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THE GREATEST AND SMALLEST VALUES OF A FUNCTION ON A SEGMENT

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Abstract
In this article discusses about the greatest and smallest values of a function on a segment.

Keywords: greatest, smallest, values, function, segment.

Introduction

So far we have considered a function on an arbitrary interval $(a, b)$and examined its monotonicity and extremes. Now we will consider a function on a segment $[a, b]$and determine its largest and smallest values.

Let a function be given $y = f(x)$on a segment $[a, b]$and a point $x_0 \in [a, b]$.

Definition 1 . The function $y = f(x)$is called bounded from above on a segment $[a, b]$, if there exists a number M such that the inequality

$$f(x) \leq M$$

true for anyone $x \in [a, b]$.

In this case, the number M is called the upper bound of the function. on $y = f(x)$the segment $[a, b]$.

Definition 2. The function $y = f(x)$is called unlimited above on the segment $[a, b]$, if for any number M there exists such $x_0 \in [a, b]$that the inequality holds

$$f(x_0) > M.$$

Note that a function bounded from above on a segment has an infinite number of upper bounds.

Definition 3. The smallest upper bound of a function $y = f(x)$on a segment $[a, b]$is called the greatest upper bound of this function and is denoted by

$$\sup f = \sup_{x \in [a,b]} \{f(x)\}.$$

Definition 4. The function $y = f(x)$is called bounded below by a segment $[a, b]$, if there exists a number m such that the inequality

$$f(x) \geq m$$

fair for anyone$x \in [a, b]$.

In this case the number m is called the lower bound of the function $y = f(x)$on the segment$[a, b]$.

Definition 5. The function $y = f(x)$is called unlimited below on the segment $[a, b]$, if for any number m there is a number such $x_0 \in [a, b]$that the inequality is true

$$f(x_0) < m.$$

Note that a function bounded from below on a segment has an infinite number of lower bounds.

Definition 6. The greatest lower bound of a function $y = f(x)$on a segment $[a, b]$is called the greatest lower bound of this function and is denoted by

$$\inf f = \inf_{x\in[a,b]} \{f(x)\}.$$

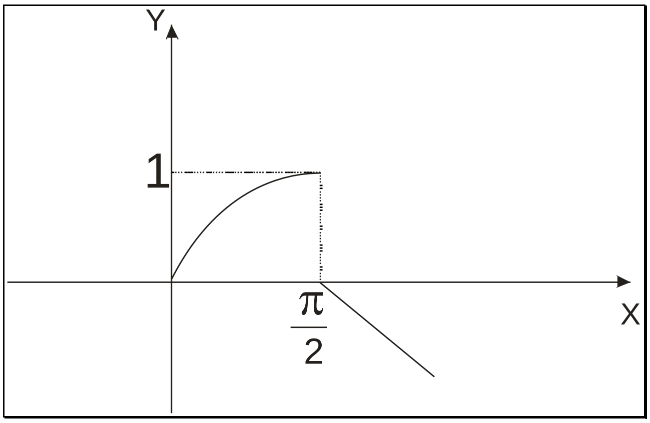
Definition 7. The function $y = f(x)$is called limited on the segment $[a, b]$, if it is bounded both above and below on this segment. Otherwise, it is called unbounded on this segment.

Example 1. Let's consider the function

$$f(x) = \begin{cases} \sin x, & x \in [0, \frac{\pi}{2}) \\ \frac{\pi}{2} - x, & x \in [\frac{\pi}{2}, \pi) \end{cases}$$

On the segment $[0, \pi]$.

This function is bounded from above by the value 1 on the segment $[0, \pi]$, which is also the greatest upper bound, but does not reach it for any values from the segment $[0, \pi]$. The given function is bounded from below on this segment by the greatest lower bound , which is $-\frac{\pi}{2}$, which it reaches at point $x = \pi$.

