

# 6th Grade Math

Understanding Numbers,  
Shapes & Problem Solving



By Jeriamiah Lewis

# Preface

This book was born out of an exciting journey at the "AI/ML Literacy and Train ML Models" camp, where curiosity met creativity and learning was brought to life. Throughout the camp, I explored the fascinating world of mathematics and technology, discovering how these subjects connect and power our everyday lives. I wanted to create a resource that would help other 6th graders see math not just as numbers and equations, but as a powerful tool for solving real-world problems.

This book is a collection of lessons, examples, and insights I gathered during my time at the camp. Each chapter is designed to make 6th grade math engaging, clear, and approachable. Whether you are a student, teacher, or parent, I hope these pages inspire you to look at mathematics with fresh eyes and a sense of adventure.

I am deeply grateful to the mentors and friends who supported and encouraged me along the way. Special thanks go to Dr. Hu, Garret Godwin, Ayodiji Williams, Tionna Freeman, Stevie Scott, Marsha Lewis, and Ashley Mervin. Their guidance, patience, and enthusiasm made this project possible.

I hope you enjoy reading and learning from this book as much as I enjoyed creating it. Together, let's unlock the wonders of math!



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The book is also available online at

<https://www.backupspirit.com/camp/2025/completion/JeremiahLewis.html>

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# Whole Numbers & Negative Numbers: Concepts, Examples, and Tests

Master basic math skills: place value, operations, negatives, coordinates, and more!

Concepts

Examples

Pre-Test

Q & A

Post-Test

## Concepts Explained

### 1. Place Value

Each digit in a whole number has a value based on its position. For example, in 4,573:

- 4 is in the thousands place (4,000)
- 5 is in the hundreds place (500)
- 7 is in the tens place (70)
- 3 is in the ones place (3)

### 2. Adding & Subtracting Whole Numbers

**Addition** joins two or more numbers.

**Subtraction** finds the difference between two numbers.

### 3. Estimating Sums & Differences

Estimation makes calculations easier by rounding numbers. For example,  $397 + 624$  can be estimated as  $400 + 600 = 1,000$ .

### 4. Multiplying Whole Numbers & Estimating Products

**Multiplication** is repeated addition. Estimation uses rounded numbers (e.g.,  $49 \times 21 \approx 50 \times 20 = 1,000$ ).

### 5. Dividing Whole Numbers & Estimating Quotients

**Division** splits a number into equal groups. Estimation helps check your answer (e.g.,  $198 \div 4 \approx 200 \div 4 = 50$ ).

### 6. Negative Numbers

Numbers less than zero (e.g.,  $-5$ ). Useful for temperatures, elevations, and finances.

## 7. Adding with Negative Numbers

When adding a negative, you move left on the number line. For example,  $7 + (-3) = 4$ .

## 8. Absolute Value

The distance a number is from zero. Always positive. E.g.,  $|-6| = 6$ .

## 9. Plotting Ordered Pairs

Ordered pairs  $(x, y)$  show positions on a coordinate plane.  $(3, 2)$  means 3 units right, 2 units up from the origin.

## 10. Distance

The straight-line length between two points. On a number line, it's the absolute difference. On a grid, use the Pythagorean theorem if needed.

## Examples

- **Place Value:** In 5,204, the digit 2 is in the hundreds place (value: 200).
- **Addition:**  $867 + 235 = 1,102$ .
- **Subtraction:**  $500 - 187 = 313$ .
- **Estimating Sums:**  $678 + 147 \approx 700 + 150 = 850$ .
- **Multiplication:**  $24 \times 6 = 144$ .
- **Estimating Products:**  $38 \times 19 \approx 40 \times 20 = 800$ .
- **Division:**  $96 \div 8 = 12$ .
- **Estimating Quotients:**  $205 \div 9 \approx 210 \div 10 = 21$ .
- **Negative Numbers:**  $-7$  is 7 units to the left of 0 on a number line.
- **Adding with Negatives:**  $5 + (-9) = -4$ .
- **Absolute Value:**  $|-15| = 15$ .
- **Plotting Ordered Pairs:** Plot  $(-2, 3)$ : move 2 units left and 3 units up from the origin.
- **Distance on a Number Line:** Between  $-3$  and  $4$ :  $|4 - (-3)| = |7| = 7$ .

## Pre-Test (40 Questions)

**Q1.** Estimate:  $125 \div 4 \approx$

- 30
- 32
- 28
- 34

**Q2.** What is  $16 \times 12$ ?

- 172
- 192
- 182

196

**Q3.** What is  $72 \div 6$ ?

11

10

12

13

**Q4.** Estimate:  $387 + 614 \approx$

900

1,000

1,100

990

**Q5.** Plot  $(5, -2)$ . What is the y-coordinate?

-2

5

2

-5

**Q6.** Estimate:  $61 \times 8 \approx$

480

500

490

520

**Q7.** Estimate:  $78 \times 12 \approx$

900

1,000

800

950

**Q8.** Subtract:  $903 - 478 = ?$

425

435

- 415
- 423

**Q9.** Multiply:  $34 \times 3 = ?$

- 102
- 105
- 99
- 97

**Q10.** Estimate:  $32 \times 29 \approx$

- 900
- 800
- 1,000
- 950

**Q11.** Estimate:  $250 \div 6 \approx$

- 40
- 42
- 45
- 50

**Q12.** What is  $|-20|$ ?

- 20
- 20
- 0
- 10

**Q13.** Multiply:  $23 \times 5 = ?$

- 115
- 120
- 110
- 105

**Q14.** What is  $8 + (-5)$ ?

- 13

- 3
- 3
- 5

**Q15.** Find the distance between  $-8$  and  $3$ .

- 5
- 10
- 11
- 8

**Q16.** In  $(-2, 4)$ , what is the x-coordinate?

- $-2$
- 4
- 2
- $-4$

**Q17.** Estimate:  $394 + 218 \approx$

- 600
- 700
- 500
- 800

**Q18.** Divide:  $144 \div 12 = ?$

- 12
- 14
- 10
- 13

**Q19.** Estimate:  $856 - 399 \approx$

- 400
- 500
- 450
- 600

**Q20.** What is  $15 \times 7$ ?

- 105
- 115
- 120
- 95

**Q21.** What is the value of the 6 in 6,427?

- 6
- 600
- 6,000
- 60

**Q22.** What is  $1,200 - 689$ ?

- 511
- 521
- 501
- 411

**Q23.** What is the absolute value of 0?

- 0
- 1
- 1
- 10

**Q24.** What is the distance between 2 and -5 on a number line?

- 7
- 3
- 5
- 2

**Q25.** What is the x-coordinate in  $(4, -2)$ ?

- 2
- 4
- 2
- 0

**Q26.** What is  $144 \div 8$ ?

- 20
- 18
- 17
- 16

**Q27.** Find the sum:  $-7 + 9 = ?$

- 2
- 2
- 16
- 16

**Q28.** What is  $574 + 219$ ?

- 783
- 793
- 813
- 800

**Q29.** What is the value of the 5 in 2,154?

- 50
- 5
- 500
- 5,000

**Q30.** Estimate:  $202 \div 9 \approx$

- 20
- 22
- 18
- 19

**Q31.** What is  $|-14|$ ?

- 14
- 14
- 0
- 7

**Q32.** What is  $6 + (-8)$ ?

- 14
- 14
- 2
- 2

**Q33.** Which is a negative number?

- 7
- 0
- 3
- 3

**Q34.** What is the opposite of  $-6$ ?

- 6
- 12
- 0
- 3

**Q35.** What is the distance between 10 and 4?

- 14
- 6
- 5
- 4

**Q36.** Plot  $(-3, 5)$ . What is the y-coordinate?

- 3
- 5
- 3
- 5

**Q37.** What is  $-4 + (-5)$ ?

- 9
- 9
- 1
- 1

**Q38.** Find the distance between  $-3$  and  $2$ .

- 5
- 4
- 3
- 6

**Q39.** In  $8,392$ , what place is the  $9$  in?

- Tens
- Hundreds
- Thousands
- Ones

**Q40.** Divide:  $180 \div 9 = ?$

- 16
- 18
- 20
- 15

Submit

## Questions & Answers from Your Pre-Test

Answer the Pre-Test to see questions and answers here!

### Post-Test (40 Questions)

**Q1.** Divide:  $144 \div 12 = ?$

- 12
- 14
- 10
- 13

**Q2.** What is the x-coordinate in  $(4, -2)$ ?

- $-2$
- 4
- 2
- 0

**Q3.** Estimate:  $856 - 399 \approx$

- 400
- 500
- 450
- 600

**Q4.** What is the absolute value of 0?

- 0
- 1
- 1
- 10

**Q5.** What is  $144 \div 8$ ?

- 20
- 18
- 17
- 16

**Q6.** What is  $-4 + (-5)$ ?

- 9
- 9
- 1
- 1

**Q7.** What is the value of the 6 in 6,427?

- 6
- 600
- 6,000
- 60

**Q8.** What is  $72 \div 6$ ?

- 11
- 10
- 12

13

**Q9.** Multiply:  $34 \times 3 = ?$

102

105

99

97

**Q10.** In 8,392, what place is the 9 in?

Tens

Hundreds

Thousands

Ones

**Q11.** Find the distance between  $-3$  and  $2$ .

5

4

3

6

**Q12.** Subtract:  $903 - 478 = ?$

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435

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**Q14.** What is  $16 \times 12$ ?

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- 182
- 196

**Q15.** Estimate:  $202 \div 9 \approx$

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- 22
- 18
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**Q16.** What is  $|-14|$ ?

- 14
- 14
- 0
- 7

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- 40
- 42
- 45
- 50

**Q18.** Multiply:  $23 \times 5 = ?$

- 115
- 120
- 110
- 105

**Q19.** Estimate:  $387 + 614 \approx$

- 900
- 1,000
- 1,100
- 990

**Q20.** Plot  $(-3, 5)$ . What is the y-coordinate?

- 3

- 5
- 3
- 5

**Q21.** Estimate:  $741 - 298 \approx$

- 400
- 500
- 450
- 600

**Q22.** Estimate:  $394 + 218 \approx$

- 600
- 700
- 500
- 800

**Q23.** Find the distance between  $-8$  and  $3$ .

- 5
- 10
- 11
- 8

**Q24.** What is the distance between  $2$  and  $-5$  on a number line?

- 7
- 3
- 5
- 2

**Q25.** What is the distance between  $10$  and  $4$ ?

- 14
- 6
- 5
- 4

**Q26.** Which is NOT a negative number?

- 7
- 2
- 0
- 11

**Q27.** What is  $|-20|$ ?

- 20
- 20
- 0
- 10

**Q28.** Estimate:  $399 \div 8 \approx$

- 50
- 60
- 40
- 55

**Q29.** Estimate:  $78 \times 12 \approx$

- 900
- 1,000
- 800
- 950

**Q30.** Divide:  $180 \div 9 = ?$

- 16
- 18
- 20
- 15

**Q31.** Estimate:  $32 \times 29 \approx$

- 900
- 800
- 1,000
- 950

**Q32.** In  $(-2, 4)$ , what is the x-coordinate?

- 2
- 4
- 2
- 4

**Q33.** Estimate:  $47 \times 19 \approx$

- 900
- 800
- 1,000
- 950

**Q34.** Add:  $379 + 618 = ?$

- 997
- 987
- 995
- 1007

**Q35.** Which digit is in the tens place of 4,978?

- 9
- 7
- 8
- 4

**Q36.** What is the opposite of 9?

- 9
- 9
- 0
- 1

**Q37.** What is the value of the 5 in 2,154?

- 50
- 5
- 500
- 5,000

**Q38.** Estimate:  $125 \div 4 \approx$

- 30
- 32
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**Q39.** What is  $8 + (-5)$ ?

