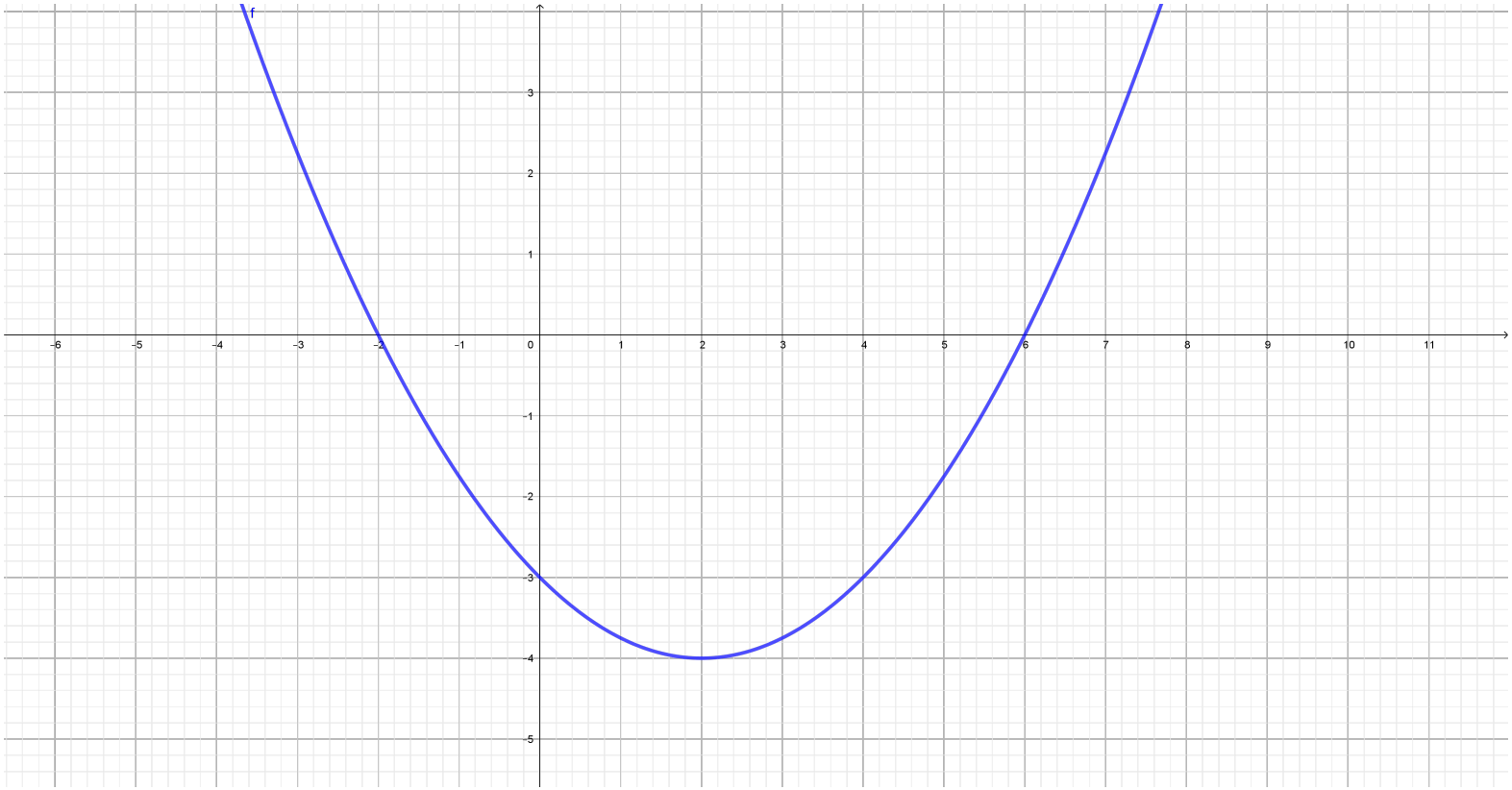
Quadratic functions

Intro

We will discuss the important features of graphs of quadratic functions, ie functions that can be written in the form $f(x) = ax^2 + bx + c$.

