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Contributing Authors: Alan R. Taylor, Ed.D. & Bill Kokoskin, M.A.

Dear Parents,

Helping kids understand and apply mathematics knowledge and skills is a collective responsibility of parents, teachers, and principals.

Students need to learn mathematics in a way that will serve them throughout their lives. Understanding mathematics can provide our students with many job and career opportunities.

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Ontario Grade 9 Principles of Mathematics
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$\frac{3}{7}$ π -15.2 2^3 $\sqrt{7}$

CHAPTER 1

NUMBER CONCEPTS

1.1 The Real Number System

1.2 Square Root of a Number

1.3 Powers, Bases and Coefficients

1.4 Laws of Exponents

$\left(\frac{2}{3}\right)^4$ $9.23251...$ 0.221 $11\frac{2}{3}$ 10.01

1.1 The Real Number System

The system of **real numbers** that we use in our everyday lives consists of a collection of smaller sets of numbers that has evolved over several centuries. It began with numbers used to count objects, used for trading and other commercial purposes. As a need for numbers to represent parts of objects and locations on the number line became important, it was extended and refined. A discussion of the sets of numbers that comprise the real number system is next. Each of these sets of numbers builds on those contained in the preceding set.

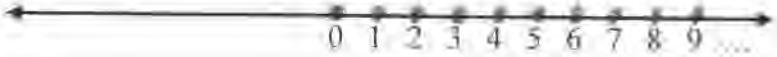
Natural Numbers

Natural numbers can be thought of as counting numbers. They can be used to identify how many objects are contained in a collection. Since a collection of objects has at least one item in it, the natural numbers begin with the number 1 and proceed to represent additional objects in the set. Counting numbers can be listed as follows: 1, 2, 3, 4, 5, 6, 7, 8, …

Whole Numbers

Whole numbers consist of the natural numbers with the addition of the number 0. Although 0 does not represent an object in a set, it is an important addition to the number system. Whole numbers can be listed as follows: 0, 1, 2, 3, 4, 5, 6, 7, 8, …

Whole numbers correspond to locations on the number line as follows:



Integers

The set of **integers** builds on the set of whole numbers by adding the negative values. As a result, it includes numbers such as -1, -2, -3, -4, -5, … Note: There is no negative value for 0.

Negative values of whole numbers are used in many situations, such as to represent a minus temperature (-22° C), distance below sea level (-8 m below the sea), or a golf score that is under par (-4 strokes under par).

Integers correspond to locations on the number line as follows:

Rational Numbers

The next extension to our number system is the set of **rational numbers**. By including these numbers, we can begin to look at parts of the counting objects discussed earlier (one-half of an item or quantity, one quarter of a degree in temperature). A **rational number** is any number that can be written in the form $\frac{a}{b}$ where a and b are integers and b $\neq 0$.

Rational numbers includes the natural numbers (1, 2, 3, …), the whole numbers (0, 1, 2, 3, …), and the integers (-3, –2, -1, 0, 1, 2, 3 …). Natural, whole, and integer numbers are rational since each can be written in the form $\frac{a}{b}$ ($1 = \frac{2}{2}$, $-3 = \frac{-3}{1}$, $0 = \frac{0}{4}$).

Examples of Rational Numbers:

All fractions and mixed numbers, both positive and negative.

$\frac{2}{3}, \frac{-3}{4}, \frac{5}{2}, -3\frac{1}{4}$

$\frac{0}{7} = 0$ is rational, but $\frac{7}{0}$ is **not rational** since it is not defined when the denominator equals 0.

All integers

–11, -3, 0, 1, 5, 68

All terminating and repeating decimals, both positive and negative

0.8, -0.32, $0.33\overline{3}$, $7.12\overline{12}$

The set of rational numbers begins to fill in many locations on the number line. However, there still remain locations that do not have corresponding numbers associated with them.

Irrational Numbers

To complete our system of real numbers, it is necessary to add an additional set. These additional numbers are called **irrational numbers**. Irrational numbers are any numbers that cannot be written as the quotient ($\frac{a}{b}$) of two integers where b $\neq 0$.

