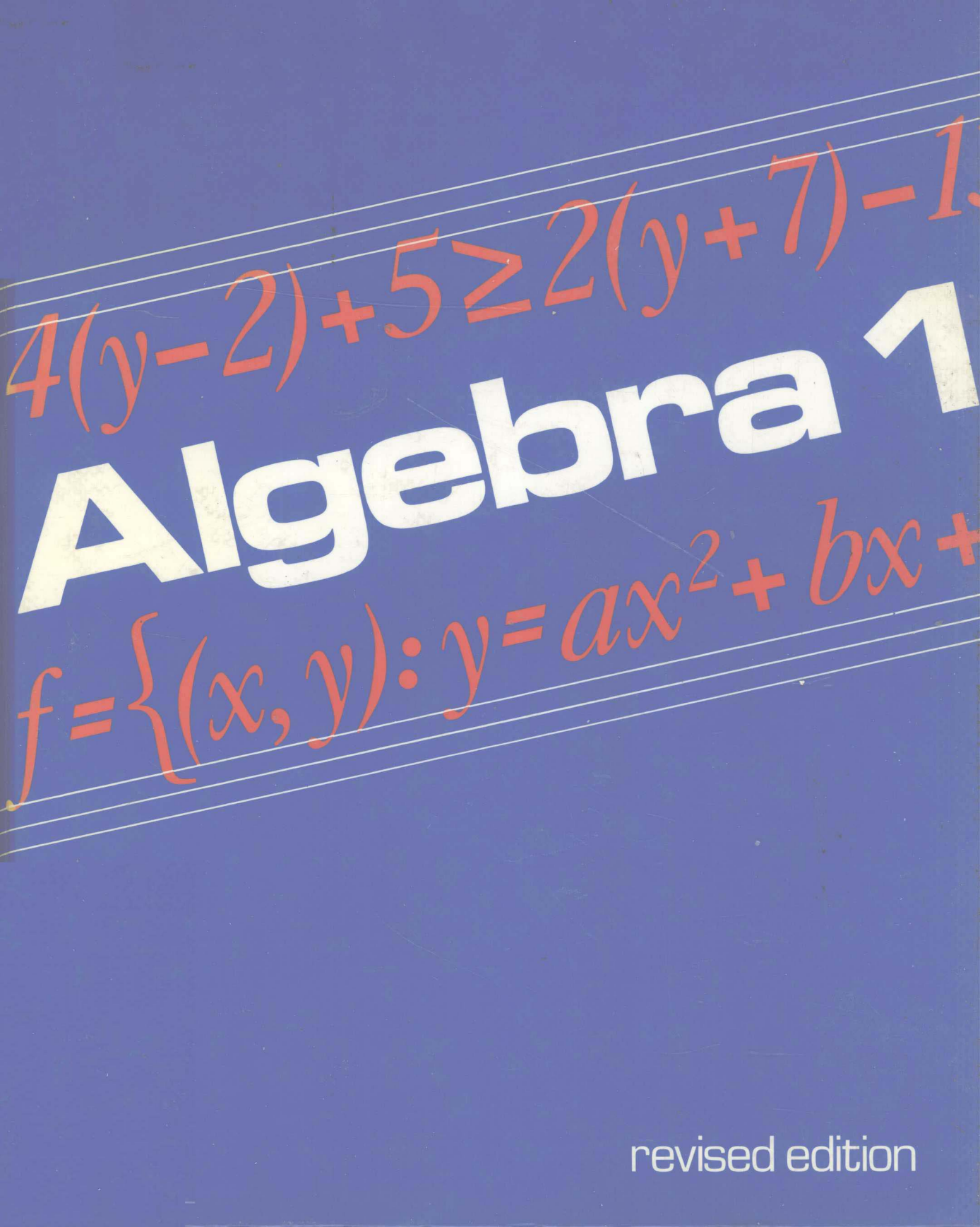
$4(y-2)+5 \geq 2(y+7)-1$
Algebra 1
$f=\{(x,y): y=ax^2+bx+$
revised edition

Algebra 1

REVISED EDITION

Mary P. Dolciani
William Wooton
Edwin F. Beckenbach

EDITORIAL ADVISER
Andrew M. Gleason

HOUGHTON MIFFLIN COMPANY/BOSTON

THE AUTHORS

Mary P. Dolciani, Professor of Mathematics, Hunter College of the City University of New York. Dr. Dolciani has been a director and teacher in numerous National Science Foundation and New York State Education Department institutes for mathematics teachers and Visiting Secondary School Lecturer for the Mathematical Association of America.

