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Refresher MATHEMATICS FOR INTERNATIONAL SCHOOL

คณิตศาสตร์ฉบับภาษาอังกฤษ

Anusorn Sornpohm, Ph.D.

- ✓ Problem-solving Emphasis
- ✓ Lots of examples and self-check exercises
- ✓ User friendly and ideal for self-study

Refresher Mathematics

by... Anusorn Sornpohm, Ph.D.

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••• PREFACE •••

The purpose of this book is to provide pre-college mathematics for undergraduate students. The author's objective in writing *Refresher Mathematics* was to provide a textbook that is readable by students. The problem-solving approach is used here as this approach helps to motivate the student by demonstrating how the procedure works. To facilitate students' comprehension of materials, an abundance and variety of examples and solved problems appear throughout the book.

This book begins with simple topics such as real numbers, fractions, decimals, percents, ratios, exponents and radicals. Then it progresses through polynomials, linear equations and inequalities, and quadratic equations. Each chapter of the text is accompanied by numerous exercises that will help students to test themselves. Answers to all exercises appear at the end of each question.

The author wishes to acknowledge the staff at Skybook, Co.Ltd. for their assistance and Martin McMurrich who contributed comments and suggestions. Finally, my special thanks also goes to my wife, Patcharavalai, and my son, Sornpatchara, for their supports.

Anusorn Sornpohm

January 1, 2004

•••CONTENTS•••

Chapter 1

REAL NUMBERS

1.1 SETS AND REAL NUMBERS

A ***set*** is a collection of objects. Examples of sets include:

(a) The set of days in a week can be written as

$\{Monday, Tuesday, Wednesday, Thrusday, Friday, Saturday, Sunday\}$,

(b) The set of odd numbers between 4 and 8 can be written as $\{5,7\}$,

(c) The set of hearts in a deck of playing cards as $\{A,2,3,4,5,6,7,8,910,J,Q,K\}$.

An object in a set is called an ***element*** of that set.

A ***set of numbers*** is a collection of identifiable numbers.

A ***finite set of numbers*** is one having a limited number of members.

An ***infinite set of numbers*** is one that is not a finite set.

Natural numbers are counting numbers (also called positive integers). [Examples of natural numbers include $1, 2, 3, \ldots$]

Whole numbers are natural numbers and zero. [e.g. $0, 1, 2, 3, \ldots$]

The *set of even numbers* consists of $0, 2, 4, 6, 8$ and all whole numbers whose last digit is one of these.

The *set of odd numbers* consists of $1, 3, 5, 7, 9$ and all whole numbers whose last digit is one of these.

Integers are natural numbers, their negatives, and zero. [Examples of integers include $\ldots, -2, -1, 0, 1, 2, \ldots$]

EXAMPLE 1

(a) The set of whole number less than 6 is a finite set of $\{0, 1, 2, 3, 4, 5\}$.

(b) The set of odd numbers less than 15 is a finite set of $\{1, 3, 5, 7, 9, 11, 13\}$.

(c) The set of natural numbers less than 7 is a finite set of $\{1, 2, 3, 4, 5, 6\}$.

(d) The set of even numbers greater than 5 and less than 11 is a finite set of $\{6, 8, 10\}$.

(e) The set of two-digit numbers whose digits have a sum of 5 is a finite set of $\{14, 23, 32, 41, 50\}$.

(f) The set of odd numbers greater than 100 can be written as an infinite set of $\{101, 103, 105, 107, 109, \ldots\}$.

(g) The set of whole numbers less than 50 whose last digit is 6 can be written as a finite set of $\{6, 16, 26, 36, 46\}$.

(h) The set of three-digit whole numbers is a finite set of $\{100, 101, 102, \ldots, 998, 999\}$.

1.2 THE SET OF REAL NUMBERS

The set of real numbers contains all rational numbers and irrational numbers.

A *rational number* is any number that can be written as $\frac{a}{b}$, where a and b are integers and $b \neq 0$. Rational numbers, when expressed as decimals, are decimal numbers that either terminate or are non-terminating repeating.