- 13
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- 3
- 5

**Q40.** What is  $574 + 219$ ?

- 783
- 793
- 813
- 800

Submit

# Jeremiah-P2: Fractions, Ratios, and Proportions

## Master Fractions, Ratios, and Proportions with Examples, Tests, and Q&A

[What is a Ratio?](#)

[Examples](#)

[Pre-Test](#)

[Questions & Answers](#)

[Post-Test](#)

### Chapter 1: What is a Ratio?

A **ratio** is a comparison of two or more quantities that shows their relative sizes. Ratios can describe how much of one thing there is compared to another.

- It can be written using a colon: **3:2**
- As a fraction:  **$\frac{3}{2}$**
- Or using words: "3 to 2"

**Example:** If there are **6 apples** and **4 oranges** in a basket, the ratio of apples to oranges is **6:4** or simplified as **3:2**.

Ratios help us compare, scale, and solve real-life problems, such as recipes, maps, and more.

### Chapter 2: Examples of the Topics

#### 1. Changing Improper Fractions to Mixed Numbers

*Example:*

$$\frac{11}{4} = 2\frac{3}{4} \text{ (11 divided by 4 is 2 with a remainder of 3)}$$

## 2. Changing Mixed Numbers to Improper Fractions

Example:

$$2\frac{3}{4} = \frac{11}{4} \quad (2 \times 4 + 3 = 11)$$

## 3. Adding Fractions with Like Denominators

$$\frac{2}{7} + \frac{3}{7} = \frac{5}{7}$$

## 4. Subtracting Fractions with Like Denominators

$$\frac{5}{9} - \frac{2}{9} = \frac{3}{9} = \frac{1}{3}$$

## 5. Adding or Subtracting Fractions with Unlike Denominators

$$\frac{1}{4} + \frac{1}{6} = \frac{3}{12} + \frac{2}{12} = \frac{5}{12}$$

## 6. Adding Mixed Numbers with Unlike Denominators

$$1\frac{1}{2} + 2\frac{2}{3} = \frac{3}{2} + \frac{8}{3} = \frac{9}{6} + \frac{16}{6} = \frac{25}{6} = 4\frac{1}{6}$$

## 7. Subtracting Mixed Numbers with Unlike Denominators

$$3\frac{3}{4} - 1\frac{2}{3} = \frac{15}{4} - \frac{5}{3} = \frac{45}{12} - \frac{20}{12} = \frac{25}{12} = 2\frac{1}{12}$$

## 8. Estimating Sums and Differences of Fractions and Mixed Numbers

$$4\frac{5}{6} \approx 5, 2\frac{1}{8} \approx 2. \text{ So, } 4\frac{5}{6} + 2\frac{1}{8} \approx 7.$$

## 9. Multiplying Fractions and Whole Numbers

$$3 \times \frac{2}{5} = \frac{6}{5} = 1\frac{1}{5}$$

## 10. Multiplying Fractions: Reciprocals

The reciprocal of  $\frac{2}{3}$  is  $\frac{3}{2}$ .

$$\frac{2}{3} \times \frac{3}{2} = 1$$

## 11. Multiplying Fractions and Mixed Numbers: Reducing

$$2\frac{1}{2} \times \frac{4}{5} = \frac{5}{2} \times \frac{4}{5} = \frac{20}{10} = 2$$

## 12. Dividing Fractions by Whole Numbers

$$\frac{3}{4} \div 2 = \frac{3}{4} \times \frac{1}{2} = \frac{3}{8}$$

## 13. Dividing Whole Numbers by Fractions

$$4 \div \frac{2}{3} = 4 \times \frac{3}{2} = 6$$

#### 14. Dividing Fractions by Fractions

$$\frac{5}{6} \div \frac{2}{3} = \frac{5}{6} \times \frac{3}{2} = \frac{15}{12} = \frac{5}{4} = 1\frac{1}{4}$$

#### 15. Dividing Mixed Numbers

$$2\frac{1}{2} \div 1\frac{1}{4} = \frac{5}{2} \div \frac{5}{4} = \frac{5}{2} \times \frac{4}{5} = 2$$

#### 16. Ratios

12 boys and 8 girls: Ratio = 12:8 = 3:2

#### 17. Proportions and Cross-Multiplying

$$\frac{2}{3} = \frac{4}{6}: 2 \times 6 = 3 \times 4, \text{ both equal } 12.$$

#### 18. Ratio Tables

If 2 pencils cost \$4, how much do 4 pencils cost?

| Pencils | 2 | 4 |

|-----|---|---|

| Cost | 4 | 8 |

Double pencils, double the cost.

#### 19. Rates

60 km in 2 hours = 30 km/hour

#### 20. Problem-Solving with Proportions

If 3 shirts cost \$18, how much do 5 shirts cost?

Set up:  $\frac{3}{18} = \frac{5}{x}$

Cross-multiply:  $3x = 90$

$x = 30$ . So, 5 shirts cost \$30.

## Chapter 3: Pre-Test (40 Questions)

1. Write the ratio of 8 dogs to 12 cats in simplest form.
2. Change  $\frac{13}{5}$  to a mixed number.
3. Convert  $3\frac{2}{7}$  to an improper fraction.
4. Add:  $\frac{4}{9} + \frac{2}{9}$
5. Subtract:  $\frac{7}{10} - \frac{3}{10}$
6. Add:  $\frac{1}{4} + \frac{1}{3}$

7. Subtract:  $\frac{5}{6} - \frac{1}{4}$
8. Add:  $1\frac{1}{2} + 2\frac{1}{3}$
9. Subtract:  $3\frac{3}{4} - 1\frac{2}{5}$
10. Estimate the sum:  $2\frac{7}{8} + 3\frac{1}{10}$
11. Multiply:  $5 \times \frac{3}{8}$
12. What is the reciprocal of  $\frac{4}{7}$ ?
13. Multiply:  $1\frac{1}{3} \times \frac{3}{4}$
14. Divide:  $\frac{5}{8} \div 2$

15. Divide:  $7 \div \frac{1}{2}$
16. Divide:  $\frac{3}{5} \div \frac{2}{3}$
17. Divide:  $2\frac{1}{4} \div 1\frac{1}{8}$
18. Simplify the ratio 12:16.
19. Solve:  $\frac{4}{5} = \frac{x}{15}$
20. Complete the ratio table: 1:4, 2:\_\_, 3:\_\_, 4:\_\_
21. Find the rate: 120 miles in 3 hours.
22. Solve: If 6 notebooks cost \$18, what is the cost of 9 notebooks?
23. Write  $\frac{14}{3}$  as a mixed number.
24. Write  $2\frac{1}{5}$  as an improper fraction.
25. Add:  $\frac{7}{12} + \frac{1}{3}$
26. Subtract:  $\frac{5}{6} - \frac{1}{3}$
27. Add:  $2\frac{3}{4} + 1\frac{1}{8}$
28. Subtract:  $4\frac{2}{5} - 2\frac{3}{10}$
29. Estimate the difference:  $6\frac{7}{9} - 2\frac{1}{11}$
30. Multiply:  $6 \times \frac{2}{3}$
31. What is the reciprocal of  $\frac{5}{9}$ ?
32. Multiply:  $3\frac{2}{5} \times \frac{5}{6}$
33. Divide:  $\frac{7}{9} \div 3$
34. Divide:  $8 \div \frac{4}{5}$
35. Divide:  $\frac{5}{6} \div \frac{1}{2}$
36. Divide:  $4\frac{2}{3} \div 1\frac{1}{3}$
37. Simplify the ratio 15:20.
38. Solve:  $\frac{3}{4} = \frac{y}{12}$
39. Fill in the ratio table: 2:5, 4:\_\_, 6:\_\_, 8:\_\_
40. Find the rate: 250 km in 5 hours.

## Chapter 4: Questions & Answers

### Q: What is a ratio?

**A:** A ratio compares two or more numbers, showing how many times one value contains or is contained within the other.

### Q: How do you add fractions with like denominators?

**A:** Add the numerators and keep the denominator the same.

### Q: What do you do before adding fractions with unlike denominators?

**A:** Find a common denominator, convert the fractions, then add.

### Q: How do you change an improper fraction to a mixed number?

**A:** Divide the numerator by the denominator. The quotient is the whole number, and the remainder over the denominator is the fraction part.

**Q: What is a reciprocal?**

**A:** The reciprocal of a fraction is what you multiply it by to get 1. For  $\frac{a}{b}$ , the reciprocal is  $\frac{b}{a}$ .

