Surjections, Injections, ~~and Inverses~~

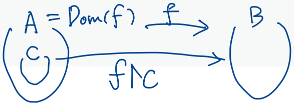
Office hours schedule change

(till the end of semester)

TW 4:45 ~ 6:15 pm

Restriction and Extension

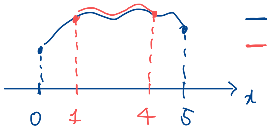
Restriction



Definition 1

Let f be a function and let $C \subseteq \mathrm{Dom}(f)$. Then *the restriction of f to C* is the function, denoted $f\restriction C$, defined by $(f\restriction C)(x) = f(x)$ for all $x \in C$.

- Note that $\mathrm{Dom}(f\restriction C) = C$.



— $f : [0,5] \to \mathbb{R}$

— $g : [1,4] \to \mathbb{R}$

$g(x) = f(x)$ for all $x \in [1,4]$

So $g = f\restriction[1,4]$.

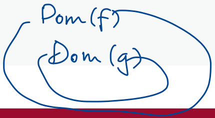
Examples.

- Let $f(x) = x^{1/3}$ for all $x \in \mathbb{R}$ and let $g(x) = x^{1/3}$ for all $x \in [1,5)$. Then $g = f\restriction[1,5)$.
- Let $f(x) = \sqrt{x}$ for all $x \in [0,\infty)$, $g(x) = 1 - x^2$ for all $x \in \mathbb{R}$, and $h(x) = 1 - x$ for all $x \in \mathbb{R}$. Then $g \circ f = h\restriction[0,\infty)$.

$(g\circ f)(x) = g(f(x))$
$= g(\sqrt{x})$
$= 1 - \sqrt{x}^2 = 1 - x$

$\mathrm{Dom}(g\circ f) = \{x \in \mathrm{Dom}(f) : f(x) \in \mathrm{Dom}(g)\}$
$= \{x \in [0,\infty) : \sqrt{x} \in \mathbb{R}\} = [0,\infty)$

Extension



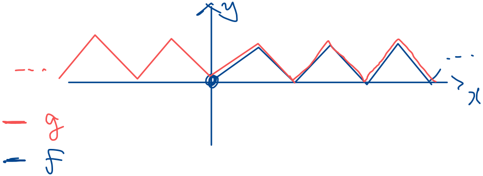
Definition 2

Let f and g be functions. To say that f *is an extension of* g means that $\mathrm{Dom}(f) \supseteq \mathrm{Dom}(g)$ and for each $x \in \mathrm{Dom}(g)$, $f(x) = g(x)$.

- Note f is an extension of g iff $\mathrm{Dom}(f) \supseteq \mathrm{Dom}(g)$ and $f \restriction \mathrm{Dom}(g) = g$.

- Example. (Even or odd periodic extensions)

Let $f : [0, \infty) \to \mathbb{R}$ whose graph is as shown below



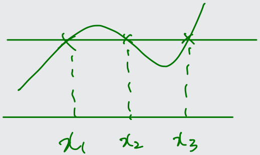
Now let $g : \mathbb{R} \to \mathbb{R}$ defined by

$$g(x) = \begin{cases} f(x) & \text{for } x \geq 0 \\ f(-x) & \text{for } x < 0. \end{cases}$$

Note: $\mathrm{Dom}(g) = \mathbb{R} \supseteq [0, \infty) = \mathrm{Dom}(f)$ and

$f(x) = g(x)$ for each $x \in [0, \infty)$.

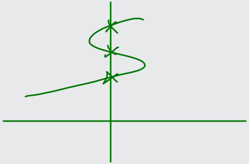
Thus g is an extension of f.



