 2 1 0` | `12 13 14` | `14 13 12 11` |

| 6.9 | 6.10 | 6.11 | 6.12 |
|---|---|---|---|
| `13 12 11 10 9` | `9 10 11` | `14 12 10 8` | `0 2 4 6 8` |

| 6.13 | 6.14 | 6.15 | 6.16 | 6.17 | 6.18 | 6.19 | 6.20 |
|---|---|---|---|---|---|---|---|
| `i = 3`<br>`a = 4` | `i = -1`<br>`a = 0` | `i = -1`<br>`a = 0` | `i = 3`<br>`a = 2` | `i = 3`<br>`a = 2` | `i = 16`<br>`a = 4` | `i = 8`<br>`a = 3` | `i = 6` |

6.21

```
b = 8
a = 5
while(a > 3)
   b = b / 2
   a = a - 1
```

6.22

```
e = 0
while(e < 4)
   print(e)
   e = e + 1
```

6.23

```
i = 4
while(i >= 0)
   print(i)
   i = i - 1
```

6.24

```
b = 0
i = 0
while(i < 4)
   b = i * 2
   i = i + 2
```

6.25

```
for(a = 1; a < 6; a = a + 2)
   print(a)
```

6.26

```
b = 0
for(a = 8; a > 1; a = a /2)
   b = b + 1
```

6.27

```
a = 8
for(b = 0; b < 3; b = b + 1)
   a = a / 2
```

6.28

```
for(a = 8, b = 0;
   a > 1 || b <= 3;
   a = a / 2, b = b + 1)
   print(a)
```

7.1

```
for(i = 0; i < 10; i++)
   print(i * 2)
```

7.2

```
for (i = 0; i < 12; i++)
   print(getal * 2 + 1)
```

7.3

```
for (i = 0; i < 7; i++)
   print(getal + 4)
```

7.4

```
for (i = 0; i < 9; i++)
   print(getal * 4 + 4)
```

7.5

```
for(i = 0; i < 10; i++)
   print(i * i)
```

7.6

```
for(i = 0; i < 15; i++)
   print(i * i + 1)
```

7.7

```
for(i = 0; i < 9; i++)
   print(i * -1 + 5)
```

7.8

```
getal = 1
for(i = 0; i < 12; i++)
   print(getal)
   getal = getal * 2
```

7.9

```
getal = 1
for(i = 0; i < 7; i++)
   print(getal)
   getal = getal * 3
```

7.10

```
getal = 2
for(i = 0; i < 10; i++)
   print(getal)
   getal = getal + 2
```

7.11

```
a = 16
for(i = 0; i < 9; i++)
   print(a)
   a = a / 2
```

7.12

```
b = 1000
for(i = 0; i < 10; i++)
   print(b)
   b = b / 10
```

7.13

```
c = 21
for(i = 0; i < 7; i++)
   print(c)
   c = c / 2
```

7.14

```
getal = 1
for(i = 0; i < 14; i++)
   if(getal % 3 == 0)
        print("*")
   else
        print(getal)
   getal = getal + 1
```

7.15

```
getal = 1
for(i = 0; i < 12; i++)
   if(getal % 3 == 0)
        print(getal + "! ")
   else
        print(getal)
   getal = getal + 1
```

7.16

```
getal = 34
for(i = 0; i < 20; i++)
   if(getal % 6 == 0)
        print(0)
   else
        print(getal)
   getal = getal - 2
```

7.17

```
getal = 1
for(i = 1; i <= 12; i++)
   if(i % 3 == 0)
        print("#")
   else
        print(getal)
   getal = getal * 2
```

7.18

```
getal = 1
for(i = 0; i < 12; i++)
   if((i + 1) % 3 == 0)
        print(i)
   else
        print(getal)
   getal = getal * 2
```

| 8.1 | 8.2 | 8.3 | 8.4 | 8.5 | 8.6 | 8.7 | 8.8 | 8.9 |
|---|---|---|---|---|---|---|---|---|
| `H` | `o` | `,` | `(space)` | `d` | `d` | `i` | `e` | `r` |

| 8.10 | 8.11 | 8.12 | 8.13 | 8.14 | 8.15 | 8.16 | 8.17 | 8.18 |
|---|---|---|---|---|---|---|---|---|
| `r` | `e` | `l` | `bounds err` | `o` | `o` | `a` | `p` | `W` |

| 8.19 | 8.20 | 8.21 | 8.22 |
|---|---|---|---|
| `Hello, world!` | `Hlo ol!` | `!dlrow ,olleH` | `Hello, world!` |