**Q: How do you divide fractions?**

**A:** Multiply by the reciprocal of the divisor.

**Q: How do you solve a proportion?**

**A:** Use cross-multiplication:  $\frac{a}{b} = \frac{c}{d}$  means  $a \times d = b \times c$ .

**Q: What is a rate?**

**A:** A rate compares two quantities with different units, such as miles per hour.

**Q: What is a ratio table?**

**A:** A table that shows pairs of numbers that form equivalent ratios.

**Q: How do you estimate sums or differences of mixed numbers?**

**A:** Round each mixed number to the nearest whole number, then add or subtract.

## Chapter 5: Post-Test (40 Questions)

- Write the ratio of 15 apples to 20 oranges in simplest form.
- Change  $\frac{17}{6}$  to a mixed number.
- Convert  $4\frac{1}{5}$  to an improper fraction.
- Add:  $\frac{5}{8} + \frac{1}{8}$
- Subtract:  $\frac{9}{12} - \frac{5}{12}$
- Add:  $\frac{2}{5} + \frac{1}{2}$
- Subtract:  $\frac{7}{9} - \frac{2}{3}$
- Add:  $2\frac{1}{3} + 3\frac{1}{4}$
- Subtract:  $5\frac{1}{2} - 2\frac{2}{3}$
- Estimate the sum:  $7\frac{3}{5} + 1\frac{7}{8}$
- Multiply:  $4 \times \frac{2}{7}$
- What is the reciprocal of  $\frac{6}{11}$ ?
- Multiply:  $2\frac{1}{4} \times \frac{4}{5}$
- Divide:  $\frac{3}{7} \div 2$
- Divide:  $9 \div \frac{3}{4}$
- Divide:  $\frac{2}{3} \div \frac{5}{6}$
- Divide:  $3\frac{1}{2} \div 1\frac{3}{4}$
- Simplify the ratio 18:24.
- Solve:  $\frac{5}{8} = \frac{y}{24}$
- Complete the ratio table: 1:3, 2:\_\_, 3:\_\_, 4:\_\_
- Find the rate: 200 km in 4 hours.
- Solve: If 8 pens cost \$24, what is the cost of 12 pens?
- Write  $\frac{16}{5}$  as a mixed number.
- Write  $3\frac{2}{3}$  as an improper fraction.
- Add:  $\frac{3}{10} + \frac{2}{5}$
- Subtract:  $\frac{7}{8} - \frac{1}{4}$
- Add:  $5\frac{1}{6} + 2\frac{5}{12}$
- Subtract:  $7\frac{2}{3} - 4\frac{5}{9}$
- Estimate the difference:  $9\frac{2}{5} - 3\frac{7}{8}$
- Multiply:  $7 \times \frac{3}{4}$
- What is the reciprocal of  $\frac{8}{13}$ ?
- Multiply:  $2\frac{3}{8} \times \frac{4}{7}$

33. Divide:  $\frac{9}{10} \div 5$

34. Divide:  $10 \div \frac{2}{3}$

35. Divide:  $\frac{7}{8} \div \frac{3}{5}$

36. Divide:  $6\frac{1}{2} \div 2\frac{1}{4}$

37. Simplify the ratio 21:28.

38. Solve:  $\frac{2}{5} = \frac{x}{25}$

39. Fill in the ratio table: 3:7, 6:\_\_, 9:\_\_,  
12:\_\_

40. Find the rate: 360 miles in 6 hours.

## Fractions, Ratios, Proportions Auto-Graded Post-Test (40 MCQ)

Name:

Date:

**Q1. Write the ratio of 15 apples to 20 oranges in simplest form.**

- 3:4
- 8:5
- 5:8
- 4:3

**Q2. Change  $\frac{17}{6}$  to a mixed number.**

- 2 6/17
- 3 1/6
- 2 11/17
- 2 5/6

**Q3. Convert  $4\frac{1}{5}$  to an improper fraction.**

- 21/5
- 5/21
- 20/4
- 9/5

**Q4. Add:  $\frac{5}{8} + \frac{1}{8}$**

- 5/16

- 6/16
- 3/4
- 5/8

**Q5. Subtract:**  $\frac{9}{12} - \frac{5}{12}$

- 2/3
- 4/24
- 1/3
- 4/13

**Q6. Add:**  $\frac{2}{5} + \frac{1}{2}$

- 9/10
- 7/10
- 3/10
- 3/7

**Q7. Subtract:**  $\frac{7}{9} - \frac{2}{3}$

- 5/9
- 3/9
- 1/9
- 1/6

**Q8. Add:**  $2\frac{1}{3} + 3\frac{1}{4}$

- 5 1/12
- 5 1/7
- 5 5/12
- 5 7/12

**Q9. Subtract:**  $5\frac{1}{2} - 2\frac{2}{3}$

- 2 2/6
- 2 5/6
- 2 1/6
- 3 1/6

**Q10. Estimate the sum:**  $7\frac{3}{5} + 1\frac{7}{8}$

- 9
- 11
- 8
- 10

**Q11. Multiply:**  $4 \times \frac{2}{7}$

- 8/11
- 7/2
- 1 1/7
- 2/7

**Q12. What is the reciprocal of  $\frac{6}{11}$ ?**

- $\frac{11}{7}$
- $\frac{11}{6}$
- $\frac{6}{11}$
- $\frac{7}{11}$

**Q13. Multiply:**  $2\frac{1}{4} \times \frac{4}{5}$

- 2 1/4
- 1 4/5
- 2 4/5
- 9/5

**Q14. Divide:**  $\frac{3}{7} \div 2$

- 2/3
- 7/3
- 3/14
- 6/7

**Q15. Divide:**  $9 \div \frac{3}{4}$

- 9/4
- 6 3/4
- 7
- 12

**Q16. Divide:**  $\frac{2}{3} \div \frac{5}{6}$

- 5/4
- 4/5
- 1/2
- 1 1/5

**Q17. Divide:**  $3\frac{1}{2} \div 1\frac{3}{4}$

- 1 1/2

- 1 3/4
- 2
- 2 1/4

**Q18. Simplify the ratio 18:24.**

- 2:3
- 4:3
- 6:8
- 3:4

**Q19. Solve:  $\frac{5}{8} = \frac{y}{24}$ . What is y?**

- 10
- 12
- 20
- 15

**Q20. Complete the ratio table: 1:3, 2:\_\_, 3:\_\_, 4:\_\_**

- 9, 12, 15
- 2, 3, 4
- 6, 9, 12
- 4, 6, 8

**Q21. Find the rate: 200 km in 4 hours.**

- 25 km/h
- 50 km/h
- 60 km/h
- 40 km/h

**Q22. If 8 pens cost \$24, what is the cost of 12 pens?**

- \$30
- \$28
- \$36
- \$32

**Q23. Write  $\frac{16}{5}$  as a mixed number.**

- 3 1/5
- 3 5/16
- 2 3/5
- 3 2/5

**Q24. Write  $3\frac{2}{3}$  as an improper fraction.**

- 2/9
- 9/2
- 8/3
- 11/3

**Q25. Add:  $\frac{3}{10} + \frac{2}{5}$**

- 7/10
- 3/5
- 1/2
- 1/5

**Q26. Subtract:  $\frac{7}{8} - \frac{1}{4}$**

- 5/8
- 1/2
- 3/8
- 7/12

**Q27. Add:  $5\frac{1}{6} + 2\frac{5}{12}$**

- 7 1/12
- 8 5/12
- 8 1/12
- 7 11/12

**Q28. Subtract:  $7\frac{2}{3} - 4\frac{5}{9}$**

- 3 1/9
- 2 5/9
- 3 2/9
- 2 1/3

**Q29. Estimate the difference:  $9\frac{2}{5} - 3\frac{7}{8}$**

- 6
- 4
- 7
- 5

**Q30. Multiply:  $7 \times \frac{3}{4}$**

- 6 1/4

- 4  $\frac{3}{4}$
- $\frac{7}{4}$
- 5  $\frac{1}{4}$

**Q31. What is the reciprocal of  $\frac{8}{13}$ ?**

- $\frac{8}{5}$
- $\frac{8}{13}$
- $\frac{13}{8}$
- $\frac{5}{8}$

**Q32. Multiply:  $2\frac{3}{8} \times \frac{4}{7}$**

- 1  $\frac{5}{14}$
- 2  $\frac{4}{7}$
- 1  $\frac{3}{7}$
- 2  $\frac{5}{14}$

**Q33. Divide:  $\frac{9}{10} \div 5$**

- $\frac{9}{5}$
- $\frac{5}{9}$
- $\frac{9}{50}$
- $\frac{2}{9}$

**Q34. Divide:  $10 \div \frac{2}{3}$**

- 5
- $\frac{20}{3}$
- 7
- 15

**Q35. Divide:  $\frac{7}{8} \div \frac{3}{5}$**

- 1  $\frac{11}{24}$
- 2  $\frac{3}{8}$
- 1  $\frac{3}{24}$
- 1  $\frac{7}{8}$

**Q36. Divide:  $6\frac{1}{2} \div 2\frac{1}{4}$**

- 2  $\frac{8}{9}$
- 3
- 2

2 1/9

**Q37. Simplify the ratio 21:28.**

- 4:3
- 7:8
- 2:3
- 3:4

**Q38. Solve:**  $\frac{2}{5} = \frac{x}{25}$

- 12
- 8
- 5
- 10

**Q39. Fill in the ratio table: 3:7, 6:\_\_, 9:\_\_, 12:\_\_**

- 6, 9, 12
- 21, 28, 35
- 14, 21, 28
- 9, 12, 15

**Q40. Find the rate: 360 miles in 6 hours.**

- 70 mph
- 50 mph
- 45 mph
- 60 mph

# Decimals, Fractions, and Percents: Concepts and Practice

[Concepts Explained](#) [Examples](#) [Pre-Test](#) [Questions & Answers](#) [Post-Test](#)

## Chapter 1: Concepts Explained

### 1. Decimal Place Value and Rounding

Each digit in a decimal number has a place value based on its position. For example, in 3.476:

- 3 is in the ones place
- 4 is in the tenths place
- 7 is in the hundredths place
- 6 is in the thousandths place

To round a decimal, look at the digit to the right of the place value you are rounding to. If it's 5 or greater, round up; otherwise, round down.

### 2. Changing Fractions to Decimals

To convert a fraction to a decimal, divide the numerator by the denominator. For example,  $\frac{3}{4} = 0.75$ .

### 3. Changing Decimals to Fractions

Write the decimal as a fraction with the appropriate denominator, then simplify. For example,  $0.6 = \frac{6}{10} = \frac{3}{5}$ .

### 4. Comparing and Ordering Decimals

Line up the decimals and compare the digits from left to right, starting with the highest place value.

### 5. Adding and Subtracting Decimals

Align the decimal points and add or subtract as with whole numbers. Fill in zeros if necessary.

### 6. Multiplying Decimals

Multiply as with whole numbers, then count total decimal places in both numbers and place the decimal accordingly in the answer.

### 7. Dividing Decimals

Move the decimal point in the divisor and dividend to make the divisor a whole number, then divide as usual.

### 8. Understanding Percent

Percent means "per hundred." 45% means 45 out of 100, or 0.45.

## Chapter 2: Examples

**1. Rounding:** Round 3.478 to the nearest hundredth.

*Solution:* Look at the thousandths (8).  $8 \geq 5$ , so round up: 3.48 becomes  $3.48 + 0.01 = 3.48$ .

**2. Fraction to Decimal:**  $7/8 = 7 \div 8 = 0.875$

**3. Decimal to Fraction:**  $0.25 = 25/100 = 1/4$

**4. Comparing Decimals:** Which is greater, 0.65 or 0.605?

*Solution:* Compare in hundredths:  $0.65 > 0.605$ .