Examples of rational numbers include (a) integers such as $-5\left(=\frac{-5}{1}\right)$, $0\left(=\frac{0}{1}\right)$, $2\left(=\frac{2}{1}\right)$, (b) fractions such as $-\frac{3}{4}$, $\frac{2}{5}$, (c) terminate decimal numbers such as $4.89, -0.367,$ and (d) non-terminating repeating decimal numbers such as $-0.666\overline{6}$, and $5.3838\overline{38}$.

An *irrational number* is a non-repeating and non-terminating decimal number. [e.g. $\sqrt{3}$, $\sqrt[3]{7}$, π, e, $2.71828\ldots$, $1.414213\ldots$]

The set of rational numbers contains all the integers and non-integer ratios of integers.

EXAMPLE 2 Classify the following statement as either *True* or *False*. If false, why?

(a) -3 is a natural number.

(b) 16 is a rational number.

(c) -1 is not a rational number.

(d) $\sqrt{81}$ is not a positive integer.

(e) π is a real number.

(f) $\frac{2}{0}$ is not a real number.

(g) $-e$ is an irrational number.

(h) $\frac{0}{7}$ is not a rational number.

Solution (a) True. (b) True.

(c) False: -1 can be written as $\frac{-1}{1}$.

(d) False: $\sqrt{81} = 9$, a positive number.

(e) True. (f) True.

(g) True.

(h) False: $\frac{0}{7}$ is in the form of $\frac{a}{b}$, where a and b are integers and $b \neq 0$.

FIGURE 1.1 below illustrates how these sets of numbers are related.

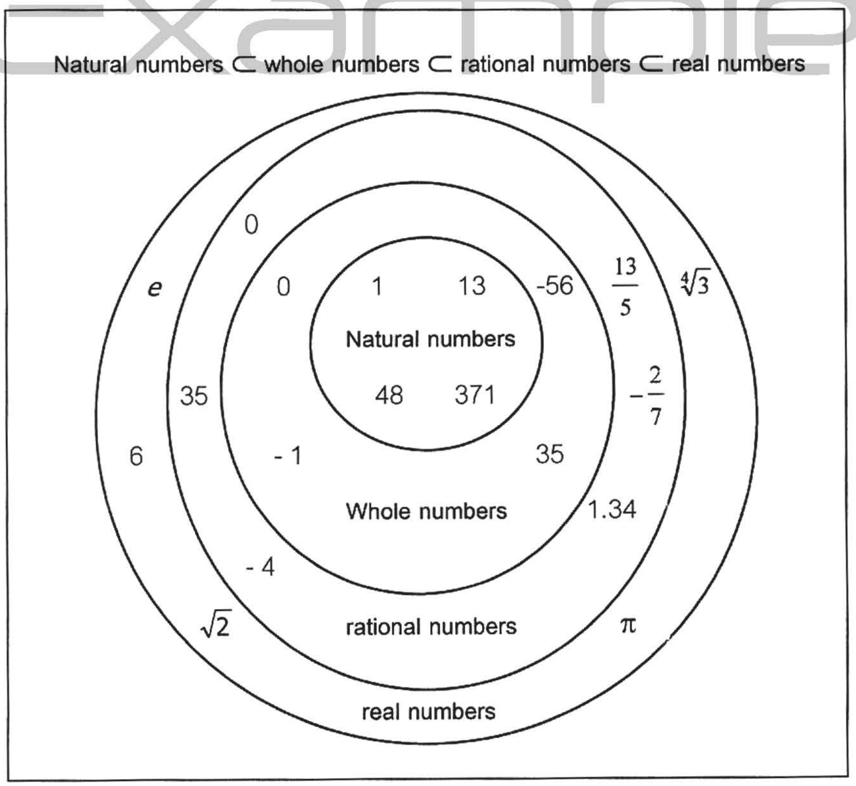


FIGURE 1.1 Sets of Numbers

Note: The symbol "$\subset$" is read "is a subset of " which by definition:

"A set X is a subset of set Y if and only if every element of X is also an element of Y."