William Wooton, former Professor of Mathematics, Los Angeles Pierce College. Mr. Wooton has taught mathematics at both the junior and senior high school levels. He has also been a team member of the National Council of Teachers of Mathematics (NCTM) summer writing projects.

Edwin F. Beckenbach, Professor of Mathematics, Emeritus, University of California, Los Angeles. Dr. Beckenbach has been a team member and coordinator of the NCTM summer writing projects for elementary mathematics teachers. He has served as Chairman of the Committee on Publications of the Mathematical Association of America.

EDITORIAL ADVISER

Andrew M. Gleason, Hollis Professor of Mathematics and Natural Philosophy, Harvard University. Professor Gleason is a well-known research mathematician. His many affiliations include membership in the National Academy of Sciences.

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Printed in the United States of America

ISBN: 0-395-27922-4

Symbols

		PAGE
5^2	five to the second power	7
$+$	addition (in BASIC)	9
$-$	subtraction (in BASIC)	9
*	multiplication (in BASIC)	9
/	division (in BASIC)	9
↑	raising to a power (in BASIC)	10
$^-1$	negative number	12
$\overline{AB}$	line segment AB	13
. . .	and so on	16
$\therefore$	therefore	16
$1.\overline{54}$	1.545454 . . .	16
{ }	set	19
$\in$	is an element of	20
$\notin$	is not an element of	20
$\subset$	is a subset of	20
$\emptyset$	empty set	20
J	set of integers	23
N	set of natural numbers	24
R	set of rational numbers	24
$\Re$	set of real numbers	24
$>$	is greater than	28
$<$	is less than	28
$\geq$	is greater than or equal to	28
$\leq$	is less than or equal to	28
W	set of whole numbers	45
$\stackrel{?}{=}$	does equal ?, is this statement true?	55
✓	Yes, it is	55
$-a$	the additive inverse of a	58
> =	is greater than or equal to (in BASIC)	61
< =	is less than or equal to (in BASIC)	61
< >	is not equal to (in BASIC)	61
$\|a\|$	the absolute value of a	61
ABS(X)	the absolute value of X (in BASIC)	67
$\frac{1}{a}$	the reciprocal, or multiplicative inverse, of a	84
$a - b$	the difference between a and b	99
$a \div b$	the quotient of a divided by b	109
$\cap$	intersection	150
$\cup$	union	150
$\angle A$	angle A	165
$p \wedge q$	p and q	179
$p \vee q$	p or q	179
$p \rightarrow q$	if p, then q	179
$p \leftrightarrow q$	p if and only if q	179
p'	not p	179
(a, b)	the ordered pair with first coordinate a, second coordinate b	188
$f: x \rightarrow 2x$	the function f that assigns $2x$ to x	195
$f(a)$	the value of the function f at a	196
%	percent	361
$\sqrt{a}$	principal square root of a	390
$\sqrt{\ }$	radical sign	390
$\approx$	is approximately equal to	392
$d(P, Q)$	the distance between the points P and Q	403
$\sqrt[n]{a}$	the real nth root of a (positive if n is even)	412
$\pm$	plus or minus	421
SQR(X)	$\sqrt{X}$, in BASIC	424
$m^\circ \angle A$	degree measure of angle A	442
$\sin A$	the sine of angle A	445
$\cos A$	the cosine of angle A	445
$\tan A$	the tangent of angle A	445
$\|\|\mathbf{v}\|\|$	norm of the vector $\mathbf{v}$	459
s	standard deviation	487
$P(E)$	probability of the event E	490

Two separate athletic events may be held simultaneously in this prototype design for a double stadium.

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1 Numbers and Variables

Naming Numbers

OBJECTIVES for Sections 1-1 through 1-4:

1. ***Simplify numerical expressions which involve arithmetic operations, powers, or grouping symbols.***
2. ***Evaluate variable expressions.***
3. ***Graph numbers, and state the coordinates of points, on the number line.***
4. ***Express measurements by means of directed numbers.***

1-1 Numbers and Variables in Expressions

One kind of symbol used in algebra is a *numeral,* or *numerical expression*. A **numerical expression** is simply a name for a number. The number is called the **value** of the expression. For example,

4×9 is a numerical expression for the number 36.
36 is the value of 4×9.