**5. Adding Decimals:**  $1.34 + 2.6 = 3.94$

**6. Multiplying Decimals:**  $0.7 \times 0.3 = 0.21$  (two decimal places)

**7. Dividing Decimals:**  $1.2 \div 0.4 =$  (Move decimal in 0.4 to make it 4, do the same to 1.2 to make it 12)  $\Rightarrow 12 \div 4 = 3$

**8. Percent to Fraction:**  $60\% = 60/100 = 3/5$

## Chapter 3: Pre-Test (Multiple Choice)

1. What is 0.37 in words?
  - Thirty-seven hundredths
  - Three and seven tenths
  - Thirty-seven tenths
2. Round 8.436 to the nearest tenth.
  - 8.4
  - 8.5
  - 8.44
3. What is  $5/8$  as a decimal?
  - 0.63
  - 0.625
  - 0.75
4. Which is 0.4 as a fraction in lowest terms?
  - $4/10$
  - $2/5$
  - $1/4$
5. Which is greater?
  - 0.48
  - 0.504
  - They are equal
6. What is  $2.56 + 3.7$ ?
  - 6.26
  - 6.36
  - 5.46
7. What is  $4.8 - 1.13$ ?
  - 3.67
  - 3.77
  - 3.87

8. What is  $\$5.75 + \$2.30$ ?

- \$7.95
- \$8.05
- \$8.15

9. Estimate:  $3.78 + 2.26$

- 6
- 7
- 5

10. Multiply:  $0.6 \times 0.5$

- 0.30
- 0.35
- 0.25

Submit

## Chapter 4: Questions & Answers

**Q:** What is the tenths place in the number 4.57?

**A:** The tenths place is 5.

**Q:** How do you convert  $1/2$  to a decimal?

**A:** Divide 1 by 2 to get 0.5.

**Q:** What is 0.6 as a fraction in simplest form?

**A:**  $0.6 = 6/10 = 3/5$ .

**Q:** How do you compare 0.78 and 0.8?

**A:** 0.8 is greater than 0.78.

**Q:** How do you multiply 0.3 by 0.2?

**A:** Multiply as whole numbers ( $3 \times 2 = 6$ ), then place decimal (two places): 0.06.

**Q:** What is 25% as a decimal and as a fraction?

**A:**  $25\% = 0.25 = 1/4$ .

## Chapter 5: Post-Test (Multiple Choice)

1. What is 0.94 in words?

- Ninety-four hundredths
- Nine and forty hundredths
- Nine hundred forty thousandths

2. Round 2.589 to the nearest tenth.

- 2.5
- 2.6
- 2.59

3. What is  $3/5$  as a decimal?

- 0.6
- 0.5
- 1.5

4. Which is 0.7 as a fraction in lowest terms?
- 7/10
  - 1/7
  - 14/20
5. Which is greater?
- 0.68
  - 0.7
  - They are equal
6. What is  $4.25 + 1.69$ ?
- 5.94
  - 5.14
  - 6.94
7. What is  $6.5 - 2.42$ ?
- 4.18
  - 4.08
  - 4.88
8. What is  $\$3.55 + \$6.45$ ?
- \$9.00
  - \$10.00
  - \$8.90
9. Estimate:  $7.18 + 1.86$
- 8
  - 9
  - 10
10. Multiply:  $0.8 \times 0.4$
- 0.32
  - 0.12
  - 0.28

Submit

# Algebra Foundations: Concepts, Examples, and Practice

Exponents, Scientific Notation, Properties, Equations, Inequalities & More

Concepts

Examples

Pre-Test

Questions & Answers

Post-Test

## Chapter 1: Key Concepts

### 1. Exponents

- An **exponent** shows how many times a number (base) is multiplied by itself.  
Example:  $3^4 = 3 \times 3 \times 3 \times 3 = 81$
- Basic rules:
  - **Multiplying same bases:**  $a^m \times a^n = a^{m+n}$
  - **Dividing same bases:**  $a^m \div a^n = a^{m-n}$
  - **Power of a power:**  $(a^m)^n = a^{mn}$
  - **Zero exponent:**  $a^0 = 1$  (if  $a \neq 0$ )

### 2. Scientific Notation

- Used to write very large or small numbers compactly.  
Format:  $a \times 10^n$ , where  $1 \leq |a| < 10$ ,  $n$  is an integer.  
Example:  $4500000 = 4.5 \times 10^6$

### 3. Order of Operations

- Use PEMDAS: Parentheses, Exponents, Multiplication/Division (left to right), Addition/Subtraction (left to right)
- Example:  $2 + 3 \times (4^2 - 1) = 2 + 3 \times (16 - 1) = 2 + 3 \times 15 = 2 + 45 = 47$

### 4. Commutative and Associative Properties

- **Commutative:** Order doesn't matter for addition/multiplication:
  - Addition:  $a + b = b + a$
  - Multiplication:  $ab = ba$
- **Associative:** Grouping doesn't matter for addition/multiplication:
  - Addition:  $(a + b) + c = a + (b + c)$
  - Multiplication:  $(ab)c = a(bc)$

## 5. Distributive Property and Identity

- **Distributive:**  $a(b + c) = ab + ac$
- **Identity:**
  - Addition identity:  $a + 0 = a$
  - Multiplication identity:  $a \times 1 = a$

## 6. Zero Property, Equality Properties

- **Zero property of multiplication:**  $a \times 0 = 0$
- **Equality properties:** If  $a = b$ , then:
  - Addition:  $a + c = b + c$
  - Multiplication:  $ac = bc$

## 7. Factors and Multiples

- **Factor:** A number that divides another number evenly.  
**Multiple:** The result of multiplying a number by an integer.  
Example: Factors of 12 are 1, 2, 3, 4, 6, 12. Multiples of 3 are 3, 6, 9, 12, etc.

## 8. Understanding Variable Expressions

- A **variable** is a symbol (like  $x$ ) representing an unknown value.
- Expressions use variables, numbers, and operations. E.g.,  $2x + 5$ .

## 9. Solving Equations by Addition and Subtraction

- Goal: Isolate the variable. Example:  $x + 7 = 12 \Rightarrow x = 12 - 7 = 5$

## 10. Solving Equations by Multiplication and Division

- Example:  $3x = 15 \Rightarrow x = 15 \div 3 = 5$

## 11. Inequalities

- Symbols:  $>$  (greater than),  $<$  (less than),  $\geq$ ,  $\leq$
- Example:  $x > 3$  means  $x$  is any number greater than 3.

## 12. Solving Equations and Inequalities by Substitution

- Replace the variable with a given value and check if the equation/inequality is true.

## Chapter 2: Examples

- **Exponents:**  $2^5 = 2 \times 2 \times 2 \times 2 \times 2 = 32$

- **Scientific Notation:**  $0.00031 = 3.1 \times 10^{-4}$
- **Order of Operations:**  $5 + 2 \times 6 = 5 + 12 = 17$
- **Commutative Property:**  $4 + 9 = 9 + 4 = 13$
- **Associative Property:**  $(1 + 2) + 3 = 1 + (2 + 3) = 6$
- **Distributive Property:**  $3(x + 4) = 3x + 12$
- **Identity:**  $0 + 7 = 7, 1 \times 5 = 5$
- **Zero Property:**  $8 \times 0 = 0$
- **Factors/Multiples:** Factors of 15: 1, 3, 5, 15. Multiples of 4: 4, 8, 12, 16, ...
- **Variable Expression:** For  $x = 2, 3x + 1 = 3(2) + 1 = 7$
- **Solving by Addition/Subtraction:**  $x - 8 = 2 \implies x = 2 + 8 = 10$
- **Solving by Multiplication/Division:**  $x/4 = 5 \implies x = 5 \times 4 = 20$
- **Inequality:** Is  $x = 7$  a solution to  $x > 4$ ? Yes, because  $7 > 4$ .
- **Substitution:** Is  $x = 3$  a solution to  $2x + 1 = 7$ ?  $2(3) + 1 = 7 \implies$  Yes.

## Chapter 3: Pre-Test (40 Multiple Choice Questions)

**Q1.** What is  $2^3$ ?

- A. 6
- B. 8
- C. 9
- D. 16

**Q2.** Rewrite 5000 in scientific notation.

- A.  $5 \times 10^4$
- B.  $5 \times 10^3$
- C.  $0.5 \times 10^4$
- D.  $50 \times 10^2$

**Q3.** Solve:  $5 + 2 \times 3$

- A. 21
- B. 16
- C. 11
- D. 13

**Q4.** What is the commutative property of addition?

- A.  $a + b = b + a$
- B.  $(a + b) + c = a + (b + c)$

- C.  $a(b + c) = ab + ac$
- D.  $a + 0 = a$

**Q5.** Simplify:  $(4 + 5) + 6$

- A. 15
- B. 9
- C. 10
- D. 11

**Q6.** Expand using distributive property:  $2(x + 7)$

- A.  $2x + 14$
- B.  $2x + 7$
- C.  $x + 14$
- D.  $2x + 7x$

**Q7.** What is the identity element for multiplication?

- A. 0
- B. 1
- C. 10
- D. None

**Q8.** What is  $9 \times 0$ ?

- A. 9
- B. 0
- C. 1
- D. Undefined

**Q9.** List all factors of 18.

- A. 1, 2, 3, 6, 9, 18
- B. 1, 2, 4, 9, 18
- C. 1, 3, 6, 18
- D. 1, 2, 3, 4, 6, 18

**Q10.** Write the first 3 multiples of 6.

- A. 6, 12, 18
- B. 1, 6, 12
- C. 6, 18, 24

D. 6, 12, 24

**Q11.** What is a variable?

- A. A number that never changes
- B. A symbol representing an unknown value
- C. A type of equation
- D. A type of answer

**Q12.** Evaluate  $x + 3$  for  $x = 5$ .

- A. 8
- B. 7
- C. 2
- D. 10

**Q13.** Solve:  $x + 4 = 9$

- A. 4
- B. 5
- C. 9
- D. 13

**Q14.** Solve:  $3x = 12$

- A. 4
- B. 3
- C. 6
- D. 12

**Q15.** What does  $x > 2$  mean?

- A.  $x$  is less than 2
- B.  $x$  is equal to 2
- C.  $x$  is greater than 2
- D.  $x$  is not equal to 2

**Q16.** Solve:  $x - 7 = 10$

- A. 3
- B. 7
- C. 10
- D. 17

**Q17.** Is 5 a solution to  $x < 7$ ?

- A. Yes, because 5 is less than 7
- B. No, 5 is not less than 7
- C. Yes, because 5 is more than 7
- D. No, 5 equals 7