1.3 THE REAL NUMBER LINE

A line with a real number associated with each point, and vice versa, is called a ***real number line***.

A real number line is constructed by dividing a line into equal segments as in FIGURE 1.2. The arrow on the right end of the line indicates a positive direction. The point with coordinate of **0** is called the ***origin***. The coordinates of all points to the left of the origin are called ***negative real numbers***, and those to the right of the origin are called ***positive real numbers***.

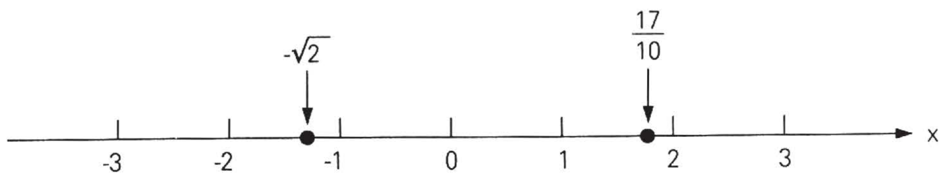


FIGURE 1.2 The real number line

Each negative real number $-x$ then lies x units to the left of the origin, and each positive real number x then lies x units to the right of the origin. In this manner each point on the real number line corresponds to exactly one real number, and each real number corresponds to exactly one point on the real number line. To represent the inequality notations, we may use the following interval notations.

Inequality Notation	Interval Notation
$x < a$	$(-\infty, a)$
$x \le a$	$(-\infty, a]$
$x > b$	(b, ∞)
$x \ge b$	$[b, \infty)$
$a \le x \le b$	$[a, b]$
$a < x < b$	(a, b)
$a \le x < b$	$[a, b)$
$a < x \le b$	$(a, b]$

EXAMPLE 3

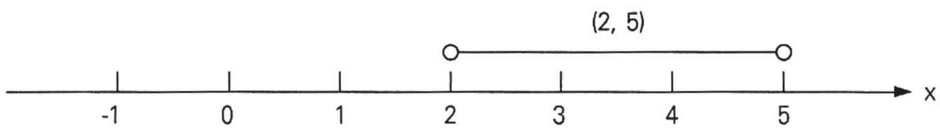
(a) Write $(2,5)$ as a double inequality and graph.

(b) Write $x \ge -3$ in an interval notation and graph.

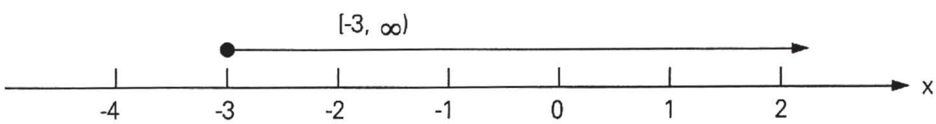
(c) Write $\left[-1, \frac{1}{2}\right]$ as a double inequality and graph.

(d) Write $-6 < x \le -2$ in an interval notation and graph.

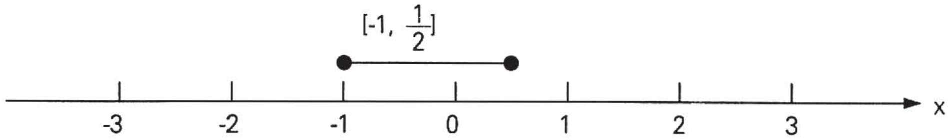
Solution (a) $(2,5)$ is equivalent to $2 < x < 5$.



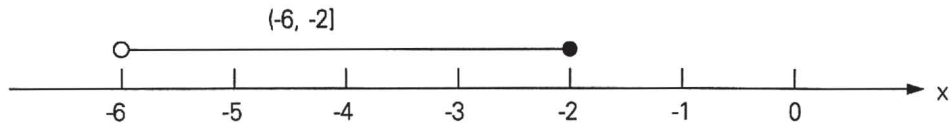
(b) $x \ge -3$ is equivalent to $[-3, \infty)$.



(c) $\left[-1,\frac{1}{2}\right]$ is equivalent to $-1 \le x \le \frac{1}{2}$.



