

## Practice with quantifiers!

(1) In this problem you will put “ $((\neg((\forall x)(x = 0))) \wedge (\neg((\forall x)(x \neq 0))))$ ” in prenex form.

(a) Draw a formula tree for the statement.

(b) Standardize the variables apart.

(c) Put in prenex form.

(2) Determine the truth of the statement in the previous problem in  $\mathbb{R}$  by giving a winning strategy for the appropriate quantifier.

(3) Let  $f : A \rightarrow B$  be a function, and consider the structure  $\langle A, B; f \rangle$ . Write down a formal sentence, that is meaningful for this structure, and which expresses “ $f$  is a surjective function”.

- (4) For each of the following instances of the previous problem, give a winning strategy for the appropriate quantifier:

(a)  $A = B = \mathbb{R}, f(x) = x^3$ .

(b)  $A = B = \mathbb{R}, f(x) = e^x$ .

- (5) Write “ $(\forall x)(\forall y)((x < y) \rightarrow (\exists z)(x < z < y))$ ” in prenex form. Is the resulting sentence true in  $\mathbb{R}$ ? in  $\mathbb{N}$ ?

- (6) Write the following in prenex form.

(a) The Axiom of Extensionality.

(b) The Axiom of Pairing.

(c) The Axiom of Union.

- (7) Is  $(\forall a)(\exists b)(\forall c)(\exists d)(a^2 + b^2 = c^2 + d^2)$  true in  $\mathbb{R}$ ? in  $\mathbb{C}$ ? For each structure, give a winning strategy for the appropriate quantifier.