Quadratic equations

Introduction

In this presentation we will review different methods for solving quadratic equations.

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$$ax^2 + bx + c = 0$$

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- factorization,
- completing the square,
- quadratic formula.

We will now review these methods.

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Solve

$$x^2 - 3x - 18 = 0$$

We factorize the left hand side to get:

$$(x-6)(x+3) = 0$$

So $x - 6 = 0$ or $x + 3 = 0$. Which gives $x = 6$ or $x = -3$.

Factorization - examples

a) Solve:

$$x^2 + 2x - 15 = 0$$

Factorization - examples

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We factorize and get:

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b) Solve

$$2x^2 + 11x = 0$$

We factor out x and get:

$$x(2x+11) = 0$$

which gives $x = 0$ or $2x + 11 = 0$,

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$$4x^2 - 81 = 0$$

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$$(x-4)(x-2) = 0$$

which gives $x - 4 = 0$ or $x - 2 = 0$,

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Factorization - examples

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$$x^2 - 4x + 4 = 0$$

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which gives $x - 2 = 0$, so $x = 2$.

f) Solve

$$3x^2 - 10x - 8 = 0$$

We factorize and get:

$$(3x+2)(x-4) = 0$$

which gives $3x + 2 = 0$ or $x - 4 = 0$,

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$$x^2 - 4x + 4 = 0$$

We factorize and get:

$$(x-2)^2 = 0$$

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f) Solve

$$3x^2 - 10x - 8 = 0$$

We factorize and get:

$$(3x+2)(x-4) = 0$$

which gives $3x + 2 = 0$ or $x - 4 = 0$, so $x = -\frac{2}{3}$ or $x = 4$.

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$$x^2 = x + 12$$

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h) Solve

$$2x^2 = 5x + 3$$

We move all terms to one side:

$$2x^2 - 5x - 3 = 0$$

Now we factorize and get:

$$(2x + 1)(x - 3) = 0$$

which gives $2x + 1 = 0$ or $x - 3 = 0$,

Factorization - examples

h) Solve

$$2x^2 = 5x + 3$$

We move all terms to one side:

$$2x^2 - 5x - 3 = 0$$

Now we factorize and get:

$$(2x + 1)(x - 3) = 0$$

which gives $2x + 1 = 0$ or $x - 3 = 0$, so $x = -\frac{1}{2}$ or $x = 3$.

Factorization

Remember that we constantly use the fact that if a product of two numbers is 0, then one of the numbers must be 0.

Important property

If $a \times b = 0$, then $a = 0$ or $b = 0$.

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Useless property

If $a \times b = 7$ (or any other non-zero number), then we don't know much about a or b.

Factorization doesn't always work and if after a few seconds we cannot factorize the given expression, then we should try a different approach.

Completing the square

Let's solve the following equation

$$x^2 + 4x - 12 = 0$$

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We have $x^2 + 4x = (x + 2)^2 - 4$

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We have $x^2 + 4x = (x + 2)^2 - 4$
So we are solving:

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We have $x^2 + 4x = (x+2)^2 - 4$
So we are solving:

$$(x+2)^2 - 4 - 12 = 0$$

We get:

$$(x+2)^2 - 16 = 0$$

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$x + 2$ squared gives 16, so $x + 2 = 4$ or $x + 2 = -4$, which gives $x = 2$ or $x = -6$.

Completing the square

The method is fairly simple:

$$x^2 + 4x - 12 = 0$$

We want to change the left hand side to the form

$$(x \ \ ...)^2 - ... = 0$$

We just need to put appropraite numbers in place of dots.

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We just need to put appropriate numbers in place of dots. The bracket is easy, we choose the number so that the first two terms are ok, so we want to get $x^2 + 4x$. So the bracket has to be $(x + 2)^2$.

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Names

Let's look at the equation once more:

$$x^2 + 4x - 12 = 0$$

The left hand side of the equation is a quadratic in a **standard form**.

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The left hand side of the equation is a quadratic in a **standard form**. We can factorize it and turn it into:

$$(x-2)(x+6) = 0$$

This form is called a **factored form**.

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Now we turned it into:

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This is called a **vertex form**.

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This form is called a **factored form**.
Now we turned it into:

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This is called a **vertex form**.

We will talk more about these forms when we will be covering quadratic functions.

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Turn $x^2 + 6x - 2$ into vertex form. Hence solve $x^2 + 6x - 2 = 0$.

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Turn $x^2 + 6x - 2$ into vertex form. Hence solve $x^2 + 6x - 2 = 0$.

We want $x^2 + 6x - 2$ in the form $(x \ ...)^2$ .... We need $+3$ in the bracket to get $6x$.
So we have $(x + 3)^2$, which gives $(x + 3)^2 = x^2 + 6x + 9$, but instead of 9 we want -2, so we need to subtract 11.

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Turn $x^2 + 6x - 2$ into vertex form. Hence solve $x^2 + 6x - 2 = 0$.

