

# Solutions to Problems in Abstract Algebra by Dummit and Foote (Chapter 1)

Isaac Dobes

## 1

### 1.1

#### 1.1.1

(a)  $*$  defined on  $\mathbb{Z}$  as  $a * b = a - b$  is not associative since  $(a - b) - c = [a + (-b)] - c = [a + (-b)] + (-c) = a + [(-b) + (-c)] = a + [-1(b + c)] = a - (b + c)$ ; in general  $a - (b + c) \neq a - (b - c)$ ; e.g.,  $1 - (1 + 1) = -1 \neq 1 = 1 - (1 - 1)$

(b)  $*$  defined on  $\mathbb{R}$  as  $a * b = a + b + ab$  is associative. Observe that

$$(a * b) * c = (a + b + ab) * c = (a + b + ab) + c + (a + b + ab)c = a + b + c + ab + ac + bc + abc$$

and

$$a * (b * c) = a * (b + c + bc) = a + (b + c + bc) + a(b + c + bc) = a + b + c + ab + ac + bc + abc$$

Therefore,  $(a * b) * c = a * (b * c)$ .

(c)  $*$  defined on  $\mathbb{Q}$  as  $a * b = \frac{a+b}{5}$  is not associative. Observe that

$$(a * b) * c = \left(\frac{a+b}{5}\right) * c = \frac{\frac{a+b}{5} + c}{5} = \frac{a+b+5c}{25}$$

and

$$a * (b * c) = a * \left(\frac{b+c}{5}\right) = \frac{a + \frac{b+c}{5}}{5} = \frac{5a+b+c}{25}$$

In general,  $\frac{a+b+5c}{25} \neq \frac{5a+b+c}{25}$ ; e.g., if  $a = 1$ ,  $b = 0$ , and  $c = -1$ , then  $(a * b) * c = -\frac{1}{25} \neq \frac{1}{25} = a * (b * c)$ .

(d)  $*$  defined on  $\mathbb{Z} \times \mathbb{Z}$  as  $(a, b) * (c, d) = (ad + bc, bd)$  is associative, but it is tedious to verify and thus proof of fact is omitted.

(e)  $*$  defined on  $\mathbb{Q} \setminus \{0\}$  as  $a * b = \frac{a}{b}$  is not associative. Observe that

$$(a * b) * c = \left(\frac{a}{b}\right) * c = \frac{\frac{a}{b}}{c}$$

and

$$a * (b * c) = a * \left(\frac{b}{c}\right) = \frac{a}{\frac{b}{c}}$$

In general,  $\frac{\frac{a}{b}}{c} \neq \frac{a}{\frac{b}{c}}$ ; e.g.,  $(1 * 2) * 3 = \left(\frac{1}{2}\right) * \frac{1}{3} = \frac{1}{6}$ , but  $1 * (2 * 3) = 1 * \left(\frac{2}{3}\right) = \frac{3}{2} \neq \frac{1}{6}$ .

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