Mathematics I - Functions 1

23/24

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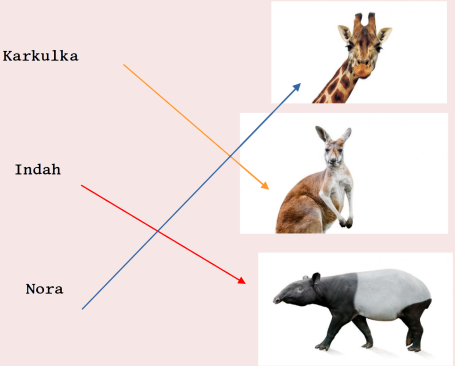

https://www.zoopraha.cz/zvirata-a-expozice/zvireci-osobnosti

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Example

- students in the classroom $\mapsto$ their date of birth
- f assigns rectangles their area
- countries $\rightarrow$ flag
- $x \mapsto \sqrt[4]{x}$, $f : [0, \infty) \rightarrow [0, \infty)$

Definition

Let $f\colon A \to B$ be a mapping.

- The subset $G_f = \{[x, y] \in A \times B;\ x \in A, y = f(x)\}$ of the Cartesian product $A \times B$ is called the graph of the mapping f.

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- The subset $G_f = \{[x, y] \in A \times B;\ x \in A, y = f(x)\}$ of the Cartesian product $A \times B$ is called the graph of the mapping f.
- The set $f(A)$ is called the range of the mapping f, it is denoted by R_f.

Exercise

Find the domain and range for the following mappings:

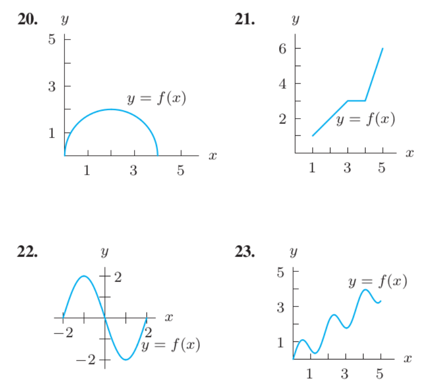

Figure: Calculus: Single and Multivariable, 6th Edition, Hughes-Hallett, col.

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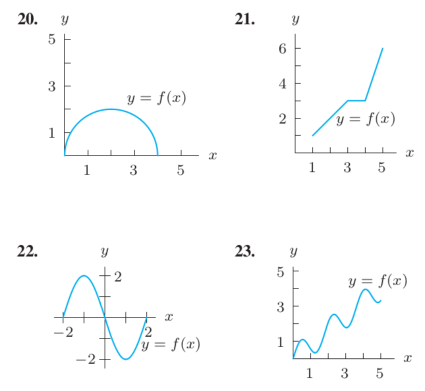

Figure: Calculus: Single and Multivariable, 6th Edition, Hughes-Hallett, col.

20. $[0, 4]$, $[0, 2]$
21. $[1, 5]$, $[1, 6]$
22. $[-2, 2]$, $[-2, 2]$
23. $[0, 5]$, $[0, 4]$

Exercise

Which of the following functions has its domain the same as its range?

A x^2 B $\sqrt{x}$ C x^3 D $|x|$ E $2x-3$

(Inspired by: Active Calculus & Mathematical Modeling, Carroll College Mathematics Department)

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B, C, E

Definition

Let $f: A \to B$ be a mapping.

- The image of the set $M \subset A$ under the mapping f is the set

$$f(M) = \{y \in B;\ \exists x \in M: f(x) = y\} \quad (= \{f(x);\ x \in M\}).$$

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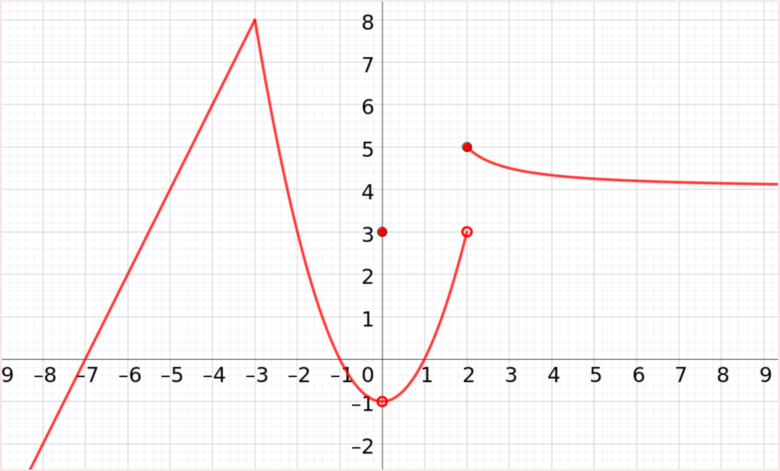
- The pre-image of the set $W \subset B$ under the mapping f is the set

$$f_{-1}(W) = \{x \in A;\ f(x) \in W\}.$$

Exercise

Find the image:

