

Exercises 9 Exponential function and equations Compound interest, exponential function

Objectives

- be able to calculate the future capital that is invested at an interest rate which is compounded annually.
- be able to treat compound interest tasks.
- be able to graph an exponential function out of its equation.
- be able to determine the equation of an exponential function out of the coordinates of two points of the graph.
- be able to treat applied tasks by means of an exponential function.

Problems

- 9.1 Compound interest at an annual rate r is paid on an initial capital C_0 .
- Assume an initial capital $C_0 = 1000.00$ CHF, and an annual interest rate $r = 2\%$. Determine the capital after one, two, three, four, and five years' time.
 - Try to develop a formula which allows you to calculate the capital C_n after n years' time for any values of C_0 , r , and n .
 - Solve the formula that you have developed in b) for C_0 and r .
- 9.2 What is the future capital if 8000 CHF are invested for 10 years at 12% compounded annually?
- 9.3 What present value amounts to 10'000 CHF if it is invested for 10 years at 6% compounded annually?
- 9.4 At what interest rate, compounded annually, would 10'000 CHF have to be invested to amount to 14'000 CHF in 7 years?
- 9.5 Ms Smith wants to invest 150'000 CHF for five years. Bank A offers an interest rate of 6.5% compounded annually. Bank B offers to pay 200'000 CHF after five years. Which bank makes the better offer?
- 9.6 The purchase of Alaska cost the United States \$ 7 million in 1869. If this money had been placed in a savings account paying 2% compounded annually, how much money would be available from this investment in 2025?
- 9.7 Mary Stahley invested 2500 CHF in a 36-month certificate of deposit (CD) that earned 8.5% annual simple interest. When the CD matured, she invested the full amount in a mutual fund that had an annual growth equivalent to 18% compounded annually. How much was the mutual fund worth 9 years later?
- 9.8 A capital is invested for 4 years at 4% and for 3 more years at 6%, compounded annually. Eventually, the capital amounts to 72'000 CHF.
- Determine the initial capital.
 - What is the average interest rate with respect to the whole period of time?
- 9.9 An unknown initial capital is invested at an unknown interest rate, compounded annually. After 2 years, the capital amounts to 5'891.74 CHF (rounded), and after another 5 years the capital is 6'997.54 CHF (rounded). Determine both initial capital (rounded to 100 CHF) and interest rate (rounded to 0.1%).

9.10 Look at the following exponential function:

$$f: \mathbb{R} \rightarrow \mathbb{R}$$

$$x \mapsto y = f(x) = 2^x$$

- Establish a table of values of f for the interval $-3 \leq x \leq 3$.
- Draw the graph of f in the interval $-3 \leq x \leq 3$ into a Cartesian coordinate system.

9.11 Graph the following exponential functions into one coordinate system:

$$f_1: \mathbb{R} \rightarrow \mathbb{R}$$

$$x \mapsto y = f_1(x) = 2^x$$

$$f_2: \mathbb{R} \rightarrow \mathbb{R}$$

$$x \mapsto y = f_2(x) = 0.2^x$$

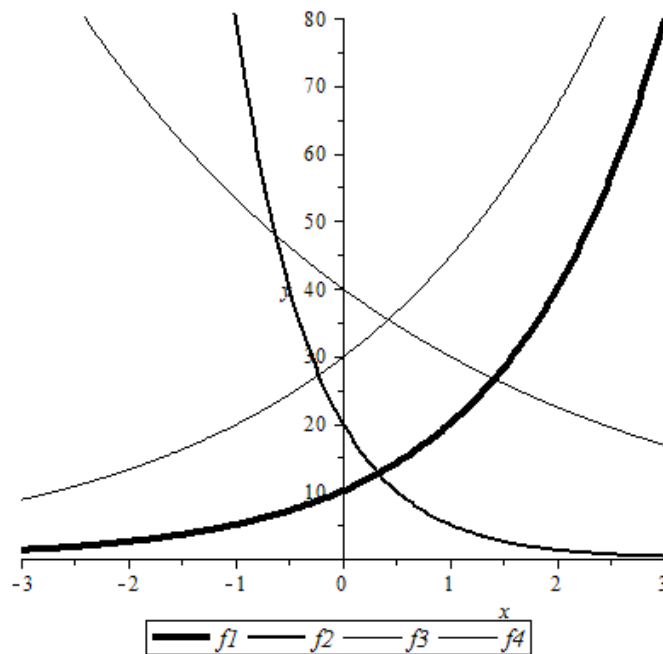
$$f_3: \mathbb{R} \rightarrow \mathbb{R}$$

$$x \mapsto y = f_3(x) = 3 \cdot 0.5^x$$

$$f_4: \mathbb{R} \rightarrow \mathbb{R}$$

$$x \mapsto y = f_4(x) = -2 \cdot 3^x$$

9.12 Look at the graphs of the exponential functions f_1 , f_2 , f_3 , and f_4 :



Determine the equations of the four functions, i.e. $y = f(x) = \dots$

9.13 The graph of an exponential function contains the points P and Q. Determine the equation of the exponential function.