| 8.23 | 8.24 | 8.25 | 8.26 | 8.27 | 8.28 | 8.29 |
|---|---|---|---|---|---|---|
| `terug` | `yes!` | `go back` | `index` | `aarrgg` | `hi!hi!` | `hi!hi!` |

| 8.30 | 8.31 | 8.32 | 8.33 |
|---|---|---|---|
| `Hello, world` | `bounds err` | `scrabble` | `a2b3` |

| 8.34 | 8.35 | 8.36 |
|---|---|---|
| `a1a2b3` | `aaarrr` | `hi` |

| 9.1 | 9.2 | 9.3 | 9.4 | 9.5 | 9.6 | 9.7 | 9.8 | 9.9 | 9.10 |
|---|---|---|---|---|---|---|---|---|---|
| `5` | `2.1` | `x` | `2` | `2` | `0.1` | `-1` | `1` | `0.6` | `0` |

| 9.11 | 9.12 | 9.13 | 9.14 | 9.15 | 9.16 | 9.17 | 9.18 |
|---|---|---|---|---|---|---|---|
| `8.1` | `6.2` | `14` | `4` | `bounds err` | `2` | `3` | `3` |

| 9.19 | 9.20 | 9.21 |
|---|---|---|
| `lop = [10, 5, 30]` | `kol = [‘h’, ‘o’, ‘i’]` | `fof = [0.1, 0.2, 1.0]` |

| 9.22 | 9.23 | 9.24 |
|---|---|---|
| `dido = [2, 15, 10]` | `l = [5, 1, 2]` | `l = [0.1, 1.0, 0.3]` |

| 9.25 | 9.26 | 9.27 |
|---|---|---|
| `yoyo = [1.5, 1.5, 1.0]` | `yoyo = [2.0, 2.0, 1.0]` | `yoyo = [1.5, 1.0, 1.0]` |

| 9.28 | 9.29 | 9.30 |
|---|---|---|
| `hipp = [42, 4, 101]` | `fle = [7, 6, 10]` | `k = [0.3, 2.0, 0.6]` |

| 9.31 | 9.32 | 9.33 |
|---|---|---|
| `r = [0, 1, 0, 0]` | `zi = [‘s’, ‘b’, ‘c’]` | `b = [false, true, true]` |

| 9.34 | 9.35 | 9.36 |
|---|---|---|
| `rol = [1, 2, 3, 0]` | `j = [0, -2, -2]` | `r = [4, 2, 1]` |

9.37

```
1 2 3 4 5
```

9.38

```
5 4 3 2 1
```

9.39

```
1 2 3
```

9.40

```
2 1
```

9.41

```
lap = [‘x’, ‘x’, ‘x’, ‘x’, ‘x’]
```

9.42

```
gop = [2, 5, 1, 8, 8]
```

9.43

```
gop = [5, 3, 6, 2, 8]
```

9.44

```
gop = [4, 4, 4, 4, 4]
```

10.1

```
fly
```

10.2

```

```

10.3

```
fly jump jump
```

10.4

```
jump
```

10.5

```
pie pie bicycle
```

10.6

```
fly rainbow
```

10.7

```
jump
```

10.8

```
jump bicycle
```

| 10.9 | 10.10 | 10.11 | 10.12 | 10.13 | 10.14 |
|---|---|---|---|---|---|
| `fly` | `jump` | `0` | `1` | `1` | `1` |

| 10.15 | 10.16 | 10.17 | 10.18 | 10.19 | 10.20 |
|---|---|---|---|---|---|
| `1` | `1` | `0` | `0` | `1` | `0` |

| 10.21 | 10.22 | 10.23 | 10.24 | 10.25 | 10.26 |
|---|---|---|---|---|---|
| `fly` | `jump` | `bear` | `hello` | `0` | `1` |

| 10.27 | 10.28 | 10.29 | 10.30 |
|---|---|---|---|
| `1` | `10` | `fly jump` | `1` |

| 11.1 | 11.2 | 11.3 | 11.4 | 11.5 | 11.6 |
|---|---|---|---|---|---|
| `hard` | `jump` | `0` | `1` | `20` | `3` |

| 11.7 | 11.8 |
|---|---|
| `cal` | `1` |

| 11.9 | 11.10 | 11.11 | 11.12 | 11.13 |
|---|---|---|---|---|
| `2` | `2` | `3` | `4` | `6` |