A $[-6, -2]$ B $[-1, 1)$ C $[0, 2)$ D $[2, \infty)$



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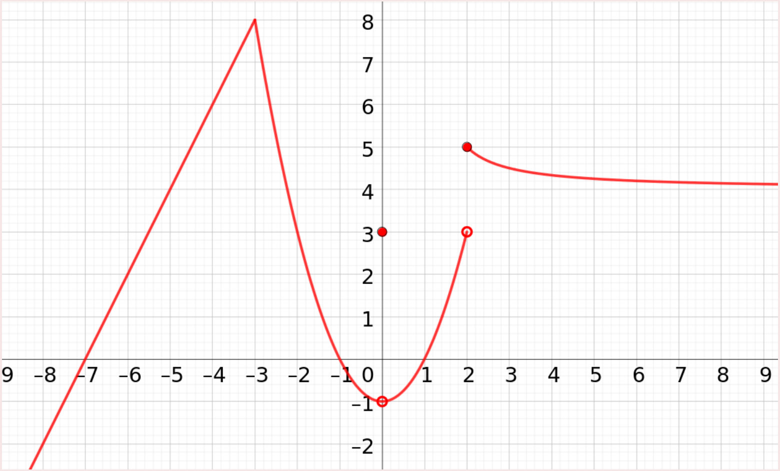
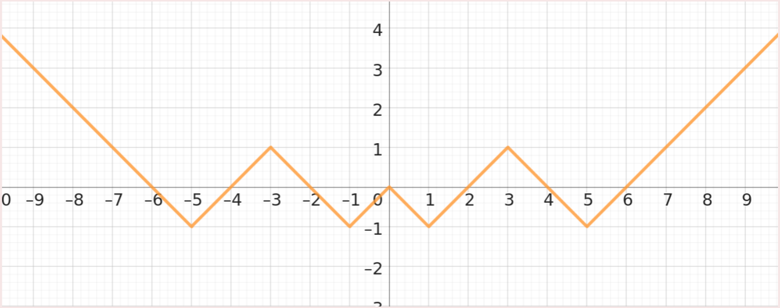


A $[2,8]$, B $(-1,0]\cup\{3\}$, C $(-1,3]$, D $(4,5]$.

Exercise

Find the preimage:

A $\{-1\}$ B $[2, 3]$ C $[0, 1]$ D $[0, 1)$



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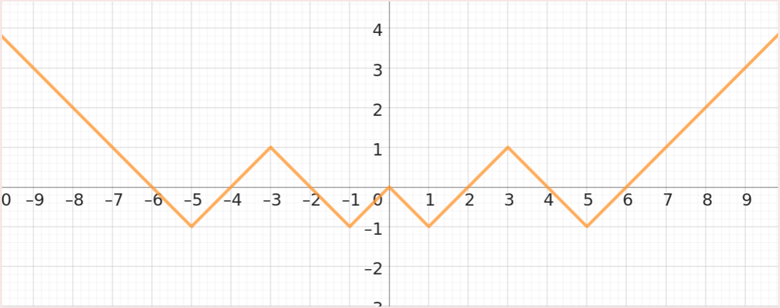


A $\{-5, -1, 1, 5\}$, B $[-9, -8] \cup [8, 9]$,
C $[-7, -6] \cup [-4, -2] \cup \{0\} \cup [2, 4] \cup [6, 7]$,
D $(-7, -6] \cup [-4, -3) \cup (-3, -2] \cup \{0\} \cup [2, 3) \cup (3, 4] \cup [6, 7)$