Graphs of quadratic functions

This is a graph of a generic quadratic function:



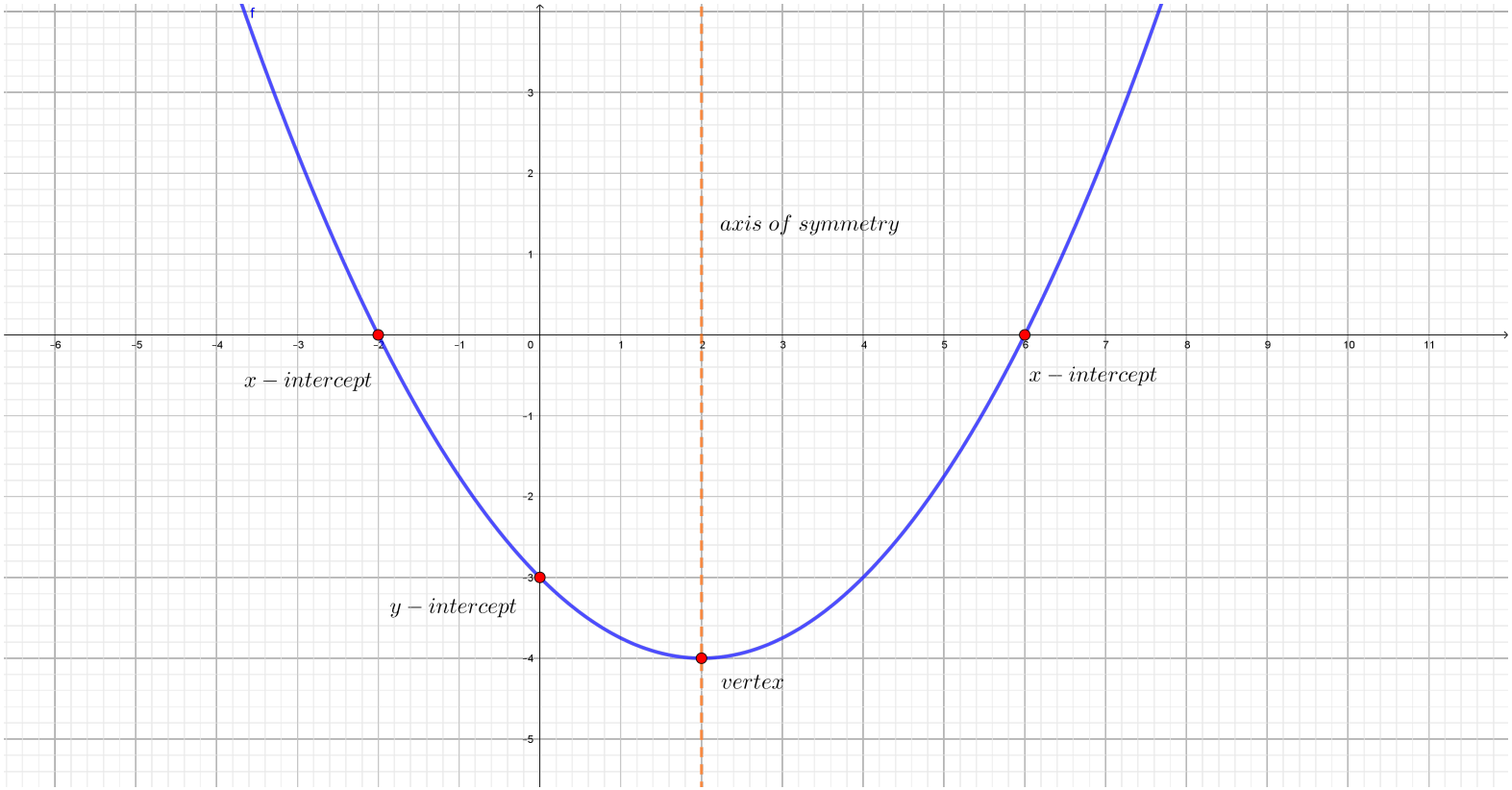
Graphs of quadratic functions

This graph has 4 important features:

- x-intercepts,
- y-intercept,
- vertex,
- axis of symmetry.

Graphs of quadratic functions

The important features of the graph:



The questions on the exam will test your understanding of these 4 features.