You can use the equality symbol, $=$, and write

$$4 \times 9 = 36.$$

Whenever you replace a numerical expression with the simplest, or most common, name of its value, you say that you have **simplified the expression.**

In simplifying a numerical expression, you use the following fact:

Substitution Principle

Changing the numeral by which a number is named in an expression does not change the value of the expression.

Below are several expressions and their values:

Numerical Expression	Value	You write:
$15 + 12$	27	$15 + 12 = 27$
$5 - 1$	4	$5 - 1 = 4$
7×8 (or $7 \cdot 8$)	56	$7 \times 8 = 56$
$42 \div 6$	7	$42 \div 6 = 7$

Another kind of symbol used in algebra is a *variable*, or a *variable expression*. A **variable** is a letter such as n, a, or x, or a symbol such as $\underline{?}$, used to stand for a number or numbers. A **variable expression** is an expression containing at least one variable, but it may also contain other symbols, including numerals. The set of numbers that a variable can stand for is called the **replacement set**, or **domain**, of the variable. The members of the domain are the **values** of the variable. For example, if n can stand for 2 or 5, then you write $n = 2$ or $n = 5$. $3 \times n$ is a variable expression.

If $n = 2$, then $3 \times n = 3 \times 2 = 6$.
If $n = 5$, then $3 \times n = 3 \times 5 = 15$.

This is called **evaluating the expression**. In a variable expression like $3 \times n$, the multiplication sign is often omitted.

$3 \times n$ may be written $3n$.

EXAMPLE Evaluate each expression for the given value of each variable.

a. $x - 3$; $x = 7$

b. $5y$; $y = 8$

c. $9 - \frac{12}{n}$; $n = 3$

d. $a + b - 2$; $a = 4$ and $b = 11$

SOLUTION

a. $x - 3 = 7 - 3 = 4$

b. $5y = 5 \times y = 5 \times 8 = 40$

c. $9 - \frac{12}{n} = 9 - \frac{12}{3} = 9 - 4 = 5$

d. $a + b - 2 = 4 + 11 - 2 = 13$

Oral Exercises

Give the simplest name of the value of each expression.

1. $12 + 31$
2. $57 - 31$
3. $120 \div 4$
4. 8×24

Evaluate each expression when $x = 4$.

5. $x - 2$
6. $7x$
7. $8 - \frac{12}{x}$
8. $10 + x$

Evaluate each expression when $a = 3$ and $b = 5$.

9. $a + b$
10. $b - a$
11. $\frac{a + b}{2}$
12. ab

13. If $y = 5$, write four variable expressions using y that have a value of 10.
14. If $m = 1$, how many variable expressions can be written using m that have a value of 1?

Written Exercises

Give the simplest name of the value of each expression.

A

1. $352 + 226$
2. $537 + 138$
3. $1642 - 853$
4. $1980 - 1974$
5. $1185 \div 5$
6. $9690 \div 19$
7. 215×13
8. 57×348
9. $3 + 12 + 413$
10. $8753 - 985$
11. $9 \times 12 \times 21$
12. $5656 \div 56$

Evaluate the expression.

13. $x + 5$ when $x = 7$
14. $7 - x$ when $x = 0$
15. $10 + x$ when $x = 3$
16. $3x$ when $x = 9$
17. $5x$ when $x = 1$
18. $\frac{15}{x}$ when $x = 3$
19. $\frac{x}{8}$ when $x = 0$
20. $x - 9$ when $x = 11$
21. $c + d$ when $c = 5$ and $d = 8$
22. $d - c$ when $c = 4$ and $d = 7$
23. $c - d$ when $c = 1$ and $d = 0$
24. cd when $c = 9$ and $d = 8$
25. $\frac{c}{d}$ when $c = 14$ and $d = 2$
26. $\frac{d}{c}$ when $c = 75$ and $d = 25$
27. $c + d - 4$ when $c = 9$ and $d = 3$
28. $c - d + 5$ when $c = 18$ and $d = 9$

B

29. $c + d$ when $c = \frac{1}{3}$ and $d = \frac{3}{4}$
30. $c + d - 1$ when $c = \frac{3}{4}$ and $d = \frac{5}{8}$
31. $c - d + 1$ when $c = 1.25$ and $d = 0.33$
32. $c - d + 1$ when $c = 0.65$ and $d = 0.27$
33. $cd + 1$ when $c = \frac{7}{8}$ and $d = \frac{4}{3}$
34. $cd - 1$ when $c = 2\frac{1}{4}$ and $d = 4$

Evaluate the expression.

