Prime Factorization

Fundamental Thm. of Arithmetic

Every integer > 1 factors uniquely into a weakly decreasing sequence of primes

Unique Prime Factorization

Example:

$$61394323221 =$$
$$53 \cdot 37 \cdot 37 \cdot 37 \cdot 11 \cdot 11 \cdot 7 \cdot 3 \cdot 3 \cdot 3$$

Prime Divisibility

Lemma: p prime and $p \mid ab$ implies $p|a$ or $p|b$

pf: say not($p|a$), so $\gcd(p,a) = 1$

so, $\underbrace{sab}_{p|} + \underbrace{tpb}_{p|} = \underbrace{1\,b}_{\text{so } p|}$

QED

Prime Divisibility

Cor: If p is prime, and

$$p \mid a_1 \cdot a_2 \cdot \cdots \cdot a_m$$

then $p \mid a_i$ for some i.

pf: by induction on m.

Unique Prime Factorization

Every integer $n > 1$ has a **unique** factorization into primes: $p_1 \cdot \cdots \cdot p_k = n$

with $p_1 \geq p_2 \geq \cdots \geq p_k$

Unique Prime Factorization

pf: suppose not. choose smallest $n > 1$:

$$n = p_1 \cdot p_2 \cdots p_k = q_1 \cdot q_2 \cdots q_m$$

$$p_1 \geq p_2 \geq \cdots \geq p_k$$

$$q_1 \geq q_2 \geq \cdots \geq q_m$$

If $q_1 = p_1$, then $p_2 \cdots p_k = q_2 \cdots q_m$ is smaller nonunique.

Unique Prime Factorization

pf: suppose not. choose smallest $n > 1$:

$$n = p_1 \cdot p_2 \cdots p_k = q_1 \cdot q_2 \cdots q_m$$

$$p_1 \geq p_2 \geq \cdots \geq p_k$$

$$q_1 \geq q_2 \geq \cdots \geq q_m$$

So can assume $q_1 > p_1 \geq p_i$

Unique Prime Factorization

pf: but $q_1 | n = p_1 \cdot p_2 \cdots p_k$

so $q_1 | p_i$ for some i by Cor,

contradicting that $q_1 > p_i$

QED

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