**Q18.** What is  $10^0$ ?

- A. 0
- B. 1
- C. 10
- D. Undefined

**Q19.** Rewrite 0.0008 in scientific notation.

- A.  $8 \times 10^{-4}$
- B.  $8 \times 10^{-3}$
- C.  $8 \times 10^{-5}$
- D.  $0.8 \times 10^{-3}$

**Q20.** True or False:  $a + 0 = a$ .

- A. True
- B. False
- C. Only if a is 0
- D. Only if a is 1

**Q21.** Solve:  $x/2 = 6$ .

- A. 3
- B. 12
- C. 8
- D. 4

**Q22.** Expand:  $5(y - 3)$

- A.  $5y - 3$
- B.  $5y - 15$
- C.  $y - 15$
- D.  $5y + 15$

**Q23.** What is the associative property of multiplication?

- A.  $a(bc) = (ab)c$
- B.  $ab = ba$
- C.  $a + b = b + a$
- D.  $a(b + c) = ab + ac$

**Q24.** List all factors of 24.

- A. 1, 2, 3, 4, 6, 8, 12, 24
- B. 1, 2, 3, 6, 9, 12
- C. 1, 3, 8, 24
- D. 2, 4, 6, 12, 24

**Q25.** What is the value of  $4^2$ ?

- A. 8
- B. 12
- C. 16
- D. 4

**Q26.** Is  $x = 3$  a solution to  $2x + 1 = 7$ ?

- A. Yes, because  $2 \times 3 + 1 = 7$
- B. No, because  $2 \times 3 + 1 = 6$
- C. Yes, because  $2 \times 3 = 7$
- D. No, because  $3 + 1 = 7$

**Q27.** Evaluate  $3x - 2$  when  $x = 4$ .

- A. 10
- B. 12
- C. 14
- D. 8

**Q28.** Solve:  $x - 5 = 0$

- A. 0
- B. 5
- C. 10
- D. 1

**Q29.** What is the multiplicative identity?

- A. 0
- B. 1
- C. 10
- D. None

**Q30.** Write 12000 in scientific notation.

- A.  $1.2 \times 10^4$
- B.  $12 \times 10^2$
- C.  $1.2 \times 10^3$
- D.  $12 \times 10^3$

**Q31.** Simplify:  $7 + (2 + 5)$

- A. 9
- B. 14
- C. 7
- D. 12

**Q32.** Solve:  $x/5 = 9$

- A. 45
- B. 14
- C. 9
- D. 5

**Q33.** What is  $0 \times 100$ ?

- A. 0
- B. 100
- C. 1
- D. Undefined

**Q34.** What does PEMDAS stand for?

- A. Parentheses, Exponents, Multiplication, Division, Addition, Subtraction
- B. Please Eat My Delicious Apple Slices
- C. Powers, Equations, Multiplication, Division, Addition, Subtraction
- D. Parentheses, Exponents, Multiples, Division, Addition, Sums

**Q35.** Solve:  $2x = 14$

- A. 7

- B. 12
- C. 6
- D. 14

**Q36.** Write the first 4 multiples of 7.

- A. 7, 14, 21, 28
- B. 7, 14, 17, 24
- C. 14, 21, 28, 35
- D. 14, 21, 28, 42

**Q37.** List all factors of 20.

- A. 1, 2, 4, 5, 10, 20
- B. 2, 4, 5, 10, 20
- C. 1, 4, 5, 20
- D. 1, 2, 5, 10, 20

**Q38.** Expand:  $4(a + 2)$

- A.  $4a + 2$
- B.  $4a + 8$
- C.  $a + 8$
- D.  $4a + 2a$

**Q39.** Is  $x = 0$  a solution to  $x + 5 = 5$ ?

- A. Yes, because  $0 + 5 = 5$
- B. No, because  $0 + 5 = 0$
- C. Yes, because  $0 - 5 = 5$
- D. No, because  $0 + 5 = 6$

**Q40.** Solve:  $x + 8 = 13$

- A. 5
- B. 8
- C. 13
- D. 21

Submit Answers

## Chapter 4: Questions & Answers

No questions! You got everything correct!

## Chapter 5: Post-Test (40 Questions)

1. What is  $3^2$ ?
2. Rewrite 0.005 in scientific notation.
3. Solve:  $4 + 3 \times 2$
4. What is the commutative property of multiplication?
5. Simplify:  $(5 + 3) + 2$
6. Expand using distributive property:  $4(x + 5)$
7. What is the identity element for addition?
8. What is  $7 \times 0$ ?
9. List all factors of 16.
10. Write the first 3 multiples of 8.
11. What is a variable expression?
12. Evaluate  $x - 2$  for  $x = 10$ .
13. Solve:  $x - 3 = 8$
14. Solve:  $5x = 20$
15. What does  $x < 6$  mean?
16. Solve:  $x + 5 = 12$
17. Is 6 a solution to  $x > 5$ ?
18. What is  $5^0$ ?
19. Rewrite 0.07 in scientific notation.
20. True or False:  $a \times 1 = a$ .
21. Solve:  $x/3 = 7$ .
22. Expand:  $3(y + 4)$
23. What is the associative property of addition?
24. List all factors of 30.
25. What is the value of  $6^2$ ?
26. Is  $x = 2$  a solution to  $3x + 1 = 7$ ?
27. Evaluate  $4x + 3$  when  $x = 2$ .
28. Solve:  $x - 7 = 0$
29. What is the additive identity?
30. Write 67000 in scientific notation.
31. Simplify:  $2 + (3 + 4)$
32. Solve:  $x/2 = 8$
33. What is  $0 \times 25$ ?
34. What does PEMDAS stand for?
35. Solve:  $4x = 24$
36. Write the first 4 multiples of 5.
37. List all factors of 14.

38. Expand:  $2(a + 6)$

39. Is  $x = 1$  a solution to  $x + 4 = 5$ ?

40. Solve:  $x + 9 = 17$

# Measurement Mastery

Your guide to Customary and Metric Units, Conversions, and Applications

[Customary Units](#)

[Metric Units](#)

[Unit Conversion](#)

[Key Concepts](#)

[Examples](#)

[Pre-test](#)

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## Customary Units

### ▼ Customary Units of Length

- **Inch (in):** Smallest unit commonly used. 12 inches = 1 foot.
- **Foot (ft):** 1 foot = 12 inches. 3 feet = 1 yard.
- **Yard (yd):** 1 yard = 3 feet = 36 inches.
- **Mile (mi):** 1 mile = 1,760 yards = 5,280 feet.

### ▼ Customary Units of Liquid Volume

- **Fluid ounce (fl oz)**
- **Cup (c):** 1 cup = 8 fl oz
- **Pint (pt):** 1 pint = 2 cups = 16 fl oz
- **Quart (qt):** 1 quart = 2 pints = 4 cups = 32 fl oz
- **Gallon (gal):** 1 gallon = 4 quarts = 8 pints = 16 cups = 128 fl oz

### ▼ Customary Units of Weight

- **Ounce (oz):** Smallest unit.
- **Pound (lb):** 1 pound = 16 ounces
- **Ton (T):** 1 ton = 2,000 pounds

### ▼ Perimeter

The distance around a two-dimensional shape.

**Example:** Perimeter of a rectangle =  $2 \times (\text{Length} + \text{Width})$

### ▼ Area

The number of square units covering a surface.

**Example:** Area of a rectangle = Length  $\times$  Width

### ▼ Volume of a Solid

The amount of space a solid occupies.

**Example:** Volume of a rectangular prism = Length  $\times$  Width  $\times$  Height

### ▼ Time

- Second (s)
- Minute (min): 1 minute = 60 seconds
- Hour (hr): 1 hour = 60 minutes
- Day: 1 day = 24 hours
- Week: 1 week = 7 days

### ▼ Temperature

- Degrees Fahrenheit (°F)
- Water freezes at 32°F, boils at 212°F

## Metric Units

### ▼ Metric Units of Length

- **Millimeter (mm)**
- **Centimeter (cm):** 1 cm = 10 mm
- **Meter (m):** 1 m = 100 cm

- **Kilometer (km):** 1 km = 1,000 m

### ▼ Metric Units of Liquid Volume

- **Milliliter (mL)**
- **Liter (L):** 1 L = 1,000 mL

### ▼ Metric Units of Mass

- **Milligram (mg)**
- **Gram (g):** 1 g = 1,000 mg
- **Kilogram (kg):** 1 kg = 1,000 g

### ▼ Perimeter, Area, and Volume of a Solid: Metric

- **Perimeter:** Sum of side lengths (measured in meters, centimeters, etc.)
- **Area:** Measured in square meters ( $m^2$ ), square centimeters ( $cm^2$ ), etc.
- **Volume:** Measured in cubic meters ( $m^3$ ), liters (L), etc.

## Conversion Between Units

### ▼ Changing from Customary Units to Metric Units

- 1 inch  $\approx$  2.54 centimeters
- 1 foot  $\approx$  0.3048 meters
- 1 mile  $\approx$  1.609 kilometers
- 1 pound  $\approx$  0.454 kilograms
- 1 ounce  $\approx$  28.35 grams
- 1 gallon  $\approx$  3.785 liters
- 1 quart  $\approx$  0.946 liters

### ▼ Changing from Metric Units to Customary Units

- 1 centimeter  $\approx$  0.3937 inches
- 1 meter  $\approx$  3.281 feet

- 1 kilometer  $\approx$  0.621 miles
- 1 kilogram  $\approx$  2.205 pounds
- 1 gram  $\approx$  0.035 ounces
- 1 liter  $\approx$  0.264 gallons

## Key Concepts Explained

### ▼ What is Measurement?

Measurement is the process of quantifying the physical properties of objects or events using standard units. It helps us compare, estimate, and understand the world around us.

### ▼ Why Are There Different Systems?

Customary units are mainly used in the United States, while the metric system is used worldwide. The metric system is based on powers of ten, making conversions simpler.

### ▼ Estimating and Choosing Units

Use smaller units for small objects (like millimeters or inches) and larger units for big distances (like kilometers or miles). Choose units that make sense for what you are measuring.