35. $\frac{c}{d}$ when $c = \frac{1}{2}$ and $d = \frac{3}{4}$

36. $\frac{c}{d} - 1$ when $c = 1.25$ and $d = 0.5$

37. $\frac{d}{c} + 1$ when $c = 1.25$ and $d = 0.5$

38. $e + f + g$ when $e = \frac{1}{2}$, $f = \frac{1}{3}$, and $g = \frac{1}{4}$

39. efg when $e = \frac{2}{3}$, $f = \frac{3}{4}$, and $g = 16$

40. gfe when $e = \frac{2}{3}$, $f = \frac{3}{4}$ and $g = 16$

41. Show that the expressions $x + y$ and $y + x$ have the same value when $x = \frac{1}{3}$ and $y = \frac{1}{5}$.

42. Show that the expressions $\frac{x + y}{2}$ and $\frac{x}{2} + \frac{y}{2}$ have the same value when $x = \frac{1}{2}$ and $y = \frac{1}{4}$.

43. Find values for x and y that make the expressions $x - y$ and $y - x$ have the same value.

44. Find values for x and y that make the expressions $x + y$ and xy have the same value.

1-2 Grouping Symbols

When more than one operation must be done to find the value of an expression, **parentheses** ( ) are often used to make clear the order in which the operations are to be carried out.

$2 \cdot 5 + 8$ could mean

Either		Or
$(2 \cdot 5) + 8 =$		$2 \cdot (5 + 8) =$
$10 + 8 =$		$2 \cdot 13 =$
$18 \longleftarrow$	different values	$\longrightarrow 26$

A pair of parentheses is a **grouping symbol.** Brackets and braces may also be used as grouping symbols:

Parentheses	Brackets	Braces
$2 \cdot (5 + 8)$	$2 \cdot [5 + 8]$	$2 \cdot \{5 + 8\}$

The product $2 \cdot (5 + 8)$ is usually written without the multiplication dot simply as $2(5 + 8)$. A product like $2 \cdot 13$ may be written

$$2(13) \quad \text{or} \quad (2)13 \quad \text{or} \quad (2)(13)$$

Variables are grouped in the same way as numbers. But:

$2n + 8$ always means $(2n) + 8$
$3n - 5$ always means $(3n) - 5$
$19 \div 4n$ always means $19 \div (4n)$

Notice that in a fraction like $\frac{3+7}{11}$ or $\frac{n+2}{9}$, the bar is both a division sign and a grouping symbol. Thus, $\frac{3+7}{11} = \frac{10}{11}$.

When $n = 5$, $\frac{n+2}{9} = \frac{5+2}{9} = \frac{7}{9}$.

In the numerical expression in Example 1, below, you see a pair of parentheses inside a pair of brackets. Notice that to simplify such an expression, you first simplify the numeral in the innermost grouping symbol, then work toward the outermost grouping symbol.

EXAMPLE 1 Find the value of $5[24 - 3(7)]$.

SOLUTION
$$\begin{aligned} 5[24 - 3(7)] &= 5[24 - 21] \\ &= 5(3) \\ &= 15 \end{aligned}$$

EXAMPLE 2 Find the value of $3(x + 4) - 2x$ when $x = 5$.

SOLUTION
$$\begin{aligned} 3(x + 4) - 2x &= 3(5 + 4) - 2(5) \\ &= 3(9) - 2(5) \\ &= 27 - 10 \\ &= 17 \end{aligned}$$

EXAMPLE 3 If n has the replacement set $\{2, 3, 4\}$, find the corresponding values of $5n - 7$.

SOLUTION

When $n = 2$,
$5n - 7 = 5(2) - 7$
$= 10 - 7$
$= 3$

When $n = 3$,
$5n - 7 = 5(3) - 7$
$= 15 - 7$
$= 8$

When $n = 4$,
$5n - 7 = 5(4) - 7$
$= 20 - 7$
$= 13$

Oral Exercises

Find the value of each expression.