(d) $-6 < x \le -2$ is equivalent to $(-6,-2]$.



1.4 FUNDAMENTAL OPERATIONS OF ARITHMETIC

The four fundamental operations of arithmetic are

(1) ADDITION (the result of this operation is a "sum")

(2) SUBTRACTION (the result of this operation is a "difference")

(3) MULTIPLICATION (the result of this operation is a "product")

(4) DIVISION (the result of this operation is a "quotient")

To perform a combined operation:

Step 1 Work all problems from left to right.

Step 2 Remove parenthesis ( ) first, then brackets [ ], and finally braces { }, if present.

Step 3 Multiplication and division precedes addition and subtraction.

EXAMPLE 4 Perform the indicated operations.

(a) $17-\{7-4[2-2(4+1)]\}$

(b) $-6\{2+[9\div(-3)+6]\}$

Solution (a) $17-\{7-4[2-2(4+1)]\}=17-\{7-4[2-2(5)]\}$

$=17-\{7-4[2-10]\}$

$=17-\{7-4[-8]\}$

$=17-\{7+32\}$

$=17-\{39\}$

$=-22$

(b) $-6\{2+[9\div(-3)+6]\}=-6\{2+[-3+6]\}$

$=-6\{2+3\}$

$=-6\{5\}$

$=-30$

1.5 REAL NUMBER PROPERTIES

Some of the basic properties of the real numbers that enable us to operate on real numbers are as follows:

(1) Commutative Properties

Let a and b be arbitrary elements in the set of real numbers.

1.1 $a+b=b+a$ [e.g. $3+4=4+3$]

1.2 $ab=ba$ [e.g. $5\cdot 2=2\cdot 5$]

(2) Associative Properties

Let a, b and c be arbitrary elements in the set of real numbers.

2.1 $(a+b)+c=a+(b+c)$ [e.g. $(7+2)+3=7+(2+3)$]

2.2 $(ab)c=a(bc)$ [e.g. $(3\cdot 5)\cdot 2=3\cdot(5\cdot 2)$]

(3) Distributive Properties

Let a, b and c be arbitrary elements in the set of real numbers.

3.1 $a(b+c)=ab+ac$ [e.g. $2(3+6)=2\cdot 3+2\cdot 6$]

3.2 $(a+b)c=ac+bc$ [e.g. $(5+7)\cdot 4=5\cdot 4+7\cdot 4$]

(4) Identity Properties

Let a be arbitrary elements in the set of real numbers.

4.1 $a+0=a$ [e.g. $(-8)+0=-8$]

4.2 $a\cdot 1=a$ [e.g. $4\cdot 1=4$]

(5) Subtraction and Division

Let a and b be arbitrary elements in the set of real numbers.

5.1 $a-b=a+(-b)$ [e.g. $(4)-(-7)=4+[-(-7)]=4+7=11$]

5.2 $a\div b=a\left(\frac{1}{b}\right)$, $b\neq 0$ [e.g. $4\div 7=4\left(\frac{1}{7}\right)=\frac{4}{7}$]

(6) Zero Properties

Let a and b be arbitrary elements in the set of real numbers.

6.1 $a\cdot 0=0$ [e.g. $(-46)(0)=0$]

6.2 $ab=0$ if and only if $a=0$ or $b=0$

[e.g. $ab=0$ if and only if $a=0$ since $(0)(b)=0$ or $b=0$ since $(a)(0)=0$]

(7) Properties of Negatives

Let a and b be arbitrary elements in the set of real numbers.