Examples of Irrational Numbers:

Numbers that are roots of whole numbers that cannot be simplified to obtain a rational number

$\sqrt{2}$, $\sqrt{5}$, $\sqrt{11}$ (Note: $\sqrt{9}$ is rational since it is equal to 3.)

Numbers whose decimal representation does not repeat in a pattern

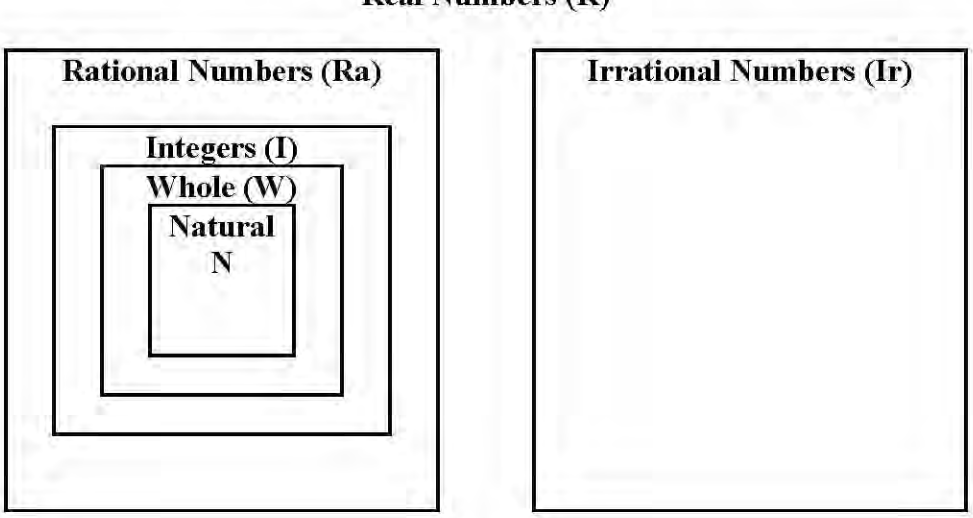
0.1357421…… (Note: $0.3\overline{3}$ is rational since it repeats a pattern and is equal to $\frac{1}{3}$.)

Special numbers such as π(which is equal to 3.1415927…)

Real Numbers

The set of **real numbers** consists of all rational and all irrational numbers. All locations on a number line correspond to a real number. We can think of the set of real numbers as filling all locations on the number line.

The diagram below shows the relationship among the sets of numbers discussed so far.



Note:

As shown in the above diagram, the set of rational numbers includes each of the following.

Natural Numbers: N = {1,2,3,4,..... ..}

Whole Numbers: W = {0,1,2,3,4,..... ..}

Integers: I = {..... −3,−2,−1,0,1,2,3,4,..... }

Rational: Ra = all of the above plus any other number that can be written in the form $\frac{a}{b}$, b $\neq 0$

(examples: 0.5, 1.24, $\frac{2}{5}$, $-1\frac{1}{4}$, 7)

All Rational and all irrational numbers make up the set of real numbers.

Identification of Rational and Irrational Numbers

Recall that:

- Rational numbers can be shown in several different formats, as long as they can be rewritten in the form $\frac{a}{b}$, b $\neq 0$.
  1. Natural numbers, whole numbers and integers (Examples: 7, -43, 0, 2761, - 403)
  2. Proper Fractions, Mixed Numbers, or Improper Fractions
     Examples: $\frac{3}{11}, -\frac{2}{9}, 3\frac{1}{4}, \frac{7}{5}, -8\frac{1}{10}, -\frac{7}{3}$
  3. Decimals – terminating or repeating (Examples: 0.8, -0.25, $0.223\overline{33}$, $2.61\overline{61}$)
- Irrational numbers cannot be shown as common fractions
  1. Decimals that do not terminate or repeat in a pattern (Example: 0.12323569…)
  2. Roots of numbers that are not rational (Examples: $\sqrt{2}, \sqrt{11}, -3\sqrt{5}, ..$)
  3. Special numbers like π

Examples with Solutions

Identify which of the following are rational and which are irrational numbers. Give a reason for your answer.