### ▼ Temperature Scales

Fahrenheit is common in the U.S., Celsius is used elsewhere. To convert:

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times \frac{5}{9}$$

$$^{\circ}\text{F} = (^{\circ}\text{C} \times \frac{9}{5}) + 32$$

## Examples

### ▼ Example 1: Converting Inches to Centimeters

**Problem:** Convert 10 inches to centimeters.

**Solution:**  $10 \text{ in} \times 2.54 = \mathbf{25.4 \text{ cm}}$

### ▼ Example 2: Area of a Rectangle (Customary Units)

**Problem:** A rectangle is 5 feet long and 3 feet wide. What is its area?

**Solution:** Area = 5 ft × 3 ft = **15 ft<sup>2</sup>**

### ▼ Example 3: Volume of a Rectangular Prism (Metric Units)

**Problem:** A box measures 20 cm × 10 cm × 5 cm. What is its volume?

**Solution:** Volume = 20 × 10 × 5 = **1,000 cm<sup>3</sup>**

### ▼ Example 4: Converting Celsius to Fahrenheit

**Problem:** What is 25°C in Fahrenheit?

**Solution:**  $(25 \times 9/5) + 32 = 77^{\circ}\text{F}$

## Pre-test (40 Questions)

1. How many inches are in a foot?
2. How many feet are in a yard?
3. How many yards are in a mile?
4. How many ounces are in a pound?
5. How many pints are in a quart?
6. How many cups are in a gallon?
7. What is the metric unit for mass?
8. How many centimeters are in a meter?
9. How many millimeters are in a centimeter?
10. How many liters are in a kiloliter?
11. Convert 5 feet to inches.
12. Convert 3 yards to feet.
13. Convert 2 miles to feet.
14. Convert 24 inches to feet.
15. What is the perimeter of a rectangle with length 6 ft and width 4 ft?
16. What is the area of a rectangle with length 8 m and width 3 m?
17. What is the volume of a box 2 m × 2 m × 2 m?
18. Convert 1.5 liters to milliliters.
19. Convert 500 grams to kilograms.
20. Convert 1000 millimeters to meters.
21. How many minutes are in an hour?
22. How many seconds in 2 minutes?
23. What is the freezing point of water in Fahrenheit?
24. What is the boiling point of water in Celsius?

25. Convert 10 kilometers to meters.
26. Convert 2500 milliliters to liters.
27. Convert 3 kilograms to grams.
28. Which is greater: 1 pound or 500 grams?
29. What metric unit would you use to measure the length of a pencil?
30. What customary unit would you use to measure the length of a football field?
31. Convert 40°F to Celsius.
32. Convert 100°C to Fahrenheit.
33. How many gallons are in 16 quarts?
34. How many quarts are in 2 gallons?
35. What is the perimeter of a square with sides of 7 cm?
36. What is the area of a square with sides of 5 m?
37. What is the volume of a cube with sides of 3 m?
38. How many days are in a week?
39. What is the metric prefix for one thousand?
40. Which is heavier: 1 kilogram or 2 pounds?

## Questions & Answers

### ▼ How do you convert inches to centimeters?

Multiply the number of inches by 2.54 to get centimeters.

### ▼ What is the formula for the area of a rectangle?

Area = Length × Width

### ▼ What is the difference between mass and weight?

Mass measures the amount of matter in an object (kilograms, grams). Weight measures the force of gravity on an object (pounds, newtons).

### ▼ How do you convert Celsius to Fahrenheit?

Multiply by  $9/5$  and add 32. ( $^{\circ}\text{F} = ^{\circ}\text{C} \times 9/5 + 32$ )

### ▼ Which is larger: a gallon or a liter?

A gallon (about 3.785 liters) is larger than a liter.

### ▼ How do you find the perimeter of a polygon?

Add up the lengths of all sides.

### ▼ What is the metric unit for temperature?

Degrees Celsius ( $^{\circ}\text{C}$ )

### ▼ How many meters are in a kilometer?

1,000 meters

## Post-test (40 Questions)

1. How many quarts are in a gallon?
2. How many feet are in a mile?
3. How many yards are in 18 feet?
4. How many ounces are in 3 pounds?
5. How many cups are in a quart?
6. What is the metric unit for length?
7. How many grams are in a kilogram?
8. How many liters are in 3 kiloliters?
9. Convert 36 inches to yards.
10. Convert 4 feet to centimeters.
11. Convert 2 miles to kilometers.
12. Convert 16 ounces to grams.

13. What is the area of a rectangle 10 ft by 4 ft?
14. What is the perimeter of a rectangle 5 m by 8 m?
15. What is the volume of a box 3 m × 4 m × 5 m?
16. Convert 1200 grams to kilograms.
17. Convert 2500 milliliters to liters.
18. Convert 5 kilometers to miles.
19. Which is more: 1 liter or 1 quart?
20. How many minutes are in 2 hours?
21. How many seconds are in 5 minutes?
22. What is room temperature in Celsius?
23. Convert 68°F to Celsius.
24. Convert 20°C to Fahrenheit.
25. How many millimeters are in 5 centimeters?
26. What is the perimeter of a square with sides of 12 m?
27. What is the area of a square with sides of 9 cm?
28. What is the volume of a cube with sides of 4 cm?
29. How many days are in a leap year?
30. What is the metric prefix for one hundred?
31. Which is heavier: 1 kilogram or 1,000 grams?
32. How many pints are in a gallon?
33. How many cups are in 2 quarts?
34. What customary unit measures a person's weight?
35. What metric unit measures the mass of a book?
36. Convert 500 ml to liters.
37. How many centimeters are in a meter?
38. Which is longer: 1 yard or 1 meter?
39. How many weeks in a year?
40. What is the boiling point of water in Fahrenheit?

# Geometry Basics: Points, Lines, Angles & Figures

A Self-Study Guide with Tests and Answers

Points & Lines

Angles

Triangles

Quadrilaterals & Polygons

Circles

Solid Figures

Surface Area

Graphing

Concepts

Examples

Pre-Test

Q & A

Post-Test

## Points and Lines

- **Point:** An exact location in space, often named by a capital letter (e.g., A).
- **Line:** A straight path extending in both directions without end; has infinite length but no thickness. Named by two points (e.g., line  $AB$ ) or a lowercase letter.
- **Line Segment:** A part of a line between two endpoints. Example: *Segment  $AB$* .
- **Ray:** A part of a line that starts at one endpoint and extends infinitely in one direction. Example: *Ray  $AB$*  starts at A and passes through B.

## Measuring Angles & Types of Angles

- **Angle:** Formed by two rays (the sides) with a common endpoint (the vertex).
- **Measuring Angles:** Angles are measured in degrees ( $^{\circ}$ ).
- **Types of Angles:**
  - **Acute:** Less than  $90^{\circ}$ .
  - **Right:** Exactly  $90^{\circ}$ .
  - **Obtuse:** Between  $90^{\circ}$  and  $180^{\circ}$ .
  - **Straight:** Exactly  $180^{\circ}$ .
  - **Reflex:** Between  $180^{\circ}$  and  $360^{\circ}$ .
  - **Adjacent, Complementary, Supplementary Angles**

## Triangles

- **Classified by Sides:**
  - **Equilateral:** 3 equal sides
  - **Isosceles:** 2 equal sides
  - **Scalene:** No equal sides
- **Classified by Angles:**
  - **Acute Triangle:** All angles  $< 90^{\circ}$
  - **Right Triangle:** One angle is  $90^{\circ}$

- **Obtuse Triangle:** One angle  $> 90^\circ$
- **Triangle Sum Theorem:** The sum of the interior angles is  $180^\circ$ .

## Quadrilaterals & Polygons

- **Quadrilaterals:** 4-sided polygons.
  - **Parallelogram**
  - **Rectangle**
  - **Square**
  - **Rhombus**
  - **Trapezoid**
- **Polygons:** Closed shapes with 3 or more straight sides (triangle, pentagon, hexagon, etc.).
  - **Regular Polygon:** All sides and angles are equal.
  - **Irregular Polygon:** Sides and/or angles are not all equal.

## Circles

- **Circle:** Set of points equidistant from a center point.
- **Radius:** Distance from center to any point on the circle.
- **Diameter:** A chord passing through the center (twice the radius).
- **Circumference:** The perimeter of the circle.
- **Chord:** A segment with endpoints on the circle.
- **Arc:** A part of the circumference.
- **Sector:** A region bounded by two radii and an arc.

## Solid Figures

- **Cuboid (Rectangular Prism)**
- **Cube**
- **Sphere**
- **Cylinder**
- **Cone**
- **Pyramid**

## Surface Area

- **Cuboid:**  $2(lw + lh + wh)$
- **Cube:**  $6a^2$
- **Cylinder:**  $2\pi r(h + r)$
- **Sphere:**  $4\pi r^2$
- **Cone:**  $\pi r(l + r)$ , where  $l$  is the slant height

## Graphing Figures

- Plotting points on the Cartesian plane (x, y).
- Graphing lines:  $y = mx + b$  (slope-intercept form).
- Graphing polygons by connecting plotted vertices.
- Graphing a circle:  $(x - h)^2 + (y - k)^2 = r^2$

## Chapter: Key Concepts Explained

- **Congruence:** Figures that have the same shape and size.
- **Similarity:** Figures that have the same shape but not necessarily the same size (corresponding angles equal, sides proportional).
- **Perimeter:** The distance around a figure.
- **Area:** The measure of the surface inside a figure.
- **Volume:** The amount of space inside a solid figure.
- **Midpoint:** The point that divides a segment into two equal parts.
- **Bisect:** To divide into two equal parts (can be an angle or a segment).
- **Parallel lines:** Lines in a plane that never meet.
- **Perpendicular lines:** Lines that meet at a right angle (90°).
- **Coordinate Geometry:** Using algebra and coordinates to study geometric properties.

## Chapter: Examples

### Example 1:

Classify the triangle with sides 5 cm, 5 cm, and 8 cm.

*Solution:* Since two sides are equal, it is **isosceles**.

### Example 2:

Find the area of a rectangle with length 10 cm and width 4 cm.

*Solution:* Area = length  $\times$  width =  $10 \times 4 = 40 \text{ cm}^2$ .

### Example 3:

Name the angle type if it measures 120°.

*Solution:* It is an **obtuse angle**.

### Example 4:

Find the circumference of a circle with radius 7 cm ( $\pi = 3.14$ ).

*Solution:* Circumference =  $2\pi r = 2 \times 3.14 \times 7 = 43.96 \text{ cm}$ .

**Example 5:**

What is the midpoint of segment AB if A(2, 3) and B(6, 11)?

