

Exercises 7 Quadratic function and equations Quadratic function

Objectives

- be able to graph a quadratic function out of the vertex form of its equation.
- be able to determine the position of the vertex of a parabola out of the vertex form of the equation of the corresponding quadratic function.
- be able to convert the vertex form of the equation of a quadratic function into the general form.
- know, understand, and be able to apply the method of completing the square.
- be able to convert the general form of the equation of a quadratic function into the vertex form.

Problems

7.1 Look at the easiest case of a quadratic function:

$$\begin{aligned} f: \mathbb{R} &\rightarrow \mathbb{R} \\ x &\rightarrow y = f(x) = x^2 \end{aligned}$$

- Establish a table of values of f for the interval $-4 \leq x \leq 4$.
- Draw the graph of f in the interval $-4 \leq x \leq 4$ into a Cartesian coordinate system.

7.2 Generally, the equation of a quadratic function can be written in the so-called vertex form below:

$$\begin{aligned} f: D &\rightarrow \mathbb{R} & (D \subseteq \mathbb{R}) \\ x &\rightarrow y = f(x) = a(x - u)^2 + v & (a \in \mathbb{R} \setminus \{0\}, u \in \mathbb{R}, v \in \mathbb{R}) \end{aligned}$$

In problems a) to d) ...

- ... sketch the graphs of the functions f_0 , f_1 , and f_2 into one coordinate system.
- ... describe the influence of the parameters u , v , and a on the graph of the quadratic function.

- Variation of parameter u ($a = 1, v = 0$)

$$\begin{aligned} y = f_0(x) &= x^2 & (u = 0) \\ y = f_1(x) &= (x - 2)^2 & (u = 2) \\ y = f_2(x) &= (x + 1)^2 & (u = -1) \end{aligned}$$

- Variation of parameter v ($a = 1, u = 0$)

$$\begin{aligned} y = f_0(x) &= x^2 & (v = 0) \\ y = f_1(x) &= x^2 + 3 & (v = 3) \\ y = f_2(x) &= x^2 - 2 & (v = -2) \end{aligned}$$

- Variation of parameter a ($u = 0, v = 0$)

$$\begin{aligned} y = f_0(x) &= x^2 & (a = 1) \\ y = f_1(x) &= 2x^2 & (a = 2) \\ y = f_2(x) &= -2x^2 & (a = -2) \end{aligned}$$

- Variation of parameter a ($u = 0, v = 0$)

$$\begin{aligned} y = f_0(x) &= x^2 & (a = 1) \\ y = f_1(x) &= \frac{1}{2}x^2 & \left(a = \frac{1}{2}\right) \\ y = f_2(x) &= -\frac{1}{2}x^2 & \left(a = -\frac{1}{2}\right) \end{aligned}$$

7.3 For each quadratic function $f: \mathbb{R} \rightarrow \mathbb{R}, x \rightarrow y = f(x)$ in a) to h) ...

- i) ... determine the parameters a, u, and v.
- ii) ... state the coordinates of the vertex of the graph.
- iii) ... state whether the parabola, i.e. the graph of the function, opens upwards or downwards.
- iv) ... graph the function.

a) $y = f(x) = (x + 2)^2$	b) $y = f(x) = -3x^2$
c) $y = f(x) = 2x^2 - 1$	d) $y = f(x) = -(x - 3)^2 + 4$
e) $y = f(x) = \frac{1}{2}(x + 3)^2 + 2$	f) $y = f(x) = -2(x - 1)^2 + 5$
g) $y = f(x) = \frac{5}{2} - \left(x - \frac{1}{2}\right)^2$	h) $y = f(x) = -\frac{1}{2} - 3(2 - x)^2$

7.4 The equation of a quadratic function can be written in the two forms below:

$$y = f(x) = ax^2 + bx + c \quad \text{general form}$$

$$y = f(x) = a(x - u)^2 + v \quad \text{vertex form}$$

- a) Verify that the vertex form of the equation can always be converted into the general form.
- b) Assume that the values of the parameters a, u, and v are known.
Use the result in a) to determine the values of the parameters b and c out of a, u, and v.

7.5 The equation of a quadratic function f is written in the vertex form. Determine the general form of the equation:

a) $y = f(x) = 2(x - 3)^2 + 4$	b) $y = f(x) = -(x + 2)^2 - 3$
c) $y = f(x) = x^2 + 5$	d) $y = f(x) = -3(x - 4)^2$

7.6 Convert the given equation of a quadratic function into the vertex form by completing the square:

a) $y = f(x) = 3x^2 - 12x + 8$	b) $y = f(x) = x^2 + 6x$
c) $y = f(x) = x^2 - 2x + 1$	d) $y = f(x) = 2x^2 + 12x + 18$
e) $y = f(x) = -2x^2 - 6x - 2$	f) $y = f(x) = x^2 + 1$
g) $y = f(x) = -\frac{1}{2}x^2 + 2x - 2$	h) $y = f(x) = -4x^2 + 24x - 43$
i) $y = f(x) = 2(x - 3)(x + 4)$	j) $y = f(x) = x + 3 - \left(x + \frac{1}{2}\right)x$

7.7 For the graphs of the quadratic functions $f: \mathbb{R} \rightarrow \mathbb{R}, x \rightarrow y = f(x)$ in a) to f) ...