Number	Rational or Irrational?	Reason
1. -1.25	Rational	It can be written as $-\frac{125}{100}$ or $-\frac{5}{4}$.
2. 0.6010347…	Irrational	The decimal doesn't terminate or repeat the same pattern.
3. $-\sqrt{25}$	Rational	It can be written as -5.
4. 0.1111 …	Rational	It repeats the same pattern and can be written as $\frac{1}{9}$.
5. $\sqrt{13}$	Irrational	The decimal version doesn't repeat the same pattern e.g. $\sqrt{13}$ = 3.6055513…
6. 4.01	Rational	It has a terminating decimal and it could be written as $4\frac{1}{400}$ or $\frac{401}{400}$.

7. $-7\frac{1}{2}$	Rational	It could be written as $-\frac{15}{2}$.
8. $2125\frac{1}{4}$	Rational	It could be written as $\frac{8501}{4}$.
9. 2.333…	Rational	The decimal repeats the same pattern and is equal to $2\frac{1}{3}$ or $\frac{7}{3}$.
10. 5.0100382…	Irrational	The decimal doesn't terminate or repeat the same pattern

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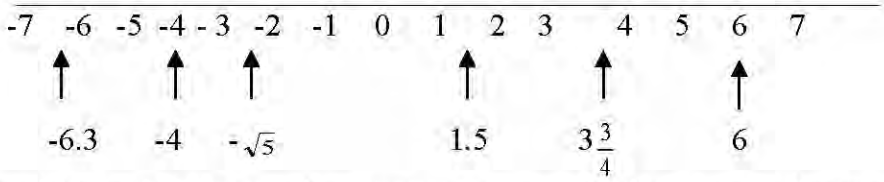
Comparing and Ordering Rational Numbers

Each rational number corresponds to a point on the number line. Several examples are shown next.



It should be noted that numbers **increase** in magnitude as you go from left to right on the line.

Examples: $1 < 3$, $2.1 < 4$; $-7 < -6$; and $2 > 1.8$; $-3 > -5$; $-1 > -10.5$

To compare the magnitudes of rational numbers where one is written in decimal and the other in common fraction form, write both either in decimal or else in common fraction form and then compare.

1. Compare 0.1 with $\frac{3}{20}$ (convert both to fractions first)
   - Change 0.1 to $\frac{1}{10}$. The common denominator is 20, $\therefore \frac{1}{10} = \frac{2}{20}$
   - $\frac{2}{20} < \frac{3}{20}$ or $0.1 < \frac{3}{20}$

2. Compare 3.15 with $3\frac{1}{11}$ (convert both to decimals first)
   - Change $3\frac{1}{11}$ to a decimal $\rightarrow 3.09\overline{09}$
   - $\therefore 3.15 > 3.09\overline{09}$ or $3.15 > 3\frac{1}{11}$

Exercises 1.1

Identify which of the following are rational and which are irrational numbers. Give a reason for your answer.

Number	Rational or Irrational	Reason
1. 0.013		
2. $5\frac{1}{2}$		
3. 7.0900134...		
3. 0.666....		
4. -10.001		
5. $\sqrt{49}$		
6. 0.122357...		
7. 0.212121...		
8. 210.013		
9. $\sqrt{8}$		
10. -5.999...		
11. 3.009		
12. $-345\frac{1}{3}$		

Use a checkmark to indicate which set(s) each number belongs to.