- P(1|12) Q(3|192)
- P(0|1.02) Q(1|1.0302)
- P(0|10'000) Q(5|777.6)
- P(5|16) Q $\left(9\left|\frac{1}{16}\right.\right)$

- 9.14 A flat that 20 years ago was worth 160'000 CHF has increased in value by 4% each year due to the market situation. What is the flat worth today?
- 9.15 Suppose a country has a population of 20 million and projects a growth rate of 2% per year for the next 20 years. What will the population of this country be in 10 years?
- 9.16 A machine is valued at 10'000 CHF. The depreciation at the end of each year is 20% of its value at the beginning of the year. Find its value at the end of 4 years.
- 9.17 The size of a certain bacteria culture grows exponentially. At 8 a.m. and 11 a.m. the number of bacteria was 2'300 and 18'400, respectively. Determine the number of bacteria at 1.30 p.m.
- 9.18 A capital pays interest, compounded annually. What is the interest rate such that the capital doubles in 20 years?
- 9.19 Decide which statements are true or false. Put a mark into the corresponding box.
In each problem a) to c), exactly one statement is true.
- a) In a compound interest scheme ...
- ... the graph that represents the growth of the capital is a parabola.
 - ... the interest paid at the end of each period only depends on the interest rate.
 - ... the interest rate depends on the capital of the previous period.
 - ... the capital grows exponentially.
- b) The graph of an exponential function ...
- ... is a parabola.
 - ... is a hyperbola.
 - ... never intersects the y-axis.
 - ... never touches the x-axis.
- c) If a quantity grows exponentially in time ...
- ... the growth factor itself grows.
 - ... the growth factor depends on the initial value.
 - ... the quantity doubles in one year if the annual growth factor is 100%.
 - ... the quantity doubles in constant time intervals.

Answers

- 9.1 a) $C_0 = 1000.00$ CHF $C_1 = 1020.00$ CHF $C_2 = 1040.40$ CHF
 $C_3 = 1061.21$ CHF (rounded) $C_4 = 1082.43$ CHF (rounded) $C_5 = 1104.08$ CHF (rounded)
 b) $C_n = C_0 (1 + r)^n$
 c) see [formulary](#)

- 9.2 $C_n = C_0 (1 + r)^n$ where $C_0 = 8000$ CHF, $r = 12\%$, $n = 10$
 $\Rightarrow C_{10} = 24'846.79$ CHF (rounded)

- 9.3 $C_0 = \frac{C_n}{(1+r)^n}$ where $C_n = 10'000$ CHF, $r = 6\%$, $n = 10$
 $\Rightarrow C_0 = 5'583.95$ CHF (rounded)

- 9.4 $r = \sqrt[n]{\frac{C_n}{C_0}} - 1$ where $C_0 = 10'000$ CHF, $C_n = 14'000$ CHF, $n = 7$
 $\Rightarrow r = 4.9\%$ (rounded)

- 9.5 Bank A: $C_5 = 205'513.00$ CHF (rounded)
 Bank B: $C_5 = 200'000.00$ CHF

- 9.6 $C_{156} = \$ 154$ million (rounded to millions)

- 9.7 13'916.24 CHF
 2 periods: 3 years of simple interest, 9 years of compound interest
 - 3 years of simple interest:
 $C_n = C_0(1 + nr)$ where $C_0 = 2500$ CHF, $r = 8.5\%$, $n = 3$
 $\Rightarrow C_3 = 3137.50$ CHF
 - 9 years of compound interest:
 $C_n = C_0 (1 + r)^n$ where $C_0 = \dots$ (= C_3 after first 3 years), $r = 18\%$, $n = 9$
 $\Rightarrow C_9 = 13'916.24$ CHF (rounded)

- 9.8 a) $C_0 = 51'675$ CHF (rounded)
 Hints:
 - First, look at the second period (3 years, starting after 4 years from now), and calculate the capital at the beginning of this second period.
 - Then, calculate the initial capital.
 b) $r = 4.85\%$ (rounded)
 Hint:
 - The average interest rate r must be such that
 $C_n = C_0 (1 + r)^n$ where $C_0 =$ initial capital, $C_n =$ capital after the whole 7 years, $n = 7$

- 9.9 (see next page)

9.9 $r = 3.5\%$, $C_0 = 5'500.00$ CHF

Hints:

- First, look at the second period of 5 years, where $C_0 = 5'891.74$ CHF and $C_5 = 6'997.54$ CHF.
- The 5'891.74 CHF can be considered as the capital C_2 at the end of the first 2 years if C_0 is the initial capital at the beginning of the whole 7 years.

9.10 ...

9.11 ...

9.12 $y = f_1(x) = 10 \cdot 2^x$ ($c = 10, a = 2$)
 $y = f_2(x) = 20 \cdot 0.25^x$ ($c = 20, a = 0.25$)
 $y = f_3(x) = 30 \cdot 1.5^x$ ($c = 30, a = 1.5$)
 $y = f_4(x) = 40 \cdot 0.75^x$ ($c = 40, a = 0.75$)

9.13 a) $y = f(x) = 3 \cdot 4^x$

Hints:

- The equation of an exponential function is $y = f(x) = c \cdot a^x$
- If $P(1|12)$ and $Q(3|192)$ are points of the graph of the exponential function, their coordinates must fulfil the equation of the exponential function, i.e. $12 = f(1) = c \cdot a^1$ and $192 = f(3) = c \cdot a^3$
- Solve the two equations for c and a .

b) $y = f(x) = 1.02 \cdot 1.01^x$

c) $y = f(x) = 10'000 \cdot 0.6^x$

d) $y = f(x) = 16'384 \cdot 0.25^x$

9.14 350'580 CHF (rounded)

Hint:

- The relation between time t ($t =$ number of years elapsed since 20 years ago) and the value V of the house is an exponential function:

$$V = f(t) = V_0 \cdot a^t$$

where $V =$ value at time t , $V_0 =$ initial value (at $t = 0$) = 160'000 CHF, $a =$ growth factor = $1 + 4\% = 1.04$

9.15 24.4 million (rounded)

9.16 4'096 CHF

9.17 104'086 (rounded)

9.18 $r = \sqrt[20]{2} - 1 = 3.5\%$ (rounded)

9.19 a) 4th statement

b) 4th statement

c) 4th statement