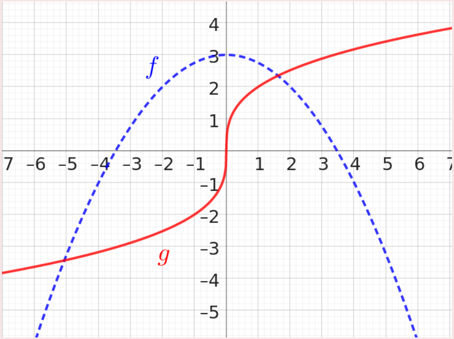
Definition

Let $f : A \to B$ and $g : B \to C$ be two mappings. The symbol $g \circ f$ denotes a mapping from A to C defined by

$$(g \circ f)(x) = g(f(x)).$$

This mapping is called a compound mapping or a composition of the mapping f and the mapping g.

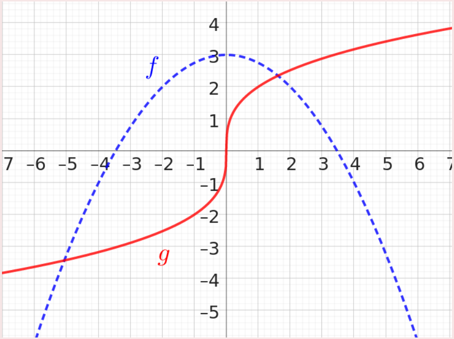
Exercise



Find $g(f(4))$.

A -2 B -1 C 0 D 1 E 2

Exercise



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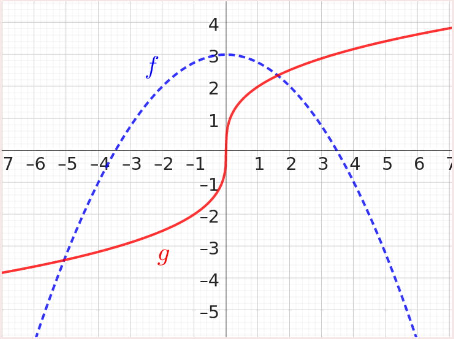

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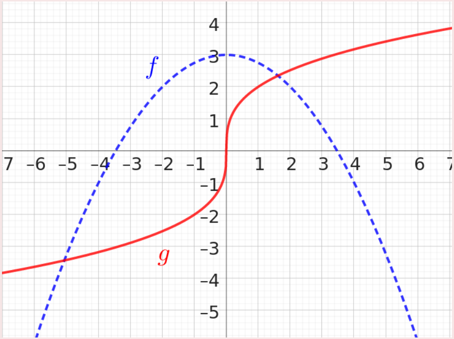
A -2   B -1   C 0   D 1   E 2

A

Find x, if $f(g(x)) = 2$.

Exercise



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B, D

Exercise

In the table we can find values of functions f and g.

x	-2	-1	0	1	2
$f(x)$	1	0	-2	2	-1
$g(x)$	-1	1	2	0	-2

Find $g(f(1))$.

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Find $g(f(1))$.

A -2 B -1 C 0 D 1 E 2

A

Find $f(f(0))$.

A -2 B -1 C 0 D 1 E 2

Exercise

In the table we can find values of functions f and g.

x	-2	-1	0	1	2
$f(x)$	1	0	-2	2	-1
$g(x)$	-1	1	2	0	-2

Find $g(f(1))$.

A -2 B -1 C 0 D 1 E 2

A

Find $f(f(0))$.

A -2 B -1 C 0 D 1 E 2

D

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In the table we can find values of functions f and g. If $f(g(x)) = -2$, find x.

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A -2   B -1   C 0   D 1   E 2

D

Definition

We say that a mapping $f : A \to B$

- maps the set A onto the set B if $f(A) = B$, i.e. if to each $y \in B$ there exist $x \in A$ such that $f(x) = y$;

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- is one-to-one (or injective) if images of different elements differ, i.e.

$$\forall x_1, x_2 \in A : x_1 \neq x_2 \Rightarrow f(x_1) \neq f(x_2),$$

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$$\forall x_1, x_2 \in A\colon x_1 \neq x_2 \Rightarrow f(x_1) \neq f(x_2),$$

- is a bijection of A onto B (or a bijective mapping), if it is at the same time one-to-one and maps A onto B.

Exercise

A e^x B x^3 C $\sin x$ D $\tan x$ E $\frac{1}{x}$

Which functions are onto $\mathbb{R}$?
Which functions are one-to-one?
Which functions are bijections?