	Set of Numbers				
Number	N	W	I	Ra	Ir
13. 0.7					
14. -45					

15. $\frac{15}{7}$

16. $0.13243\ldots$

17. $0.\overline{7}$

18. 2

19. $1\frac{5}{8}$

20. -160

21. 0

22. $\sqrt{81}$

23. 0.93

24. $\sqrt{15}$

Note: N = Natural Numbers, W = Whole Numbers, I = Integers, Ra = Rational Numbers, Ir = Irrational Numbers

25. Locate the following numbers on the number line.

$3.1, 2\frac{5}{8}, -\frac{13}{12}, -\sqrt{6}, -\sqrt{16}$

-4 -3 -2 -1 0 1 2 3 4

26. Arrange the following numbers from smallest to largest.

a. -0.57, -0.507, -5.07, -5.70

b. 3.4, $-\frac{11}{3}$, -3.4, -3.5

c. $-\frac{3}{8}$, $-\frac{2}{3}$, -0.6, -0.4

27. Put the correct symbol (>, =, <) between each pair of numbers.

a. 0.15 ☐ $\frac{7}{40}$

b. -1.8 ☐ $-\frac{9}{5}$

c. -2.8 ☐ $-\frac{13}{5}$

28. Express each term in common fraction form (as a quotient of two integers)

a. 0.17

b. $-0.\overline{5}$

c. $-1\frac{2}{3}$

d. 3.07

29. Which rational number is greater?

a. $-0.\overline{6}$ or –0.6 ?

b. –0.25 or $-\frac{1}{3}$?

c. $-\frac{2}{3}$ or $-\frac{4}{5}$?

Extra for Experts

30. List the set of all integers greater than -4 and less than $\frac{1}{2}$.

31. Is $\sqrt{\frac{4}{9}}$ rational or irrational? Give a reason for your answer.

32. Is the sum of the following numbers rational or irrational? Give a reason for your answer.

$0.1 + 0.01 + 0.001$

33. Is the sum of the following numbers rational or irrational? Give a reason for your answer.

$0.333\ldots + 0.666\ldots + 0.999\ldots$

34. If the sum of $3.82 + 12.\underline{ab}$ is an integer, what digits must go in place of $\underline{ab}$?

35. If the sum of $\mathbf{-12} + \mathbf{-8}\frac{1}{2} + \mathbf{n}$ is a natural number, what is the smallest number that can replace **n**?

ANSWERS TO EXERCISES AND CHAPTER TESTS

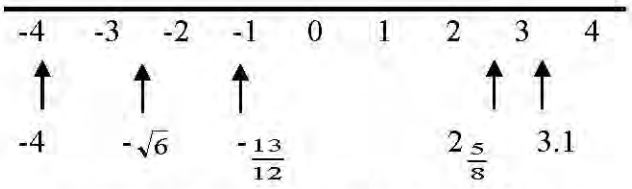
CHAPTER 1

Exercises 1.1 (page 7)

Number	Rational/ Irrational	Reason
1. 0.013	Rational	Can be written as 13/1000
2. 5 1/2	Rational	Can be written as 11/2
3. 7.0900134...	Irrational	Decimal doesn't terminate or repeat
3. 0.666....	Rational	Repeating decimal equal to 2/3
4. -10.001	Rational	Can be written as -10 001/10 000
5. $\sqrt{49}$	Rational	Equal to 7
6. 0.12231353...	Irrational	Decimal doesn't terminate or repeat
7. 0.212121...	Rational	Repeating decimal equal to 21/99
8. 210.013	Rational	Terminating decimal
9. $\sqrt{8}$	Irrational	Decimal value doesn't terminate or repeat 2.8284271...
10. -5.333...	Rational	Decimal repeats and can be written as -16/3
11. 3.009	Rational	Decimal terminates and can be written as 3009/1000
12. -345 1/3	Rational	Can be written as -1036/3

		Set of Numbers				
	Number	N	W	I	Ra	Ir
13.	0.7				√	
14.	-45			√	√	
15.	$\frac{15}{7}$				√	
16.	0.13243...					√
17.	$0.\overline{7}$				√	
18.	2	√	√	√	√	
19.	$1\frac{5}{8}$				√	
20.	-160			√	√	
21.	0		√	√	√	
22.	$\sqrt{81}$	√	√	√	√	
23.	0.93				√	
24.	$\sqrt{15}$					√