7.1 $-(-a)=a$

7.2 $(-1)a=-a$

7.3 $(-a)b=-(ab)=a(-b)=-ab$

7.4 $(-a)(-b)=ab$

7.5 $\frac{-a}{b}=\frac{a}{-b}=-\frac{a}{b}$, $b\neq 0$

7.6 $\frac{-a}{-b}=-\frac{-a}{b}=-\frac{a}{-b}=\frac{a}{b}$, $b\neq 0$

(8) Fraction Properties

8.1 $\frac{a}{b}=\frac{c}{d}$, $(b,d\neq 0)$ if and only if $ad=bc$

[e.g. $\frac{2}{5}=\frac{6}{15}$ since $2\cdot 15=5\cdot 6$]

8.2 $\frac{na}{nb}=\frac{a}{b}$, $b\neq 0$

[e.g. $\frac{8\cdot 2}{8\cdot 5}=\frac{2}{5}$]

8.3 $\frac{a}{b}\cdot\frac{c}{d}=\frac{ac}{bd}$, $(b,d\neq 0)$

[e.g. $\frac{3}{5}\cdot\frac{4}{9}=\frac{3\cdot 4}{5\cdot 9}$]

8.4 $\frac{a}{b}\div\frac{c}{d}=\frac{a}{b}\cdot\frac{d}{c}$, $(b,c,d\neq 0)$

[e.g. $\frac{3}{5}\div\frac{4}{9}=\frac{3}{5}\cdot\frac{9}{4}$]

8.5 $\frac{a}{b}+\frac{c}{b}=\frac{a+c}{b}$, $b\neq 0$

[e.g. $\frac{3}{5}+\frac{4}{5}=\frac{3+4}{5}$]

8.6 $\frac{a}{b}-\frac{c}{b}=\frac{a-c}{b}$, $b\neq 0$

[e.g. $\frac{3}{5}-\frac{2}{5}=\frac{3-2}{5}$]

8.7 $\frac{a}{b}+\frac{c}{d}=\frac{ad+bc}{bd}$, $(b,d\neq 0)$

[e.g. $\frac{2}{3}+\frac{4}{5}=\frac{2\cdot 5+3\cdot 4}{3\cdot 5}$]

8.8 $\frac{\frac{a}{b}}{\frac{c}{d}}=\frac{a}{b}\div\frac{c}{d}=\frac{a}{b}\cdot\frac{d}{c}=\frac{ad}{bc}$

[e.g. $\frac{\frac{3}{4}}{\frac{5}{7}}=\frac{3}{4}\div\frac{5}{7}=\frac{3}{4}\cdot\frac{7}{5}=\frac{3\cdot 7}{4\cdot 5}=\frac{21}{20}$]

8.9 $\dfrac{\frac{a}{b}}{c} = \dfrac{a}{b} \div c = \dfrac{a}{b} \cdot \dfrac{1}{c} = \dfrac{ab}{c}$

[e.g. $\dfrac{\frac{3}{5}}{4} = \dfrac{3}{5} \div 4 = \dfrac{3}{5} \cdot \dfrac{1}{4} = \dfrac{3}{20}$]

8.10 $\dfrac{a}{\frac{b}{c}} = a \div \dfrac{b}{c} = a \cdot \dfrac{c}{b} = \dfrac{ac}{b}$

[e.g. $\dfrac{3}{\frac{5}{4}} = 3 \div \dfrac{5}{4} = 3 \cdot \dfrac{4}{5} = \dfrac{12}{5}$]

1.6 ABSOLUTE VALUE

The ***absolute value*** of a number is its distance from the origin. Since distance is a positive quantity, the absolute value of any real number is either positive or zero.

The absolute value of m expressed as $|m|$ are

$$|m| = \begin{cases} m & ,(m \geq 0) \\ -m & ,m < 0 \end{cases}$$

Examples are $|7| = 7$, $|-10| = 10$, and $|0| = 0$.

EXAMPLE 5 Evaluate the following.

(a) $|-8+3|$ (b) $|-5|-|-11|$

Solution (a) $|-8+3| = |-5| = 5$

(b) $|-5|-|-11| = (5)-(11) = -6$

Absolute-Value Properties

1. $-|x| \leq x \leq |x|$
2. $|x-y| = |y-x|$
3. $|xy| = |x| \cdot |y|$
4. $\left|\dfrac{x}{y}\right| = \dfrac{|x|}{|y|}, \quad y \neq 0$

EXAMPLE 6 The following are examples of four basic properties of the absolute value.