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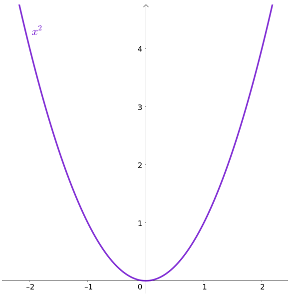
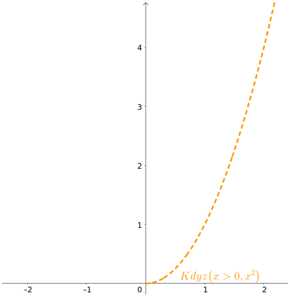
Which functions are onto $\mathbb{R}$?
Which functions are one-to-one?
Which functions are bijections?
B, D
A, B, E
B

Definition

Let A, B, C be sets, $C \subset A$ and $f : A \to B$. The mapping $\tilde{f} : C \to B$ given by the formula $\tilde{f}(x) = f(x)$ for each $x \in C$ is called the restriction of the mapping f to the set C. It is denoted by $f|_C$.





Definition

Let $f : A \to B$ be bijective (i.e. one-to-one and onto). An inverse mapping $f^{-1} : B \to A$ is a mapping that to each $y \in B$ assigns a (uniquely determined) element $x \in A$ satisfying $f(x) = y$.

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Exercise

Find inverse mappings at $\mathbb{R}$:

A e^x

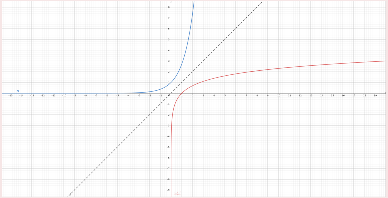
B $2x + 1$

C $\sqrt[3]{x}$

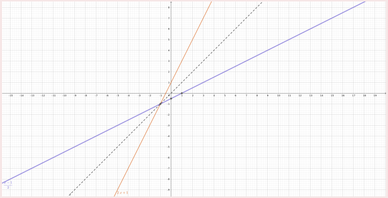
D x^2

Exercise

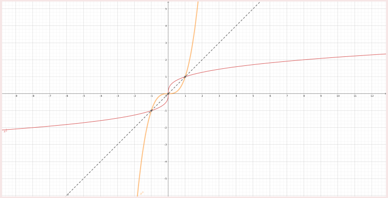
e^x vs $\log x$



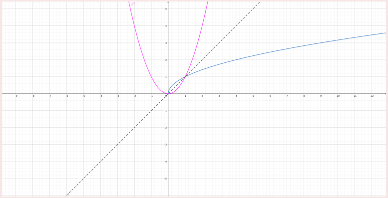
$2x + 1$ vs $\frac{x-1}{2}$



x^3 vs $\sqrt[3]{x}$



x^2 vs $\sqrt{x}$



IV. Functions of one real variable

Definition

A function f of one real variable (or a function for short) is a mapping $f : M \to \mathbb{R}$, where M is a subset of real numbers.

Definition

A function $f : J \to \mathbb{R}$ is increasing on an interval J, if for each pair $x_1, x_2 \in J$, $x_1 < x_2$ the inequality $f(x_1) < f(x_2)$ holds. Analogously we define a function decreasing (non-decreasing, non-increasing) on an interval J.

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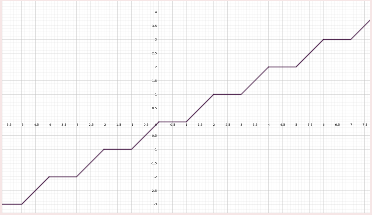
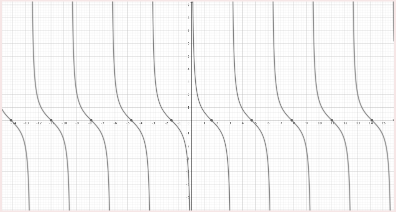
Definition

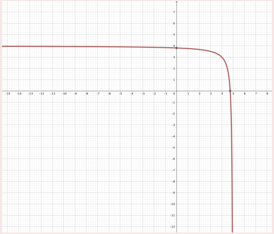
A monotone function on an interval J is a function which is non-decreasing or non-increasing on J. A strictly monotone function on an interval J is a function which is increasing or decreasing on J.