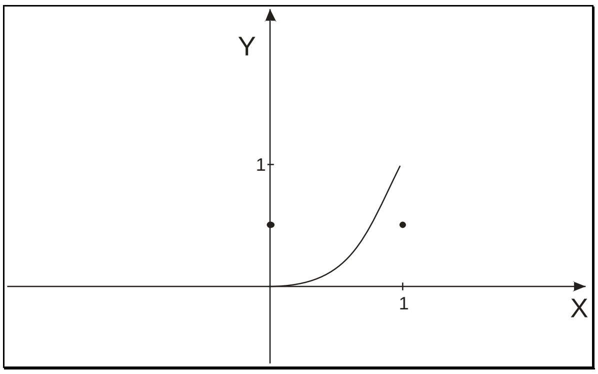


Example 2. Let's consider the function

$$f(x) = \begin{cases} x^2, & x \in (0,1) \\ \frac{1}{2}, & x = 0, x = 1 \end{cases}$$

On the segment$[0,1]$.

This function is bounded on a segment $[0,1]$and has an exact upper bound $\sup f = 1$and an exact lower bound on this segment $\inf f = 0$. However, at no point on the segment does $[0,1]$this function take values equal to these bounds.



Example 3. Let 's consider the function

$$f(x) = \begin{cases} \frac{1}{x}, & x \in (0,1] \\ 0, & x = 0 \end{cases}$$

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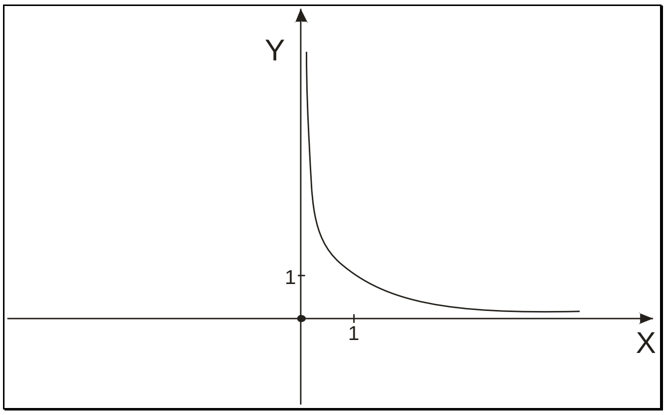
This function is bounded below by the number 0, and is not bounded above. This means that it is unbounded on the given segment.



Examples 1–2 show that the exact upper and lower bounds of a function on a segment are, generally speaking, not attainable.

Definition 8. If the inequality is true for any$x \in [a, b]$

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then the point $x_0$is called the point of global maximum of the function $f(x)$on the interval $[a, b]$.
The meaning $f(x_0)$is called the largest or maximum value of the function on this segment.

Definition 9. If the inequality is true for any$x \in [a, b]$

$$f(x) \geq f(x_0),$$

then the point $x_0$is called the point of the global minimum of the function $f(x)$on the segment $[a, b]$.

The meaning $f(x_0)$is called the smallest or minimum value of the function on this segment.

In other words, the greatest value of a function on a segment $[a, b]$is called the largest, and the least value is called the smallest of all its values on this segment.

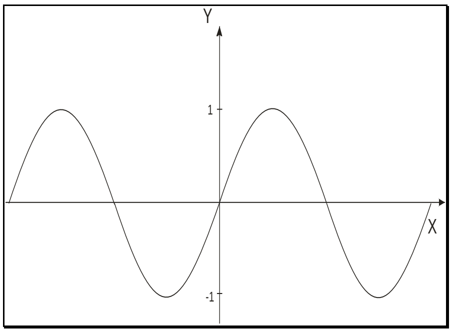
A function may have only one largest value or only one smallest value on a segment, or it may not have them at all.

Example 4. Let's consider the function

$$y = \sin x$$

On the segment $[-2\pi, 2\pi]$.