(a) $-|4| \le 4 \le |4|$

(b) $|5-p| = |p-5|$

(c) $|5-3| = |3-5| = 2$

(d) $|(-4)(3)| = |-4| \cdot |3| = 12$

(e) $\left|\frac{-5}{-4}\right| = \frac{|-5|}{|-4|} = \frac{5}{4}$

(f) $\left|\frac{2x-7}{-6}\right| = \frac{|2x-7|}{|-6|} = \frac{|2x-7|}{6}$

••• Problem 1 •••

1. Classify the following statements as either *True* or *False*. If false, why?

   (a) -5 is a natural number.

   (b) 7 is a rational number.

   (c) 0 is not a number.

   (d) $\sqrt{49}$ is a positive integer.

   (e) π is not a real number.

   (f) -5 is to the right of -4 on the real number line.

   (g) $\frac{0}{4}$ is not a rational number.

   (h) $\frac{4}{0}$ is not a real number.

2. List each set

   (a) The set of whole number less than 8.

   (b) The set of odd numbers less than 21.

   (c) The set of natural numbers less than 9.

   (d) The set of even numbers greater than 13 and less than 21.

   (e) The set of two-digit numbers the sum of whose digits is 4.

   (f) The set of odd numbers greater than 50.

   (g) The set of whole numbers less than 100 whose last digit is 9.

   (h) The set of four-digit whole numbers.

3. Identify the following as finite or infinite.

   (a) $\{1, 3, 5, \ldots\}$

   (b) $\{2, 3, 4\}$

   (c) $\{0, 1, 2, \ldots, 99, 100\}$

   (d) $\{-3, -2, -1, 0\}$

(e) $\left\{\frac{1}{3}, \frac{4}{9}, \frac{7}{12}\right\}$

(f) $\{\ldots, -2, -1, 0, 1, 2, \ldots\}$

4. Decide whether the following expressions represent rational numbers.

(a) $\frac{3}{5}$ (b) $\frac{-4}{7}$

(c) e (d) -3

(e) $\sqrt{2}$ (f) 0.4

5. On a real number line, locate the point (as nearly as possible) represented by the following numbers.

(a) 2.6 (b) -0.9

(c) $-\sqrt{9}$ (d) $2\sqrt{3}$

(e) π (f) $\frac{1}{4}$

6. Write each of the following interval notation as a double inequality and graph.

(a) $(-3, \infty)$ (b) $\left[\frac{4}{5}, 6\right)$

(c) $(-1.5, 2.5]$ (d) $(-\infty, \infty)$

7. Write each of the following in an interval notation and graph.

(a) $x > 3$ (b) $1 \le x \le 3$

(c) $4 \le x < 7$ (d) $x \le -1$

8. Find the sums of these real numbers.

(a) $105 + [-14 + 2]$ (b) $(.06) + (-3.1) + (-0.4)$

(c) $-3 + 2\{3 + 5[7 + (-6)]\}$

9. Evaluate the following.

(a) $\frac{2}{3} - \frac{3}{4} + \frac{4}{5}$

(b) $\frac{6}{29} \cdot \frac{87}{72} \cdot \frac{144}{3}$

(c) $\frac{5}{7} - \frac{6}{13} \cdot \frac{3}{4} + \frac{2}{9} \div \frac{1}{2}$

10. Use the properties of real numbers to simplify each of the following, if possible.

(a) $-3 \div (-9)$

(b) $-5 - (-12)$

(c) $-5[-3 + (-x)]$

(d) $\frac{1}{2}(y - 6)$

(e) $4x\left(\frac{-5}{4x}\right)$

(f) $\frac{y}{4} - \frac{x}{4}$

(g) $\dfrac{\frac{-2}{3}}{\frac{6}{7}}$

(h) $\dfrac{\frac{m}{n}}{4}$

(i) $\dfrac{-3}{\frac{x}{7}}$

11. Find the sum of these real numbers.

(a) $|1.5| + |-2.4| - 7$

(b) $|-2.5| + |2.5| - |-5|$

(c) $\left|-\frac{4}{9}\right| + \frac{3}{9} + \left(-\frac{3}{9}\right)$

••• SOLUTION 1 •••

1. Classify the following statements as either *True* or *False*. If false, why?
   (a) True.
   (b) True.
   (c) False: 0 is a natural number.
   (d) True.
   (e) False: π is an irrational number.
   (f) False: -5 is to the *left* of -4 on the real number line.
   (g) False: both 0 and 4 are integers.
   (h) True.