We want $x^2 + 6x - 2$ in the form $(x \dots)^2 \dots$. We need $+3$ in the bracket to get $6x$.
So we have $(x+3)^2$, which gives $(x+3)^2 = x^2 + 6x + 9$, but instead of 9 we want -2, so we need to subtract 11. Finally:

$$x^2 + 6x - 2 = (x+3)^2 - 11$$

Completing the square - example

Now we want to solve:

$$x^2 + 6x - 2 = 0$$

Completing the square - example

Now we want to solve:

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We turn the left hand side into vertex form:

$$(x+3)^2 - 11 = 0$$

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Now we want to solve:

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We turn the left hand side into vertex form:

$$(x+3)^2 - 11 = 0$$

so:

$$(x+3)^2 = 11$$

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Now we want to solve:

$$x^2 + 6x - 2 = 0$$

We turn the left hand side into vertex form:

$$(x+3)^2 - 11 = 0$$

so:

$$(x+3)^2 = 11$$

so $x + 3 = \sqrt{11}$ or $x + 3 = -\sqrt{11}$.

Completing the square - example

Now we want to solve:

$$x^2 + 6x - 2 = 0$$

We turn the left hand side into vertex form:

$$(x+3)^2 - 11 = 0$$

so:

$$(x+3)^2 = 11$$

so $x + 3 = \sqrt{11}$ or $x + 3 = -\sqrt{11}$.
This gives $x = -3 + \sqrt{11}$ or $x = -3 - \sqrt{11}$.

Completing the square - example

Now we want to solve:

$$x^2 + 6x - 2 = 0$$

We turn the left hand side into vertex form:

$$(x+3)^2 - 11 = 0$$

so:

$$(x+3)^2 = 11$$

so $x + 3 = \sqrt{11}$ or $x + 3 = -\sqrt{11}$.
This gives $x = -3 + \sqrt{11}$ or $x = -3 - \sqrt{11}$.

Note that we wouldn't be able to solve the equation $x^2 + 6x - 2 = 0$ by factorizing it, or at least it would be very hard.

Completing the square - example

If we want to solve an equation like:

$$2x^2 + 6x - 3 = 0$$

We will first divide both sides by 2, this gives:

Completing the square - example

If we want to solve an equation like:

$$2x^2 + 6x - 3 = 0$$

We will first divide both sides by 2, this gives:

$$x^2 + 3x - \frac{3}{2} = 0$$

Completing the square - example

If we want to solve an equation like:

$$2x^2 + 6x - 3 = 0$$

We will first divide both sides by 2, this gives:

$$x^2 + 3x - \frac{3}{2} = 0$$

Now we complete the square:

$$\left(x + \frac{3}{2}\right)^2 - \frac{15}{4} = 0$$

Completing the square - example

If we want to solve an equation like:

$$2x^2 + 6x - 3 = 0$$

We will first divide both sides by 2, this gives:

$$x^2 + 3x - \frac{3}{2} = 0$$

Now we complete the square:

$$\left(x + \frac{3}{2}\right)^2 - \frac{15}{4} = 0$$

So

$$\left(x + \frac{3}{2}\right)^2 = \frac{15}{4}$$

which gives $x + \frac{3}{2} = \pm\frac{\sqrt{15}}{2}$, so $x = -\frac{3}{2} \pm \frac{\sqrt{15}}{2}$.

Completing the square - example

If we want to solve an equation like:

$$2x^2 + 6x - 3 = 0$$

We will first divide both sides by 2, this gives:

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Now we complete the square:

$$\left(x + \frac{3}{2}\right)^2 - \frac{15}{4} = 0$$

So

$$\left(x + \frac{3}{2}\right)^2 = \frac{15}{4}$$

which gives $x + \frac{3}{2} = \pm\frac{\sqrt{15}}{2}$, so $x = -\frac{3}{2} \pm \frac{\sqrt{15}}{2}$. Note $\pm$ means that there are two solutions, one when we add the given number, the other when we subtract.

Quadratic formula

The method of completing the square led us to a formula for solving quadratic equations:

$$ax^2 + bx + c = 0$$

Quadratic formula

The method of completing the square led us to a formula for solving quadratic equations:

$$ax^2 + bx + c = 0$$

The formula we derived is $x = \dfrac{-b \pm \sqrt{\Delta}}{2a}$, where $\Delta = b^2 - 4ac$.

Quadratic formula

If we want to solve:

$$2x^2 + 6x - 3 = 0$$

then we have $a = 2$, $b = 6$ and $c = -3$.

Quadratic formula

If we want to solve:

$$2x^2 + 6x - 3 = 0$$

then we have $a = 2$, $b = 6$ and $c = -3$.

We first calculate Δ:

$$\Delta = 6^2 - 4(2)(-3) = 60$$

Quadratic formula

If we want to solve:

$$2x^2 + 6x - 3 = 0$$

then we have $a = 2$, $b = 6$ and $c = -3$.

We first calculate Δ:

$$\Delta = 6^2 - 4(2)(-3) = 60$$

So $x = \dfrac{-6 \pm \sqrt{60}}{4} = \dfrac{-6 \pm 2\sqrt{15}}{4} = \dfrac{-3 \pm \sqrt{15}}{2}$

Practice

When you solve a quadratic equation, you should start by trying factorization, then if it doesn't work use the quadratic formula. The completing the square method is still important and we will use it when we will be dealing with quadratic functions.