1. $6(3) + 5$
2. $56 - 3(8)$
3. $4(3 + 7)$
4. $9(8 - 4)$
5. $(4 \cdot 4) + (5 \cdot 5)$
6. $(7 \cdot 6) - (5 \cdot 4)$
7. $\frac{23 + 4}{3 + 6}$
8. $\frac{5(6)}{4(15)}$
9. $\frac{5 \times 9}{2 + 7}$
10. $2(5) + \frac{18}{6}$
11. $\frac{18 - 4}{1 \times 2}$
12. $(7 - 4)(3 + 5)$
13. $2x + (x + 1)$ when $x = 4$
14. $3(x - 1) - x$ when $x = 6$
15. $5x - 3$ when $x = 3$
16. $x + 2(x + 3)$ when $x = 5$
17. If y has the replacement set $\{1, 2, 3\}$, find the corresponding values of $3y - 2$.
18. Can you find the replacement set for $2x + 3$ if the corresponding values are 3, 13, and 19?

Written Exercises

Find the value of each expression.

A

1. $20(5)(3)$
2. $17 + (5 + 15)$
3. $(23 + 4) + 7$
4. $8(3) + 30(3)$
5. $5(25 + 15)$
6. $(17 + 8)9$
7. $\dfrac{80 - 10}{15 + 20}$
8. $\dfrac{(5 \cdot 7) + 5}{(9 \cdot 3) - 7}$
9. $\dfrac{(6)(6) + (8)(8)}{(4)(4) + (3)(3)}$
10. $[18 - (9)(2)]3$
11. $4[3(3) + 4(5)]$
12. $[35 - 3(4)] + 25$
13. $[(8)(7) - (2)(3)] \div 2$
14. $[5(5) + 4(6)] \div 7$
15. $[9(7) - 8(0)] \div 9$
16. $2(x + 2) - 2$ when $x = 2$
17. $16 - 3(y - 5)$ when $y = 7$
18. $5(a + 5) + 5$ when $a = 10$
19. $15 + 6(w + 1)$ when $w = 6$
20. $2u + (u + 3)$ when $u = 8$
21. $9v - 10$ when $v = 25$
22. $(7x - 5) + 3$ when $x = 12$
23. $15 + (5y - 5)$ when $y = 1$
24. If x has the replacement set $\{2, 4, 6\}$, find the corresponding values of $4x - 1$.
25. If y has the replacement set $\{1, 3, 5\}$, find the corresponding values of $5y + 3$.
26. If t has the replacement set $\{2, 3, 5\}$, find the corresponding values of $100t - 10$.

B

27. $[7(2) - 4] + [9 + 8(4)]$
28. $2[3(5) - 7] + [10 + 4(6)]$
29. $[5(9) + 8][8 + 9(5)]0$
30. $5[(8)(4) + 8] - (8)5$
31. $\{6 + 2[3(2) + 1] + 1\}3$
32. $2\{[3(2) + 5] + 3\}$
33. $\{(6 \cdot 250) \div [8(8) \div (4 \cdot 4)]\} + [25(12 \div 6)]$
34. $\{[(23 - 7)(6 + 4)] + 340\} - \{(48 \div 4)[24(7) \div (18 - 4)]\}$
35. $2(x - 1) + 3(x + 2) + 1$ when $x = 10$
36. $3(2y + 3)(y - 2)$ when $y = 3$
37. $5[(3w - 4) + (2w + 4)]$ when $w = 2$
38. $(3w - 1)(3w + 1) + (2w + 1)(2w - 1)$ when $w = 2$
39. $\dfrac{4u + 3}{2u + 3} + 2u + 1$ when $u = 6$
40. If x has the replacement set $\{10, 20, 30\}$, find the corresponding values of $10x + 2(x + 10)$.
41. If y has the replacement set $\{0, 2, 4, 6, 8\}$, find the corresponding values of $\dfrac{4y + 4}{2}$.
42. If t has the replacement set $\{10, 100, 1000, 10{,}000\}$, find the corresponding values of $4(t - 1) + 2(t - 1)$.
43. If u has the replacement set $\{1, 2, 3, 4, 5, 6, 7, 8, 9\}$, find the greatest corresponding value of $\dfrac{2u - 1}{2u}$.
44. If v has the replacement set $\{\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, \frac{1}{5}\}$, find the corresponding values of $\dfrac{1}{2v}$. Which is the least corresponding value?

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