2. List each set
   (a) $\{0,1,2,3,4,5,6,7\}$
   (b) $\{1,3,5,7,9,11,13,15,17,19\}$
   (c) $\{1,2,3,4,5,6,7,8\}$
   (d) $\{14,16,18,20\}$
   (e) $\{13,22,31,40\}$
   (f) $\{51,53,55,57,59,\ldots\}$
   (g) $\{9.19.29.39.49.59.69.79.89,99\}$
   (h) $\{1000,1001,1002,1003,\ldots,9997,9998,9999\}$

3. Identify the following as finite or infinite.
   (a) Infinite.
   (b) Finite.
   (c) Finite.
   (d) Finite.
   (e) Finite.
   (f) Infinite.

4. Decide whether the following expressions represent rational numbers.

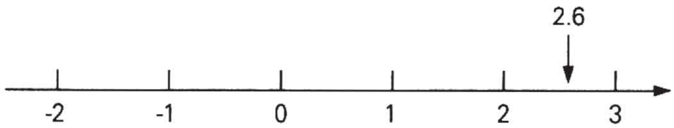
(a) Yes. (b) Yes.

(c) No. (d) Yes.

(e) No. (f) Yes.

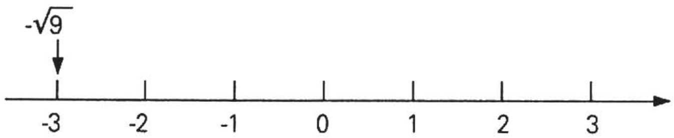
5. On a real number line, locate the point (as nearly as possible) represented by the following numbers.