*Solution:* Midpoint =  $((2+6)/2, (3+11)/2) = (4, 7)$

## Pre-Test: Geometry (40 Questions)

**1. What is a point?**

- The intersection of two lines
- An exact location in space
- A line with no endpoints
- A segment between two points

**2. What do you call a part of a line with two endpoints?**

- Ray
- Chord
- Line segment
- Diameter

**3. Which of these is a ray?**

- AB (with both ends)
- AB (with one endpoint and one arrow)
- A circle
- A square

**4. How many degrees in a right angle?**

- 45°
- 90°
- 120°
- 180°

**5. An angle measuring 74° is called:**

- Acute
- Right
- Obtuse
- Reflex

**6. The sum of the angles in a triangle is:**

- 90°
- 180°

- 270°
- 360°

**7. A triangle with all sides equal is called:**

- Scalene
- Isosceles
- Equilateral
- Right

**8. A quadrilateral with 2 pairs of parallel sides and all angles equal is a:**

- Square
- Rectangle
- Rhombus
- Parallelogram

**9. A polygon with 6 sides is a:**

- Pentagon
- Hexagon
- Heptagon
- Octagon

**10. What is the center of a circle called?**

- Radius
- Diameter
- Chord
- Center

**11. The distance from the center of a circle to a point on the circle is called:**

- Radius
- Diameter
- Chord
- Arc

**12. A cube has how many faces?**

- 4
- 6
- 8
- 12

**13. The formula for the area of a rectangle is:**

- $2 \times (l + w)$
- $l \times w$

- $l + w$
- $l \div w$

**14. The surface area of a sphere is:**

- $2\pi r^2$
- $4\pi r^2$
- $\pi r^2$
- $\pi d$

**15. Which is NOT a polygon?**

- Triangle
- Square
- Circle
- Hexagon

**16. The sum of the angles in a quadrilateral is:**

- $90^\circ$
- $180^\circ$
- $270^\circ$
- $360^\circ$

**17. A triangle with one  $90^\circ$  angle is called:**

- Acute triangle
- Obtuse triangle
- Right triangle
- Equilateral triangle

**18. What is a line that touches a circle at only one point called?**

- Chord
- Tangent
- Radius
- Diameter

**19. The perimeter of a figure is:**

- The amount of space inside it
- The sum of its sides
- Its height
- Its diameter

**20. A parallelogram with all sides equal and all angles  $90^\circ$  is a:**

- Rectangle
- Rhombus

- Square
- Trapezoid

**21. An angle greater than  $90^\circ$  and less than  $180^\circ$  is:**

- Acute
- Right
- Obtuse
- Reflex

**22. The formula for the volume of a cuboid is:**

- $l \times w \times h$
- $2(l + w + h)$
- $l \times w$
- $l \times h$

**23. The longest chord of a circle is called:**

- Radius
- Diameter
- Arc
- Tangent

**24. How many sides does a decagon have?**

- 8
- 9
- 10
- 12

**25. Which figure has only one curved surface?**

- Cylinder
- Sphere
- Cube
- Pyramid

**26. A triangle with sides 3 cm, 4 cm, 5 cm is:**

- Equilateral
- Isosceles
- Right triangle
- Obtuse triangle

**27. The number of diagonals in a pentagon is:**

- 2
- 5

- 6
- 10

**28. A straight angle measures:**

- $90^\circ$
- $180^\circ$
- $270^\circ$
- $360^\circ$

**29. The area of a triangle is:**

- base  $\times$  height
- $(\text{base} \times \text{height}) \div 2$
- base + height
- $2 \times (\text{base} + \text{height})$

**30. Two lines that never meet are:**

- Parallel
- Perpendicular
- Intersecting
- Tangent

**31. A regular polygon has:**

- Equal sides and angles
- Equal sides only
- Equal angles only
- No equal sides

**32. What is the formula for circumference of a circle?**

- $\pi r^2$
- $2\pi r$
- $\pi d^2$
- $2\pi d$

**33. The number of faces on a rectangular prism is:**

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**34. A line that divides a figure into two equal parts is called:**

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- Bisector
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**35. The midpoint of segment AB with A(2,3) and B(6,7) is:**

- (4,5)
- (8,10)
- (2,7)
- (3,5)

**36. The sum of the interior angles of a hexagon is:**

- $360^\circ$
- $540^\circ$
- $720^\circ$
- $900^\circ$

**37. A segment from the center of a circle to any point on the circle is:**

- Chord
- Radius
- Diameter
- Arc

**38. The height in a triangle is:**

- The longest side
- A side perpendicular to the base
- The base
- Any side

**39. In coordinate geometry, the y-intercept is:**

- Where the graph crosses the y-axis
- Where the graph crosses the x-axis
- The slope
- The midpoint

**40. A triangle with all angles less than  $90^\circ$  is:**

- Right triangle
- Obtuse triangle
- Acute triangle
- Equilateral triangle

Submit

## Chapter: Questions & Answers

Questions and answers will appear here after you complete the pre-test.  
Each incorrect pre-test answer will be explained below.

### Post-Test: Geometry (40 Questions)

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- (base  $\times$  height)  $\div$  2
- base + height
- 2  $\times$  (base + height)

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Submit

# Train a Single Neuron for Linear Regression

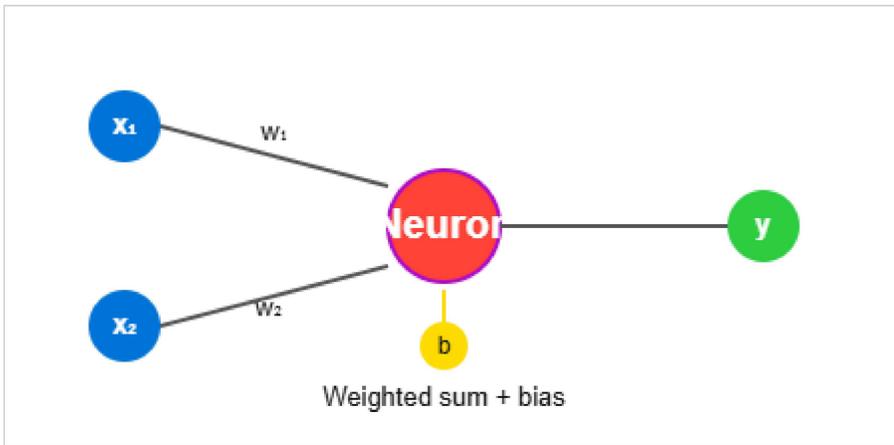
## Introduction to Linear Regression

Linear regression is a fundamental technique in machine learning and statistics. It models the relationship between a dependent variable ( $y$ ) and one or more independent variables ( $x$ ) by fitting a straight line through the data points. The equation of this line is typically written as:

$$y = w_1x_1 + w_2x_2 + \dots + b$$

where  $w$  are the weights (slopes for each input), and  $b$  is the bias (y-intercept).

## How Does a Single Neuron Work?



## Example: Predicting House Price

Suppose we want to predict the price of a house ( $y$ ) based on its size ( $x_1 = 50 \text{ m}^2$ ) and number of bedrooms ( $x_2 = 2$ ).

Assume our neuron has learned the weights:  $w_1 = 2,000$ ,  $w_2 = 10,000$ , and  $b = 5,000$ .

- The neuron computes:  
 $y = 2,000 \times 50 + 10,000 \times 2 + 5,000 = 100,000 + 20,000 + 5,000 = 125,000$
- So, the estimated house price is **125,000** (currency units).

This is how a single neuron can be used for linear regression: it learns weights for each input and a bias to make predictions.

## Train a Single Neuron for Linear Regression

Enter your data points below (one  $(x, y)$  pair per line, separated by a comma), then train the single neuron to fit a line:

```
0,1
1,3
2,5
3,7
```

Train Neuron



## TensorFlow.js Discussion

**TensorFlow.js** is an open-source library that enables machine learning directly in the browser or in Node.js using JavaScript. With TensorFlow.js, developers can train and run machine learning models without needing Python or server-side computation. This is particularly useful for interactive web-based applications, real-time inference, and privacy-preserving computation since all processing can occur on the client side.

- Offers support for all major operating systems and devices that support web browsers.
- Provides GPU acceleration through WebGL for fast computations.
- Allows importing models trained in Python (TensorFlow/Keras) and running them in JavaScript environments.
- Ideal for education, interactive demos, or production-ready AI in web apps.

In this demo, we use TensorFlow.js to create and train a basic model: a single neuron performing linear regression.

## Classic Libraries for Model Definition, Training, and Visualization

### Model Definition and Training Libraries

- **TensorFlow.js (v0.x)**: The first versions of [TensorFlow.js](#) (e.g., v0.6.0, released in early 2018) enabled users to define, train, and run neural network models directly in the browser using JavaScript. These early releases provided layers, optimizers, and basic data handling, establishing the foundation for machine learning in the browser.
- **ConvNetJS**: Released by Andrej Karpathy in 2014, [ConvNetJS](#) is one of the earliest neural network libraries for browsers. It supports defining and training neural nets (including linear regression, multi-layer perceptrons, and convolutional nets) entirely in JavaScript with no dependencies.

### Visualization Libraries

- **D3.js (v3)**: [D3.js v3](#) is a pioneering JavaScript library for data-driven document manipulation (visualization), released in 2012. It was widely used for plotting data, drawing graphs, and making interactive visualizations in the browser. Many early machine learning demos and model visualizations used D3 v3 for rendering.
- **Chart.js (v1)**: [Chart.js v1](#) (2014) is a simple library for drawing charts on web pages using the HTML5 canvas. It was popular for visualizing training loss, accuracy, and regression lines in early

web-based machine learning projects.

These libraries paved the way for interactive, browser-based machine learning and visualization tools that are now common in education and research.

Run

## Discussion: The Cars Dataset

The dataset from [carsData.json](#) contains information about various car models, including attributes such as miles per gallon (mpg) and horsepower. This dataset is often used for regression tasks and demonstration of machine learning techniques in JavaScript tutorials.

The data may contain missing values or non-numeric entries. Before using it for training models, it is important to clean the dataset by removing records with incomplete or invalid data.

Load Dataset

## Visualization of Cleaned Data: Horsepower vs. Miles per Gallon

Now that the dataset is cleaned and available as `cleanedData`, we can visualize the relationship between **Horsepower** and **Miles\_per\_Gallon**. This scatter plot will help us understand the data points that will be used for training our model.

Show Visualization

## Splitting the Dataset: Training and Testing Sets

To evaluate a machine learning model fairly, it's important to train it on a portion of the data and test it on data it hasn't seen. The dataset is typically split into a **training set** (for model learning) and a **testing set** (for evaluation). A common split is 70% for training and 30% for testing.