Practice

Solve:

$$x^2 - 6x - 7 = 0$$

Practice

Solve:

$$x^2 - 6x - 7 = 0$$

Method:

Practice

Solve:

$$x^2 - 6x - 7 = 0$$

Method: factorization!

Practice

Solve:

$$x^2 - 6x - 7 = 0$$

Method: factorization!

$$(x-7)(x+1) = 0$$

so $x = 7$ oraz $x = -1$.

Practice

Solve:

$$2x^2 - x - 15 = 0$$

Practice

Solve:

$$2x^2 - x - 15 = 0$$

Method:

Practice

Solve:

$$2x^2 - x - 15 = 0$$

Method: factorization!

Practice

Solve:

$$2x^2 - x - 15 = 0$$

Method: factorization!

$$(2x + 5)(x - 3) = 0$$

so $x = -2.5$ oraz $x = 3$.

Practice

Solve:

$$x^2 + 5x + 1 = 0$$

Practice

Solve:

$$x^2 + 5x + 1 = 0$$

Method:

Practice

Solve:

$$x^2 + 5x + 1 = 0$$

Method: quadratic formula (factorization doesn't work nicely)

Practice

Solve:

$$x^2 + 5x + 1 = 0$$

Method: quadratic formula (factorization doesn't work nicely)
$a = 1$, $b = 5$, $c = 1$, so

$$\Delta = 25 - 4(1)(1) = 21$$

Practice

Solve:

$$x^2 + 5x + 1 = 0$$

Method: quadratic formula (factorization doesn't work nicely)
$a = 1,\ b = 5,\ c = 1$, so

$$\Delta = 25 - 4(1)(1) = 21$$

So we have:

$$x = \frac{-5 \pm \sqrt{21}}{2}$$

Practice

Solve:

$$3x^2 + 5x = 0$$

Practice

Solve:

$$3x^2 + 5x = 0$$

Method:

Practice

Solve:

$$3x^2 + 5x = 0$$

Method: factorization!

Practice

Solve:

$$3x^2 + 5x = 0$$

Method: factorization!

$$x(3x+5) = 0$$

so $x = 0$ oraz $x = -\frac{5}{3}$.

Practice

Solve:

$$2x^2 + 3x - 1 = 0$$

Practice

Solve:

$$2x^2 + 3x - 1 = 0$$

Method:

Practice

Solve:

$$2x^2 + 3x - 1 = 0$$

Method: quadratic formula (factorization doesn't work)

Practice

Solve:

$$2x^2 + 3x - 1 = 0$$

Method: quadratic formula (factorization doesn't work)
$a = 2$, $b = 3$, $c = -1$, so

$$\Delta = 9 - 4(2)(-1) = 17$$

Practice

Solve:

$$2x^2 + 3x - 1 = 0$$

Method: quadratic formula (factorization doesn't work)
$a = 2$, $b = 3$, $c = -1$, so

$$\Delta = 9 - 4(2)(-1) = 17$$

So we have:

$$x = \frac{-3 \pm \sqrt{17}}{4}$$

Practice

Solve:

$$9x^2 - 4 = 0$$

Practice

Solve:

$$9x^2 - 4 = 0$$

Method:

Practice

Solve:

$$9x^2 - 4 = 0$$

Method: factorization!

Practice

Solve:

$$9x^2 - 4 = 0$$

Method: factorization!

$$(3x - 2)(3x + 2) = 0$$

so $x = \frac{2}{3}$ oraz $x = -\frac{2}{3}$.

Practice

Solve:

$$3x^2 + 14x + 8 = 0$$

Practice

Solve:

$$3x^2 + 14x + 8 = 0$$

Method:

Practice

Solve:

$$3x^2 + 14x + 8 = 0$$

Method: factorization!

Practice

Solve:

$$3x^2 + 14x + 8 = 0$$

Method: factorization!

$$(3x + 2)(x + 4) = 0$$

so $x = -\frac{2}{3}$ oraz $x = -4$.

Practice

Solve:

$$2x^2 - 6x + 3 = 0$$

Practice

Solve:

$$2x^2 - 6x + 3 = 0$$

Method:

Practice

Solve:

$$2x^2 - 6x + 3 = 0$$

Method: quadratic formula (factorization doesn't work)

Practice

Solve:

$$2x^2 - 6x + 3 = 0$$

Method: quadratic formula (factorization doesn't work)
$a = 2,\ b = -6,\ c = 3$, so

$$\Delta = 36 - 4(2)(3) = 12$$

Practice

Solve:

$$2x^2 - 6x + 3 = 0$$

Method: quadratic formula (factorization doesn't work)
$a = 2,\ b = -6,\ c = 3$, so

$$\Delta = 36 - 4(2)(3) = 12$$

So we have:

$$x = \frac{6 \pm \sqrt{12}}{4} = \frac{6 \pm 2\sqrt{3}}{4} = \frac{3 \pm \sqrt{3}}{2}$$

Make sure you practice all three methods and are confident using them all.