

# Abstract Algebra: An Introduction, 3rd

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## Chapter 1

### Arithmetic in $\mathbb{Z}$ Revisited

#### 1.1 The Division Algorithm

- $q = 4, r = 1.$
  - $q = 0, r = 0.$
  - $q = -5, r = 3.$
- $q = -9, r = 3.$
  - $q = 15, r = 17.$
  - $q = 117, r = 11.$
- $q = 6, r = 19.$
  - $q = -9, r = 54.$
  - $q = 62720, r = 92.$
- $q = 15021, r = 132.$
  - $q = -14940, r = 335.$
  - $q = 39763, r = 3997.$
- Suppose  $a = bq + r$ , with  $0 \leq r < b$ . Multiplying this equation through by  $c$  gives  $ac = (bc)q + rc$ . Further, since  $0 \leq r < b$ , it follows that  $0 \leq rc < bc$ . Thus this equation expresses  $ac$  as a multiple of  $bc$  plus a remainder between 0 and  $bc - 1$ . Since by Theorem 1.1 this representation is unique, it must be that  $q$  is the quotient and  $rc$  the remainder on dividing  $ac$  by  $bc$ .
- When  $q$  is divided by  $c$ , the quotient is  $k$ , so that  $q = ck$ . Thus  $a = bq + r = b(ck) + r = (bc)k + r$ . Further, since  $0 \leq r < b$ , it follows (since  $c \geq 1$ ) that  $0 \leq r < bc$ . Thus  $a = (bc)k + r$  is the unique representation with  $0 \leq r < bc$ , so that the quotient is indeed  $k$ .
- Answered in the text.
- Any integer  $n$  can be divided by 4 with remainder  $r$  equal to 0, 1, 2 or 3. Then either  $n = 4k$ ,  $4k + 1$ ,  $4k + 2$  or  $4k + 3$ , where  $k$  is the quotient. If  $n = 4k$  or  $4k + 2$  then  $n$  is even. Therefore if  $n$  is odd then  $n = 4k + 1$  or  $4k + 3$ .
- We know that every integer  $a$  is of the form  $3q$ ,  $3q + 1$  or  $3q + 2$  for some  $q$ . In the last case  $a^2 = (3q + 2)^2 = 9q^2 + 12q + 4 = 3(3q^2 + 4q + 1) + 1$ . Other cases are similar.
- Suppose  $a = bq + r$  where  $0 \leq r < a$  and  $c = bq' + r'$  where  $0 \leq r' < a$ . If  $r = r'$  then  $a - c = b(q - q')$  and  $k = q - q'$  is an integer. Conversely, given  $a - c = ak$  we can substitute to find:  $(r - r') = a(k - q + q')$ . Suppose  $r \geq r'$  (the other case is similar). The given inequalities imply that  $0 \leq (r - r') < a$  and it follows that  $a(k - q + q') < 1$  and we conclude that  $k - q + q' = 0$ . Therefore  $r = r' = 0$ , so that  $r = r'$  as claimed.

# Manual Abstract Algebra Hungerford

**CH Cherryholmes**



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