

True or False?

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2) If $D = \mathbb{Q}$ then is the statement is true? Yes. Take $z = \frac{x+y}{2}$.

Find Domains such that ...

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Give a domain where this is F. \mathbb{Z} since, $\forall x, x - 1 < x$.

Expressing Math With Quantifiers

Expressing Properties of Numbers: EVEN

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$$\text{EVEN}(x) \equiv (\exists y)[x = 2y]$$

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$$\text{ONEFIVE}(x) \equiv (\exists y)[x = 5y + 1]$$

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NAH, we want -7 to be a prime.

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$$\text{PRIME}(x) \equiv (x \notin \{0, 1, -1\}) \wedge (\forall y, z)[x = yz \rightarrow (y = \pm 1) \vee (z = \pm 1)]$$

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$$7 = i \times -i \times 7.$$

We don't really want to count the i and $-i$.

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Def Let D be a domain. The **units of D** are the elements of D that have a multiplicative inverse.

The Unit are the exceptions. If $x \in D$, u is a unit, and v is its inverse, then

$$x = uvx$$

We don't want to say x is not prime. u, v should not matter!

Units and Primes

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$$\text{PRIME}(x) \equiv$$

$$(x \neq 0, x \notin \text{UNIT}) \wedge (\forall y, z)[x = yz \rightarrow ((y \in \text{UNIT}) \vee (z \in \text{UNIT}))].$$

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3) Let $\text{ONEFOUR} = \{n : n \equiv 1 \pmod{4}\}$. The only unit is 1.

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What are the primes in ONEFOUR? **Work in Groups**

Primes in ONEFOUR

Elements of ONEFOUR: 1, 5, 9, 13, 17, 21, 25. We stop here.

1: a unit

5: a prime

9: a prime! Note that $3 \notin \text{ONEFOUR}$ so cannot say $9 = 3 \times 3$.

13,17: Primes

21: a prime!

25: 5×5 are first composite.

Expressing Theorems: Four-Square Theorem

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$$(\forall x)(\exists x_1, x_2, x_3, x_4)[x = x_1^2 + x_2^2 + x_3^2 + x_4^2]$$

Expressing Statements: Goldbach's Conjecture

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$$(\exists x)(\forall y > x)$$

$$[\text{EVEN}(y) \rightarrow (\exists y_1, y_2)[\text{PRIME}(y_1) \wedge \text{PRIME}(y_2) \wedge (y = y_1 + y_2)]]$$

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$$[ODD(y) \rightarrow$$

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Note that using $\neg(\exists x, y) \equiv (\forall x, y)\neg$ ended up not having a \neg in the final expression.

Order Notation

Sometimes We Don't Care About Constants

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BILL: What are c, d, e ?

LEO: Who freakin cares! I solved SAT without using brute force and you are concerned with the constants!

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Once we have exhausted all of our tricks to get it into (say) roughly n^2 time we THEN would do things to get the constant down, perhaps non-rigorous things.

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We leave it to the reader to prove that

$$18n^3 + 8n^2 + 12n + 1000 = O(n^3)$$

by finding the values of n_0, c, d .

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You will see $O()$ a lot in CMSC 351 and 451 when you deal with algorithms and want to bound the run time, roughly.

Other Ways to Use $O()$

$f \in n^{O(1)}$ means poly time.

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$f \in 2^{O(n)}$ means 2^{cn} for some c , and after some n_0 .

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This notation is used to express that an algorithm **requires** some amount of time.

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You would still get the \$1,000,000.