This function has a maximum value equal to one, which it reaches at points $x_1 = \frac{\pi}{2}, x_2 = -\frac{3\pi}{2}$and the smallest value equal to minus one, which it reaches at points $x_1 = -\frac{\pi}{2}, x_2 = \frac{3\pi}{2}$.

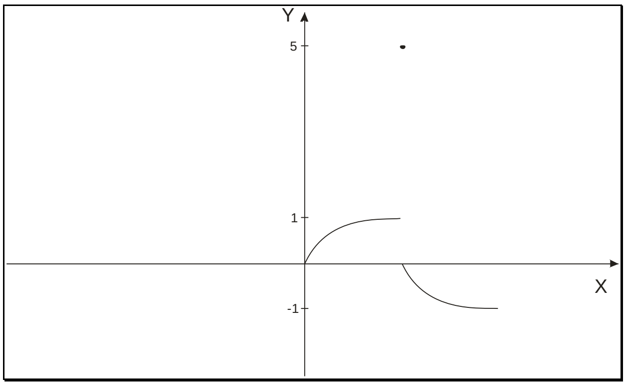


Example 5. Let 's consider the function

$$f(x) = \begin{cases} sinx, & x \in [0, \frac{\pi}{2}) \\ 5, & x = \frac{\pi}{2} \\ cosx, & x \in (\frac{\pi}{2}, \pi) \end{cases}$$

on the segment $[0, \pi]$.

The largest value of this function on the segment $[0, \frac{\pi}{2}]$is 5, which it reaches at the point $x_1 = \frac{\pi}{2}$, and the smallest value is -1, which it reaches at the point $x_2 = \pi$.



It is clear that if a function has the greatest value on a segment $[a, b]$, then it is equal to the least upper bound of this function on this segment. Similarly, if a function has the least value on a segment $[a, b]$, then it is equal to the least lower bound of this function on this segment. The converse statements do not always hold, i.e. the existence of least upper and least lower bounds does not, generally speaking, imply the existence of the greatest and least values of a function on a segment. (See examples 1–2).

Therefore, the question of finding the largest and smallest values of a function on a segment is reduced to the question: does the function reach its exact upper and lower bounds on this segment.

The basis for finding the largest and smallest values of a continuous function on a segment is the following:

Theorem 1. (Weierstrass's second theorem). If a function is continuous on a segment $[a, b]$, then it attains its exact upper and lower bounds on this segment.

Theorem 1 can be formulated as follows: a continuous function on a segment$[a, b]$ $y = f(x)$on this segment there are maximum and minimum values.

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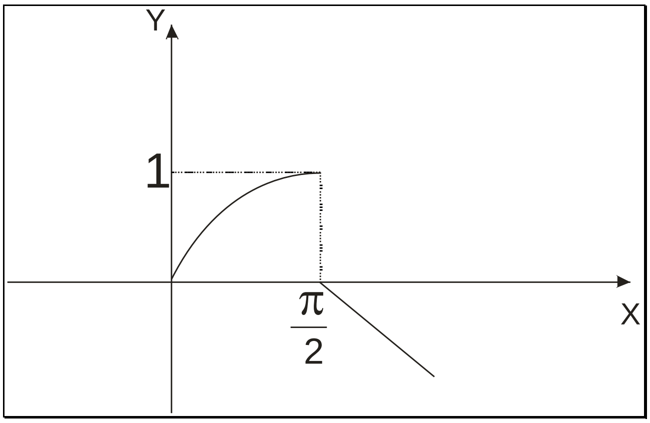

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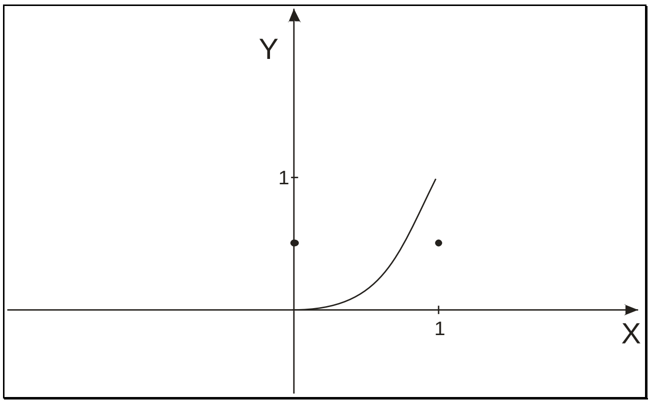