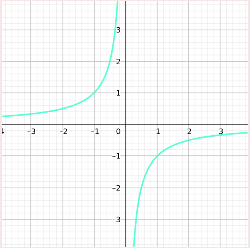
Exercise

Decide, which functions are monotone on its domain:









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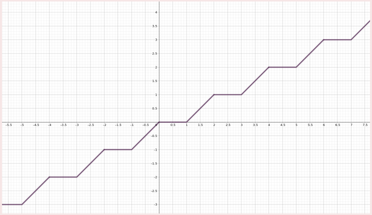

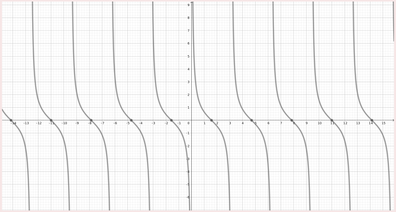

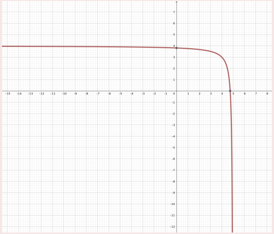

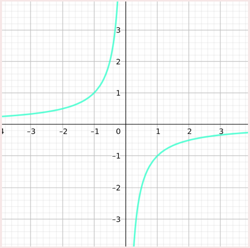

non-decreasing, nothing,
decreasing, nothing

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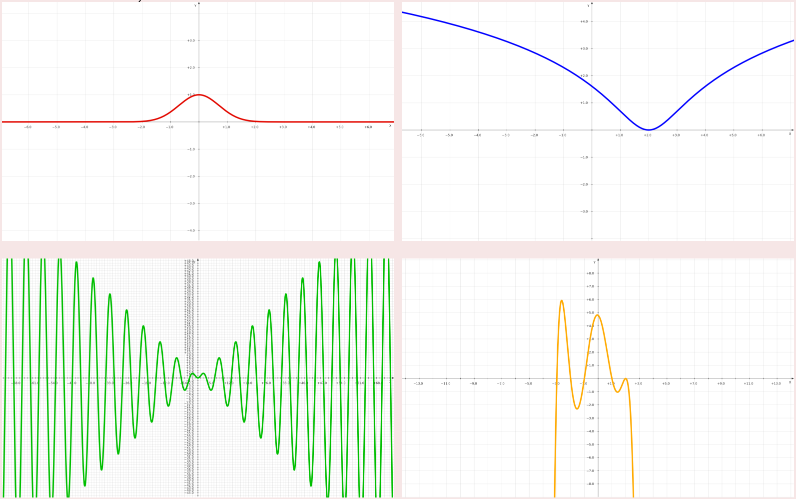
- bounded from below on M if there is $K \in \mathbb{R}$ such that $f(x) \geq K$ for all $x \in M$,
- bounded on M if there is $K \in \mathbb{R}$ such that $|f(x)| \leq K$ for all $x \in M$,

Exercise

Decide, which functions are bounded from above, bounded from below, bounded:



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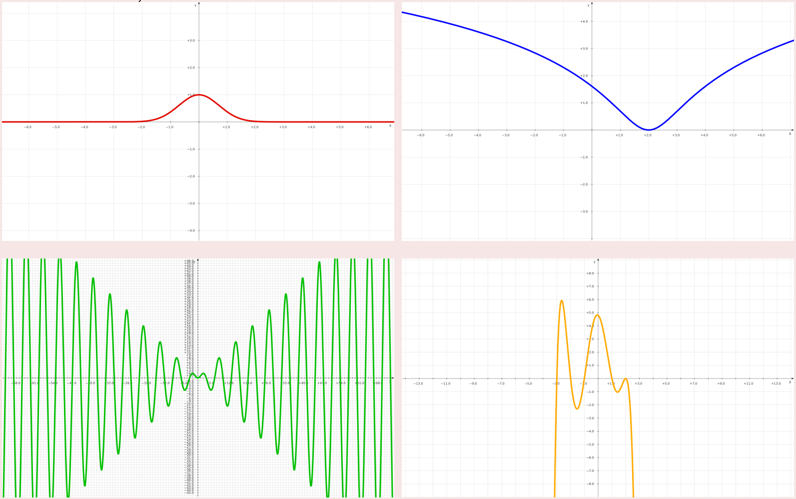

red: bounded, blue: bounded from below,
green: unbounded, yellow: bounded from above