(a) 2.6

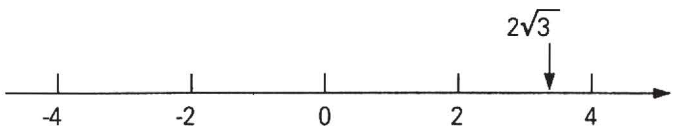


(b) -0.9

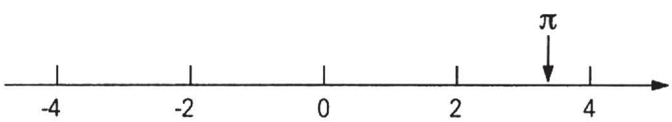
(c) $-\sqrt{9}$



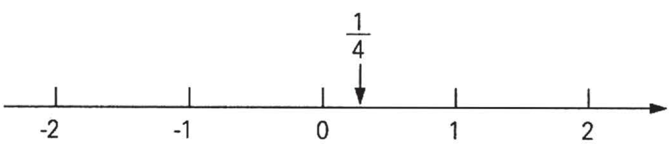
(d) $2\sqrt{3}$



(e) π

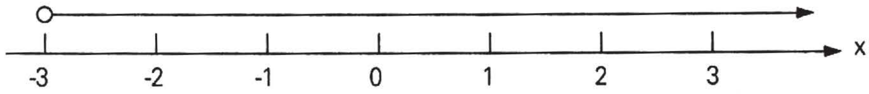


(f) $\frac{1}{4}$

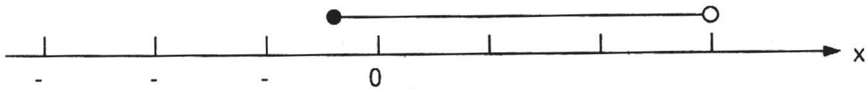


6. Write each of the following interval notation as a double inequality and graph.

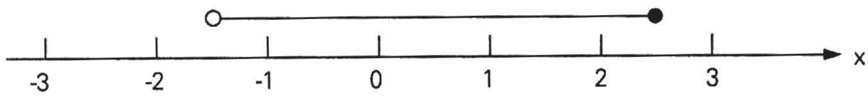
(a) $-3 < x < \infty$



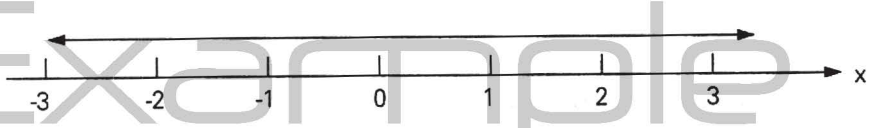
(b) $\frac{4}{5} \le x < 6$



(c) $-1.5 < x \le 2.5$

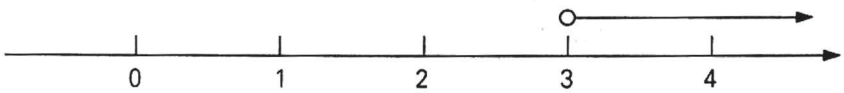


(d) $-\infty < x < \infty$

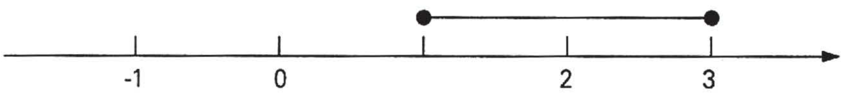


7. Write each of the following in interval notation and graph.

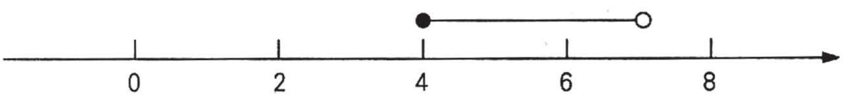
(a) $(3, \infty)$



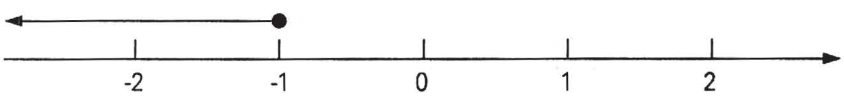
(b) $[1,3]$



(c) $[4,7)$



(d) $(-\infty,-1]$



8. Find the sums of these real numbers.

(a) $105 + [-14 + 2] = 105 + [-12]$
$= 105 - 12$
$= 93$

(b) $(.06) + (-3.1) + (-0.4) = .06 - 3.1 - 0.4$
$= .06 - 3.5$
$= -3.44$

(c) $-3 + 2\{3 + 5[7 + (-6)]\} = -3 + 2\{3 + 5[7 - 6]\}$
$= -3 + 2\{3 + 5[1]\}$
$= -3 + 2\{3 + 5\}$
$= -3 + 2\{8\}$
$= -3 + 16$
$= 13$

9. Evaluate the following.

(a) $\frac{2}{3} - \frac{3}{4} + \frac{4}{5} = \frac{2(4) - 3(3)}{(3)(4)} + \frac{4}{5}$
$= \frac{8 - 9}{12} + \frac{4}{5}$
$= \frac{-1}{12} + \frac{4}{5}$
$= \frac{-1(5) + 4(12)}{(12)(5)}$
$= \frac{-5 + 48}{60}$
$= \frac{43}{60}$

(b) $\frac{6}{29} \cdot \frac{87}{72} \cdot \frac{144}{3} = \frac{6}{1} \cdot \frac{3}{72} \cdot \frac{144}{3}$
$= \frac{6}{1} \cdot \frac{3}{1} \cdot \frac{2}{3}$
$= \frac{6}{1} \cdot \frac{1}{1} \cdot \frac{2}{1}$
$= 6 \cdot 2$
$= 12$

(c) $\frac{5}{7} - \frac{6}{13} \cdot \frac{3}{4} + \frac{2}{9} \div \frac{1}{2} = \frac{5}{7} - \left(\frac{2(3)}{13} \cdot \frac{3}{2(2)}\right) + \frac{2}{9} \cdot \frac{2}{1}$