Split the dataset

## Building an Artificial Neural Network Model

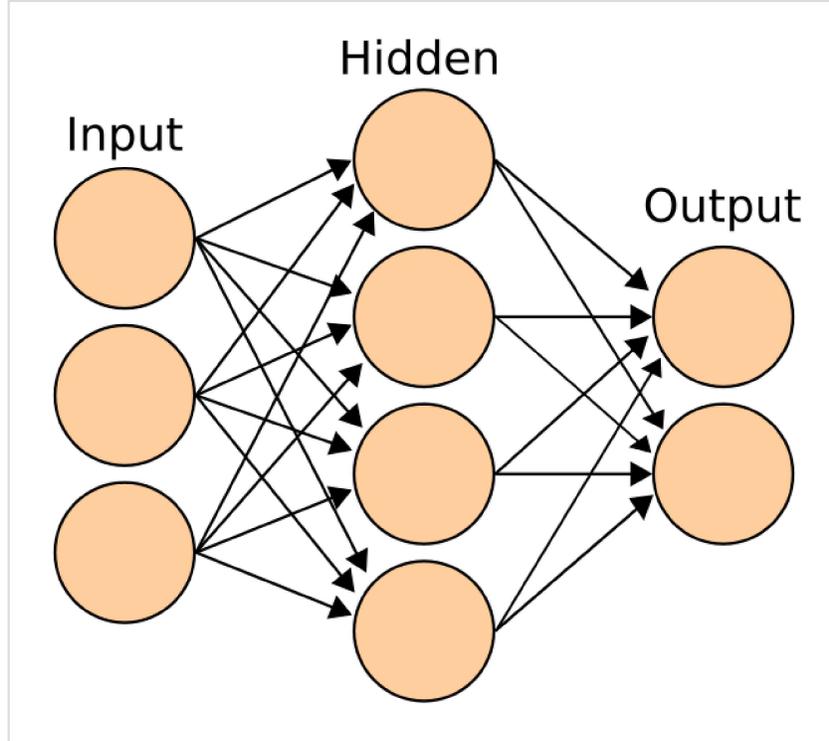
Neural networks are powerful tools for modeling complex nonlinear relationships in data. Here, we'll create a simple artificial neural network (ANN) that learns to predict **Miles\_per\_Gallon** from **Horsepower** using the training data we prepared earlier.

Define Neural Network Model

## What is an Artificial Neural Network?

An **artificial neural network** (ANN) is inspired by biological brains. It consists of interconnected layers of simple processing units called **neurons**. Each neuron receives inputs, applies weights, computes a sum, and then applies an *activation function* to determine its output.

- The **input layer** receives features (here, horsepower).
- The **hidden layer** processes the input through several neurons.
- The **output layer** produces the final prediction (here, miles per gallon).



*An example of a simple neural network with an input, a hidden, and an output layer.*

In this project, the model will learn from the **training set** you created to estimate the relationship between horsepower and miles per gallon, aiming to predict efficient vehicle performance.

## Training the Neural Network Model

Training means letting the neural network learn patterns from data. Here, the model will learn to predict **Miles\_per\_Gallon** from **Horsepower** using the `cleanedData` you loaded previously.

Train the Model

## Evaluating the Trained Neural Network Model

Once the model is trained, it's important to check how well it performs on new data it hasn't seen before. This is done using the **test set** that was separated from the `cleanedData`. Here, we'll compare the model's predictions with the real values to understand its performance.

Evaluate the model

## Understanding the Confusion Matrix

The **confusion matrix** is a useful tool for evaluating classification models. It shows the number of correct and incorrect predictions made by the model compared to the actual outcomes (labels). The matrix helps you see not only the overall accuracy, but also the types of errors the model makes.

- **True Positive (TP):** Model correctly predicts the positive class.
- **True Negative (TN):** Model correctly predicts the negative class.
- **False Positive (FP):** Model incorrectly predicts positive when it is actually negative (Type I error).
- **False Negative (FN):** Model incorrectly predicts negative when it is actually positive (Type II error).

A confusion matrix for a binary classifier looks like this:

|       |             |             |    |
|-------|-------------|-------------|----|
|       |             | Actual      |    |
|       |             | 1           | 0  |
|       |             | -----+----- |    |
|       | 1           | TP          | FP |
| Pred. | -----+----- |             |    |
|       | 0           | FN          | TN |

To use a confusion matrix with this regression demo, we will convert the regression output into two classes: for example, cars with **MPG above 23** are "Efficient" (1), and those with **MPG 23 or below** are "Not Efficient" (0). The threshold can be adjusted as needed.

Show confusion matrix

# Training a Convolutional Neural Network (CNN) in the Browser

## Introduction: What is a Convolutional Neural Network?

Convolutional Neural Networks (CNNs) are a class of deep learning models specialized for processing grid-like data, such as images. Introduced in the late 1990s, they have become the standard for image classification, object detection, and other computer vision tasks.

- **Convolutional Layers:** Extract features from input images using filters.
- **Pooling Layers:** Reduce the spatial dimensions, helping make the representations smaller and more manageable.
- **Fully Connected Layers:** Perform high-level reasoning and output predictions.

The main advantage of CNNs is their ability to automatically and adaptively learn spatial hierarchies of features from input images.

## How to Train a CNN

1. **Prepare the Dataset:** Gather and preprocess images, often normalizing and resizing them.
2. **Design the Model:** Stack convolutional, pooling, and dense layers to define the network architecture.
3. **Compile the Model:** Specify a loss function, optimizer, and metrics for evaluation.
4. **Train:** Feed the network batches of images and labels, allowing it to optimize its filters and weights through backpropagation.
5. **Evaluate & Improve:** Test the model on unseen data and tune hyperparameters or architecture as needed.

Training involves letting the model learn patterns in the data by minimizing the loss function through iterative updates.

## What Does a CNN Look Like?

A CNN is made of several layers, each containing many "neurons" (small computational units). The main types of layers are convolutional, pooling, and dense (fully connected) layers.



Layer (Output) Prediction

Diagram: Example flow in a simple CNN. Each layer transforms the image into a new set of features, ending in an output prediction.

## Easy Example: Recognizing Handwritten Digits

Imagine you want your computer to recognize whether a picture shows the digit “3” or “7”. You show it thousands of examples of hand-drawn numbers.

- The **input layer** takes the image as a grid of pixels.
- **Convolution layers** look for small patterns like edges or curves.
- **Pooling layers** simplify the information, focusing on the most important features.
- **The fully connected/output layer** combines this information to decide, for example, “this is likely a 3”.

The network learns by adjusting its inner connections every time it makes a mistake, until it gets very good at telling 3’s and 7’s apart—even if it’s never seen your handwriting before!

## TensorFlow.js: CNNs in JavaScript

[TensorFlow.js](#) is a JavaScript library for training and running machine learning models in the browser and on Node.js.

- **Easy Prototyping:** Build, train, and deploy models directly in the browser without server-side code.
- **GPU Acceleration:** Leverage WebGL for fast computation.
- **CNN Support:** Offers high-level layers like `tf.layers.conv2d`, `tf.layers.maxPooling2d`, and more for constructing CNNs.
- **Data Handling:** Built-in utilities for handling images and tensors, and even loading pre-made datasets such as MNIST.

With TensorFlow.js, you can experiment and visualize neural networks directly in the browser.

## Libraries for Building, Training, and Visualizing Neural Networks

Several JavaScript libraries make it possible to define, train, and visualize neural network models directly in your web browser:

- **TensorFlow.js** ([docs](#)): The main library for machine learning in JavaScript. It supports both model definition and training.
- **Keras.js** ([docs](#)): Enables running pre-trained Keras models in the browser.
- **TensorFlow.js Vis** ([docs](#)): Provides visualization tools for model training and evaluation in the browser.

These tools allow you to build, train, and monitor neural networks interactively and visually on the client side.

Run

## About the MNIST Dataset and Labels

The MNIST dataset consists of grayscale images of handwritten digits (0-9), commonly used for training and testing image classification models. The images are stored in a PNG file, where each digit is a 28x28 pixel square. Each image has an associated label, which indicates the digit it represents.

- **Images:** [mnist\\_images.png](#) — Contains thousands of handwritten digit images in a single large grid.
- **Labels:** [mnist\\_labels\\_uint8](#) — A binary file where each value corresponds to the label (0-9) of an image.

Together, these files provide the input data (images) and the ground-truth answers (labels) for training and evaluating neural network models.

Load MNIST Dataset

## Visualizing the Cleaned MNIST Dataset

Once the MNIST dataset is loaded, it can be helpful to visualize some sample images with their labels. This allows you to verify that the data was loaded correctly and to better understand the nature of the data your neural network will process.

Show Random Samples

## Splitting the Dataset: Training and Testing Sets

To evaluate machine learning models fairly, we divide the dataset into two parts: **training** and **testing**. The training set is used to teach the model, while the testing set is reserved for checking performance on unseen data. A typical split is 80% training and 20% testing.

Split the dataset

## Defining a Convolutional Neural Network (CNN)

Convolutional Neural Networks (CNNs) are highly effective for image recognition tasks like MNIST digit classification. Let's define a simple CNN model using TensorFlow.js. Click the button below to create the model and see its layer structure.

Define CNN Model

# What Is a Convolutional Neural Network?

A CNN processes images step-by-step:

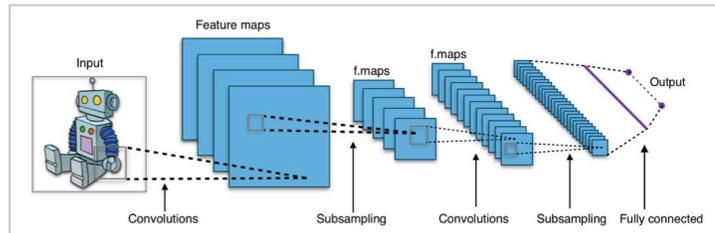


Image: Wikipedia, [Convolutional neural network](#)

1. **Convolutional Layers:** Detect features (like edges and shapes) by sliding filters over the image.
2. **Pooling Layers:** Reduce image size while keeping key information, making the network faster and more robust.
3. **Flatten & Dense Layers:** Combine detected features to predict the digit class (0–9).

CNNs are the backbone of modern image recognition systems, automatically learning which features matter most for the task.

## Training the CNN Model

Now that we have split our dataset and defined a CNN model, it's time to train the model using the training set. Training means letting the model learn the relationship between input images and their correct labels by adjusting its internal parameters.

1. Click the **Train Model** button below to begin training.
2. The process will run for several epochs (full passes over the training data), showing accuracy and loss for each epoch.
3. A chart below will update to show your model's progress visually.

Train Model

## Testing (Evaluating) the CNN Model

After training, we need to test our model on unseen data to measure how well it generalizes. This is called **model evaluation**.

We use the testing set (not used in training) and calculate metrics such as accuracy and loss.

1. Click the **Test Model** button below to evaluate the CNN on the test dataset.
2. The chart will show loss and accuracy for each test batch.
3. Final results will be displayed once testing is complete.

## Understanding the Confusion Matrix

A **confusion matrix** is a table used to evaluate the performance of a classification model. Each row of the matrix represents the instances of an actual class, while each column represents the instances of a predicted class.

- The diagonal cells show the number of correct predictions for each class (where the predicted label matches the actual label).
- Off-diagonal cells show where the model made mistakes (misclassifications), indicating which classes were confused by the model.

The confusion matrix provides deeper insight into how your model performs on each class, beyond just overall accuracy.