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- odd if for each $x \in D_f$ we have $-x \in D_f$ and $f(-x) = -f(x)$,

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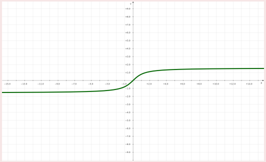
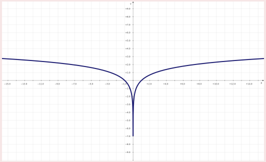
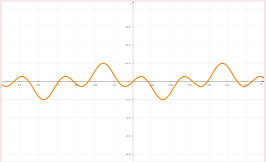
- even if for each $x \in D_f$ we have $-x \in D_f$ and $f(-x) = f(x)$,
- periodic with a period a, where $a \in \mathbb{R}$, $a > 0$, if for each $x \in D_f$ we have $x + a \in D_f$, $x - a \in D_f$ and $f(x + a) = f(x - a) = f(x)$.

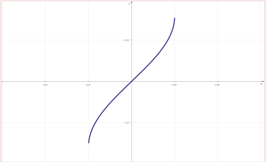
Exercise

Decide, which functions are even or odd:









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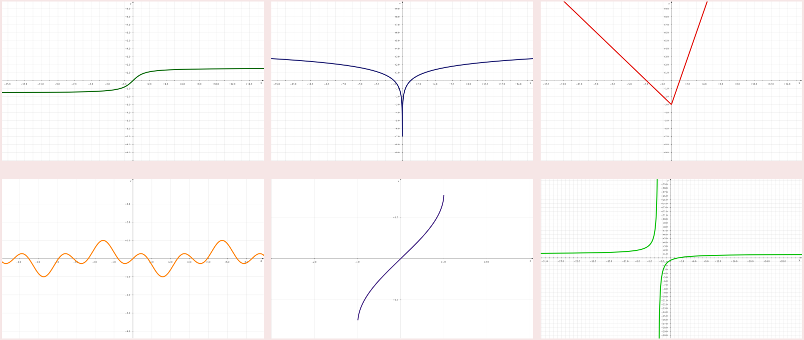

A odd, B even, D odd, E odd

Exercise

Decide, which functions are even or odd:

- A $x^3 + 1$
- B $x(x^2 + 1)$
- C $|x - 2|$
- D $e^{x^2} \sin x$
- E $|1 + \cos x|$

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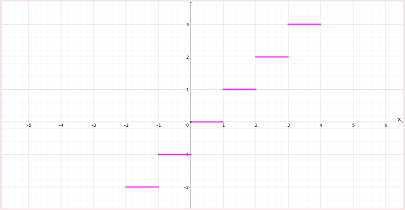
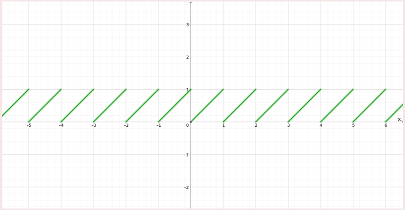
B odd, D odd, E even

Exercise

Decide, which functions are periodic





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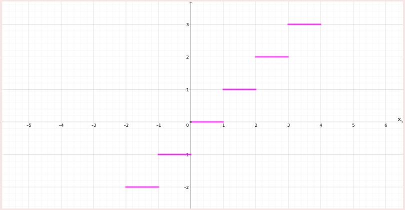
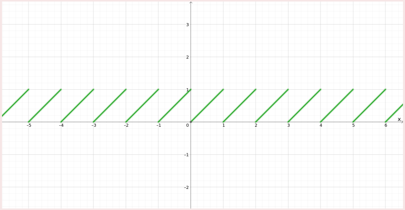
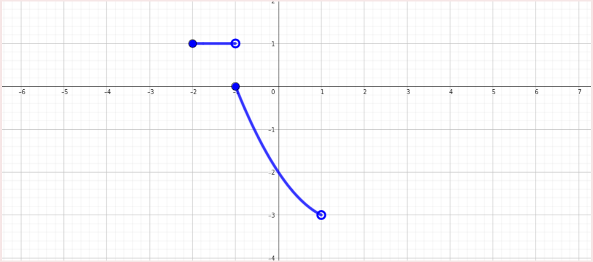




No, yes

Exercise

Sketch in the function so that it is periodic with the smallest possible period



Exercise

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