3 forms of quadratic functions

The quadratic function may be written in 3 forms:

- standard form $f(x) = ax^2 + bx + c$,
- vertex form $f(x) = a(x - h)^2 + k$,
- factored form $f(x) = a(x - p)(x - q)$.

Note that the factored form doesn't always exist (ie it is not always possible to factorize a quadratic function).

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Suppose we have a function in the vertex form $f(x) = (x-2)^2 - 9$.

Can we change it to the other forms:

- standard form:

$$(x-2)^2 - 9 = x^2 - 4x + 4 - 9 = x^2 - 4x - 5$$

so the function in the standard form is $f(x) = x^2 - 4x - 5$.

- factored form:

$$(x-2)^2 - 9 = (x-2)^2 - 3^2 = (x-2-3)(x-2+3) = (x-5)(x+1)$$

so the function in the factored form is $f(x) = (x-5)(x+1)$.

Note that we've used the following important formulae $(a-b)^2 = a^2 - 2ab + b^2$ (in the first case) and $a^2 - b^2 = (a-b)(a+b)$ in the second case.

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Why do we need 3 forms? Each of them is good for a particular thing. Remember there were 4 important features of the graph of a quadratic functions.

- standard form is good for the y-intercept,
- vertex form is good for the axis of symmetry and (surprise, surprise) the vertex,
- factored form is good for the x-intercepts.

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y-intercept

y-intercept of any function is calculated by substituting 0 for x. This is because the x-coordinate of the point on the y-axis is 0.

Suppose our function is $f(x) = x^2 + 3x - 2$. What is its y-intercept? We substitute 0 for x and get:

$$y = 0^2 + 3 \times 0 - 2 = -2$$

so $y = -2$. The graphs intersects the y-axis at $(0, -2)$.

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To find x-intercepts we set $y = 0$ and solve for x. So we need to solve:

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vertex

Now let's suppose that we have a function $f(x) = 2(x-3)^2 + 5$. We want to find the vertex of the graph of this function. The vertex gives the minimum/maximum value of the function. What is the minimum value of the given function.

We have $f(x) = 2(x-3)^2 + 5$, now the first part $2(x-3)^2$, because it's squared, can never be less than 0, so the least it can be is 0. We add 5, so the least value y of our function is 5. For what x do we get this value? We get the least value of y, when the part $2(x-3)^2$ is 0, so when $x = 3$.

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We have $f(x) = 2(x-3)^2 + 5$, now the first part $2(x-3)^2$, because it's squared, can never be less than 0, so the least it can be is 0. We add 5, so the least value y of our function is 5. For what x do we get this value?

We get the least value of y, when the part $2(x-3)^2$ is 0, so when $x = 3$.

This means that the vertex has coordinates $(3, 5)$, because the minimum value y of our function is 5 and it occurs when $x = 3$.

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What is the vertex of the graph of the function $f(x) = 3(x+2)^2 + 1$?

The part $3(x+2)^2$ can never get below 0, so the minimum value y is 1. It occurs when $3(x+2)^2$ is 0, so when $x = -2$.

The vertex has coordinates $(-2, 1)$.

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Now let $f(x) = a(x-h)^2 + k$, what are the coordinates of the vertex?

The part $a(x-h)^2$ has minimum/maximum (depending on whether a is positive or negative) value 0, so the minimum/maximum value of y is k. It occurs when $a(x-h)^2$ is 0, so when $x = h$.

The vertex has coordinates (h, k).

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Practice

Find the coordinates of the point, where the function intersects the y-axis:

- $f(x) = 2x^2 + 3x + 5$,
  point of intersection with y-axis: $(0, 5)$,
- $f(x) = -x^2 + 2x + 3$,
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- $f(x) = 4x^2 + 1$,
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Practice

Find the coordinates of the vertex of the graphs of the following functions

- $f(x) = (x-1)^2 + 6$,
  coordinates of the vertex: $(1, 6)$,
- $f(x) = (x+3)^2 + 2$,
  coordinates of the vertex: $(-3, 2)$,
- $f(x) = 4(x+7)^2 - 1$,
  coordinates of the vertex: $(-7, -1)$,
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The lesson from this presentation should be to be able to figure out which form is suitable for which purpose and to use this form for that purpose.