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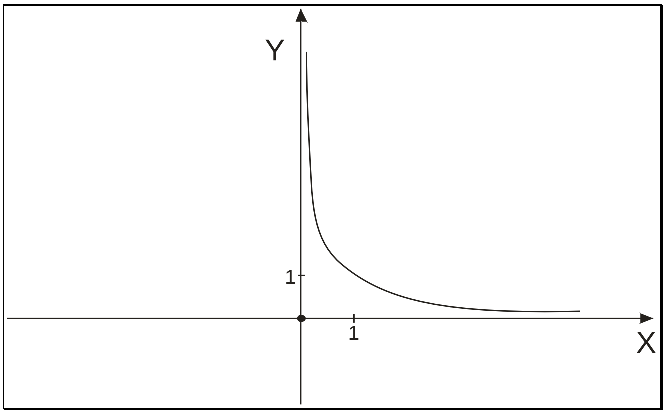

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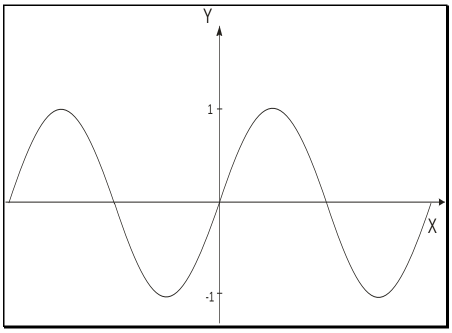

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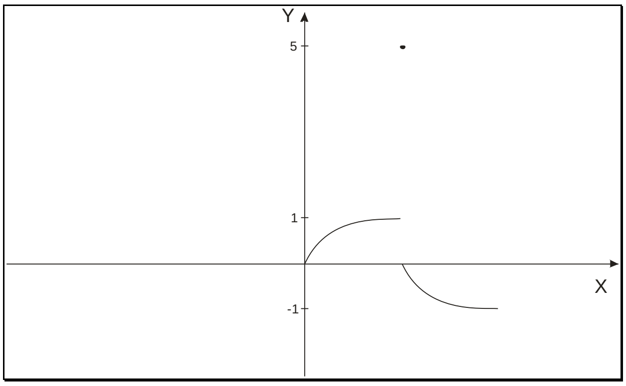

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Theorem 1 can be formulated as follows: a continuous function on a segment$[a, b]$ $y = f(x)$on this segment there are maximum and minimum values.

QUESTIONS AND TASKS FOR SELF-CHECKING

1. Definition of bounded and unbounded function.
2. The exact lower upper bound of a function.
3. Determination of global extremes.
4. Determine the smallest and largest values of the function on the given segments:

1.	$f(x) = x^4 - 8x^2 - 9, [-1; 1]$	6.	$f(x) = 2sinx + sin2x, [0; 2\pi]$
2.	$f(x) = \frac{x^2 + 4}{x}, [-4; -1]$	7.	$f(x) = x^2 + \frac{81}{x}, [1; 4]$

3. $f(x) = x^5 - 5x^3, [0; 2]$
4. $f(x) = \frac{x}{x+1}, [-3; -2]$
5. $f(x) = 2sinx + cos2x, [0; 2\pi]$
8. $f(x) = x + \frac{1}{x+2}, [-5; -2{,}5]$
9. $f(x) = \frac{1 - x + x^2}{1 + x - x^2}, [0; 1]$
10. $f(x) = x^5 - 5x^4 + 1, [-1; 2]$

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