25. First, change $-\sqrt{6}$ to -2.449 and $-\sqrt{16}$ to -4. Next, plot locations on the number line as shown below.



26. a) -5.70, -5.07, -0.57, -0.507 **b)** $-\frac{11}{3}$, -3.5, -3.4, 3.4 **c)** $-\frac{2}{3}$, -0.6, -0.4, $-\frac{3}{8}$ **27. a)** < **b)** = **c)** < **28. a)** $\frac{17}{100}$ **b)** $-\frac{5}{9}$ **c)** $-\frac{5}{3}$ **d)** $3\frac{7}{100} = \frac{307}{100}$

29. a) -0.6; It is to the right of $-0.\overline{6}$ on the number line. **b)** -0.25 **c)** $-\frac{2}{3}$ (change to $-\frac{10}{15}$ and $-\frac{12}{15}$) **30.** -3, -2, -1, 0 **31.** Rational – Can be written as 2/3. **32.** Rational – Can be written as $\frac{111}{1000}$. **33.** Rational – Can be written as 2. **34.** 18 **35.** $21\frac{1}{2}$

Exercises 1.2 (page 17)

1. a) 3 **b)** 15 **c)** $\frac{5}{7}$ **d)** $\frac{9}{4}$ **e)** 0.9 **f)** 0.02
2. a) 2.6 **b)** 5.3 **c)** 8.4 **d)** 14.1 **3. a)** $x = \pm 6$ **b)** $x = \pm 7.1$ **c)** $x = \pm 0.9$ **d)** $x = \pm 0.25$ **e)** $x = \pm 200$ **4.** B, D, E **5. a)** ±9 **b)** ±7 **c)** ±0.3 **6. a)** 2.75 **b)** 11.38 **c)** 0.55
7. a) ±10.25 **b)** ±6.18 **c)** ±5.91 **d)** ±6.90
8. 7.42 cm **9. a)** 4.53 cm **b)** 0.57 m
10. 40.16 m **11. a)** 10.83 cm^2 **b)** 7.35 cm^2 **c)** 9.07 cm **12. a)** 942 cm^3 **b)** 1.82 cm

Exercises 1.3 (page 25)

1. a) 8 **b)** 9 **c)** 64 **d)** 81 **e)** 25 **f)** 32 **g)** 216 **h)** 729 **i)** 125 **j)** 243 **2. a)** 25 **b)** 49 **c)**16 **d)** 64 **e)** -9 **f)** 9 **g)** -27 **h)** -27 **i)** 20 **j)** 36
3. a) 625 **b)** $\frac{8}{27}$ **c)** 0.0009 **d)** 92.61 **e)** 6.827769 **f)** $\frac{1}{81}$ **g)** 0.25947 **h)** 0.008 **i)** 0.03125 **j)** y^4 **k)** $72n^7$ **4.** $\frac{9y}{4x}$ **5.** $\frac{9}{32}$ or 0.28125 **6.** x^7 **7.** $9x^4$ **8.** 1.331 **9.** $\frac{4}{3}$

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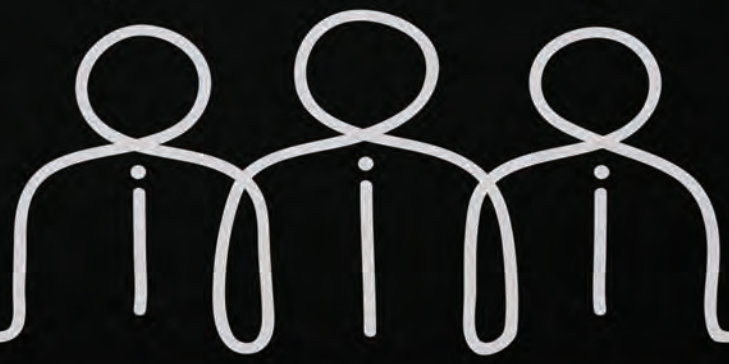

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