

Rosen, Discrete Mathematics and Its Applications, 6th edition  
Extra Examples

Section 3.5—Primes and Greatest Common Divisors



— Page references correspond to locations of Extra Examples icons in the textbook.

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**p.211, icon at Example 2**

#1. Find the prime factorization of:

- (a) 487.
- (b) 6600.

**Solution:**

(a) If we try to divide 487 by all primes from 2 to  $\lfloor \sqrt{487} \rfloor = 22$  (that is, 2, 3, 5, 7, 11, 13, 17, 19), we find that none of these divides 487 without a remainder. Therefore 487 is prime.

(b) Begin by writing 6600 as any product of smaller positive factors, such as  $6600 = 66 \cdot 100$ . We continue this process until only primes are obtained:

$$\begin{aligned} 6600 &= 66 \cdot 100 \\ &= (6 \cdot 11)(10 \cdot 10) \\ &= (2 \cdot 3 \cdot 11) \cdot (2 \cdot 5 \cdot 2 \cdot 5) \\ &= 2^3 \cdot 3 \cdot 5^2 \cdot 11. \end{aligned}$$

If we initially factor 6600 in a different way, such as  $6 \cdot 1100$ , we would still arrive at the same product of prime factors.

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**p.214, icon at Example 6**

#1. Suppose the odd primes 3, 5, 7, 11, 13, 17, ... in order of increasing size are  $p_1, p_2, p_3, \dots$ . Prove or disprove:

$$p_1 p_2 p_3 \dots p_k + 2 \text{ is prime, for all } k \geq 1.$$

**Solution:**

We begin by trying a few cases. Hopefully we will either get an idea of how to prove the result, or we will find a counterexample.

$$\begin{aligned} 3 + 2 &= 5 \\ 3 \cdot 5 + 2 &= 17 \\ 3 \cdot 5 \cdot 7 + 2 &= 107 \\ 3 \cdot 5 \cdot 7 \cdot 11 + 2 &= 1,157 \\ 3 \cdot 5 \cdot 7 \cdot 11 \cdot 13 + 2 &= 15,017 \\ 3 \cdot 5 \cdot 7 \cdot 11 \cdot 13 \cdot 17 + 2 &= 255,257. \end{aligned}$$

We stop at this step because the number 255,257 is not prime; it can be factored as  $47 \cdot 5,431$ . Therefore we have a counterexample to the statement that  $p_1 p_2 p_3 \dots p_k + 2$  is always prime.

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**p.214, icon at Example 6**

**#2.** Suppose the odd primes 3, 5, 7, 11, 13, 17, ... in order of increasing size are  $p_1, p_2, p_3, \dots$ . Prove or disprove:

$$p_i p_{i+1} + 2 \text{ is prime, for all } i \geq 1.$$

**Solution:**

We begin by trying a few cases. Hopefully we will either get an idea of how to prove the result, or we will find a counterexample.

$$\begin{aligned} 3 \cdot 5 + 2 &= 17 \\ 5 \cdot 7 + 2 &= 37 \\ 7 \cdot 11 + 2 &= 79 \\ 11 \cdot 13 + 2 &= 145. \end{aligned}$$

We stop here because 145 is not prime. The number 145 is a counterexample. Therefore the original statement is false.

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**p.214, icon at Example 6**

**#3.** (Problem A1 from the 1989 William Lowell Putnam Mathematics Competition.) Consider the sequence of integers (in base 10): 101, 10101, 1010101, 101010101, 10101010101, ... Prove that 101 is the only number in this sequence that is prime. (*Hint:* Use place value to write each number in terms of the sum of its digits; for example,  $abcde = a10^4 + b10^3 + c10^2 + d10 + e$ . Then examine how the sum might be factored.)

**Solution:**

It is easily checked that 101 is prime. Given any number of the form 10101...01 greater than 101, write the number in terms of its digits. Then there is an integer  $n \geq 2$  such that

$$\begin{aligned} 10101 \dots 01 &= 10^{2n} + 10^{2n-2} + \dots + 10^4 + 10^2 + 1 && \text{(this is a geometric series)} \\ &= \frac{10^{2n+2} - 1}{99} && \text{(the geometric series has this sum)} \\ &= \frac{(10^{n+1})^2 - 1}{99} && \text{(by the law of exponents } a^{bc} = (a^b)^c \text{)} \\ &= \frac{(10^{n+1}-1)(10^{n+1} + 1)}{99} && (10^{n-1}-1 \text{ is an integer of the form } 999 \dots 9, \text{ which is} \\ & && \text{divisible by 9)} \\ &= \frac{a_n(10^{n+1} + 1)}{11}, \end{aligned}$$

where  $a_n$  is the integer that is a string of  $n + 1$  1's. The reader can verify that if  $n$  is odd, then  $11|a_n$ , and if  $n$  is even, then  $11|(10^{n+1} + 1)$ . In either case, 10101...01 is a product of two integers, each greater than 1. Therefore 10101...01 is not prime if  $n > 1$ .

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