- i) ... determine the coordinates of the vertex.
- ii) ... state whether the parabola opens upwards or downwards.

a) $y = f(x) = 2x^2 + 12x + 20$	b) $y = f(x) = \frac{1}{2}x^2 + \frac{3}{2}x + \frac{1}{2}$
c) $y = f(x) = 12x - 3x^2 - 11$	d) $y = f(x) = x(-0.2x + 1.2) - 2.8$
e) $y = f(x) = \frac{17 + 12x + 2x^2}{4}$	f) $y = f(x) = 7x(3 - x) - 13.25$

Answers

7.1 see theory

7.2 see theory

- 7.3
- a)
 - i) $a = 1, u = -2, v = 0$
 - ii) $V(-2|0)$
 - iii) parabola opens upwards
 - iv) ...
 - b)
 - i) $a = -3, u = 0, v = 0$
 - ii) $V(0|0)$
 - iii) parabola opens downwards
 - iv) ...
 - c)
 - i) $a = 2, u = 0, v = -1$
 - ii) $V(0|-1)$
 - iii) parabola opens upwards
 - iv) ...
 - d)
 - i) $a = -1, u = 3, v = 4$
 - ii) $V(3|4)$
 - iii) parabola opens downwards
 - iv) ...
 - e)
 - i) $a = \frac{1}{2}, u = -3, v = 2$
 - ii) $V(-3|2)$
 - iii) parabola opens upwards
 - iv) ...
 - f)
 - i) $a = -2, u = 1, v = 5$
 - ii) $V(1|5)$
 - iii) parabola opens downwards
 - iv) ...
 - g)
 - i) $a = -1, u = \frac{1}{2}, v = \frac{5}{2}$
 - ii) $V\left(\frac{1}{2}|\frac{5}{2}\right)$
 - iii) parabola opens downwards
 - iv) ...

- h) i) $a = -3, u = 2, v = -\frac{1}{2}$
 ii) $V\left(2|-\frac{1}{2}\right)$
 iii) parabola opens downwards
 iv) ...
- 7.4 a) $y = f(x) = a(x - u)^2 + v = \dots = ax^2 - 2aux + au^2 + v = ax^2 + (-2au)x + (au^2 + v)$
 Hints:
 - Expand the term $(x-u)^2$.
 - Simplify the whole expression.
 b) $b = -2au$
 $c = au^2 + v$
 Hint:
 - Compare the resulting expression in a) with the general form $ax^2 + bx + c$.
- 7.5 a) $y = f(x) = 2x^2 - 12x + 22$
 b) $y = f(x) = -x^2 - 4x - 7$
 c) $y = f(x) = x^2 + 5$
 Notice:
 - This is both the general and the vertex form of the equation.
 d) $y = f(x) = -3x^2 + 24x - 48$
- 7.6 a) $y = f(x) = 3(x - 2)^2 - 4$
 b) $y = f(x) = (x + 3)^2 - 9$
 c) $y = f(x) = (x - 1)^2$
 d) $y = f(x) = 2(x + 3)^2$
 e) $y = f(x) = -2\left(x + \frac{3}{2}\right)^2 + \frac{5}{2}$
 f) $y = f(x) = x^2 + 1$
 g) $y = f(x) = -\frac{1}{2}(x - 2)^2$
 h) $y = f(x) = -4(x - 3)^2 - 7$
 i) $y = f(x) = 2\left(x + \frac{1}{2}\right)^2 - \frac{49}{2}$
 j) $y = f(x) = -\left(x - \frac{1}{4}\right)^2 + \frac{49}{16}$
- 7.7 a) i) $V(-3|2)$
 ii) parabola opens upwards
 c) i) $V(2|1)$
 ii) parabola opens downwards
 e) i) $V\left(-3|-\frac{1}{4}\right)$
 ii) parabola opens upwards
 b) i) $V\left(-\frac{3}{2}|-\frac{5}{8}\right)$
 ii) parabola opens upwards
 d) i) $V(3|-1)$
 ii) parabola opens downwards
 f) i) $V\left(\frac{3}{2}|\frac{5}{2}\right)$
 ii) parabola opens downwards