Horiz. line test

- one-to-one
- horizontal line test
- one-to-one

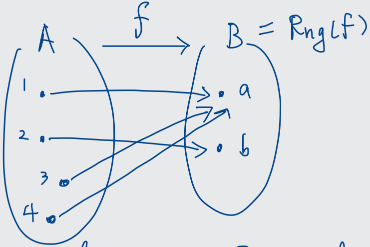
$\longrightarrow$ inverse



Vert. line test

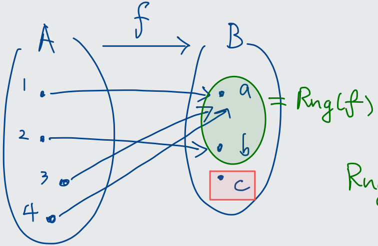
Surjections, Injections, and Inverses

<u>f is a surjection from A to B</u>



Every single element in B is realized as a function value.

<u>f is not a surjection from A to B</u>



$\text{Rng}(f) \subsetneq B$

c doesn't get any pick!

Surjections

Definition 3

Let A and B be sets. To say that *f is a surjection from A to B* means that f is a function from A to B and for each $y \in B$, there exists $x \in A$ such that $f(x) = y$.

$(\forall y \in B)(\exists x \in A)(f(x) = y)$

at least one!

Notes.

- A surjection from A to B is also said to be a function from A *onto* B.
- Any function is a surjection from its domain to its range.
- f is a surjection from A to B

  iff f is a function, $\mathrm{Dom}(f) = A$, and $\mathrm{Rng}(f) = B$

  iff for each $y \in B$, the equation $f(x) = y$ has at least one solution x in A.

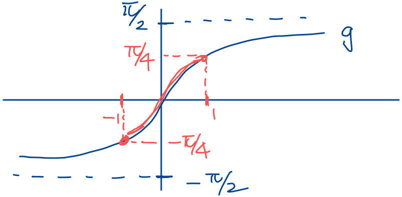
Surjections (cont')

Example 4

- Let $f(x) = \sin(x)$ for all $x \in \mathbb{R}$. Then f is a surjection from $\mathbb{R}$ to $[-1, 1]$, but f is not a surjection from $\mathbb{R}$ to $\mathbb{R}$.
- Let $g(x) = \arctan(x)$ for all $x \in \mathbb{R}$. Then f is a surjection from $\mathbb{R}$ to $(-\pi/2, \pi/2)$.

Q. $g \restriction [-1, 1]$ is a surjection from $\underline{[-1, 1]}$ to $\underline{[-\pi/4, \pi/4]}$.

$\mathrm{Rng}(g \restriction [-1,1])$



Injections

Definition 5

To say that f *is an injection* means that f is a function and for all $x_1, x_2 \in \mathrm{Dom}(f)$, if $f(x_1) = f(x_2)$, then $x_1 = x_2$.

$(\forall x_1, x_2 \in \mathrm{Dom}(f))[f(x_1) = f(x_2) \Rightarrow x_1 = x_2] \equiv (\forall x_1, x_2 \in \mathrm{Dom}(f))[x_1 \neq x_2 \Rightarrow f(x_1) \neq f(x_2)]$

Note.

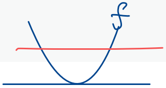
- To say that f *is an injection from A to B* means that f is a function from A to B and f is an injection.
- An injection is also said to be a *one-to-one* function.
- f is an injection from A to B

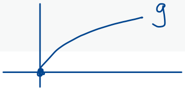
  iff for each $y \in B$, the equation $f(x) = y$ has *at most* one solution x in A

  iff for all $x_1, x_2 \in A$, if $x_1 \neq x_2$, then $f(x_1) \neq f(x_2)$.

cf) Surj. : "at least"

Injections (cont')





Example 6

Let $f(x) = x^2$ for all $x \in \mathbb{R}$ and let $g(x) = \sqrt{x}$ for all $x \in [0, \infty)$. Then:

- f is not an injection from $\mathbb{R}$ to $[0, \infty)$ because

  $$f(2) = 4 = f(-2).$$

- g is an injection from $[0, \infty)$ to $[0, \infty)$ because

  Let $x_1, x_2 \in [0, \infty)$. Suppose that $g(x_1) = g(x_2)$.

  Then

  $$\sqrt{x_1} = \sqrt{x_2}$$

  $$\sqrt{x_1}^2 = \sqrt{x_2}^2$$

  $$x_1 = x_2.$$

  Thus g is an injection. $\square$