Chapter 2
Reasoning and Proof

What You’ll Learn

- **Lessons 2-1 through 2-3**  Make conjectures, determine whether a statement is true or false, and find counterexamples for statements.
- **Lesson 2-4**  Use deductive reasoning to reach valid conclusions.
- **Lessons 2-5 and 2-6**  Verify algebraic and geometric conjectures using informal and formal proof.
- **Lessons 2-7 and 2-8**  Write proofs involving segment and angle theorems.

Key Vocabulary

- inductive reasoning (p. 62)
- deductive reasoning (p. 82)
- postulate (p. 89)
- theorem (p. 90)
- proof (p. 90)

Why It’s Important

Logic and reasoning are used throughout geometry to solve problems and reach conclusions. There are many professions that rely on reasoning in a variety of situations. Doctors, for example, use reasoning to diagnose and treat patients. You will investigate how doctors use reasoning in Lesson 2-4.
Prerequisite Skills  To be successful in this chapter, you’ll need to master these skills and be able to apply them in problem-solving situations. Review these skills before beginning Chapter 2.

For Lesson 2-1
Evaluate each expression for the given value of $n$.  (For review, see page 736.)

1. $3n - 2; n = 4$
2. $(n + 1) + n; n = 6$
3. $n^2 - 3n; n = 3$
4. $180(n - 2); n = 5$
5. $\frac{n(n - 3)}{2}; n = 8$

For Lessons 2-6 through 2-8
Solve each equation.  (For review, see pages 737 and 738.)

7. $6x - 42 = 4x$
8. $8 - 3n = -2 + 2n$
9. $3(y + 2) = -12 + y$
10. $12 + 7x = x - 18$
11. $3x + 4 = \frac{1}{2}x - 5$
12. $2 - 2x = \frac{2}{3}x - 2$

For Lesson 2-8
Adjacent and Vertical Angles
For Exercises 13–14, refer to the figure at the right.  (For review, see Lesson 1-5.)

13. If $m\angle AGB = 4x + 7$ and $m\angle EGD = 71$, find $x$.
14. If $m\angle BGC = 45$, $m\angle CGD = 8x + 4$, and $m\angle DGE = 15x - 7$, find $x$.

Reasoning and Proof  Make this Foldable to help you organize your notes. Begin with eight sheets of $8\frac{1}{2}$ by $11$ grid paper.

Step 1  Staple
Stack and staple the eight sheets together to form a booklet.

Step 2  Cut Tabs
Cut the bottom of each sheet to form a tabbed book.

Step 3  Label
Label each of the tabs with a lesson number. Add the chapter title to the first tab.

Reading and Writing  As you read and study each lesson, use the corresponding page to write proofs and record examples of when you used logical reasoning in your daily life.
MAKE CONJECTURES

A conjecture is an educated guess based on known information. Examining several specific situations to arrive at a conjecture is called inductive reasoning. **Inductive reasoning** is reasoning that uses a number of specific examples to arrive at a plausible generalization or prediction.

**Example 1 Patterns and Conjecture**

The numbers represented below are called **triangular numbers**. Make a conjecture about the next triangular number based on the pattern.

![Triangular Numbers Pattern](image)

**Observe:** Each triangle is formed by adding another row of dots.

**Find a Pattern:**

\[
\begin{align*}
1 & \quad 3 & \quad 6 & \quad 10 & \quad 15 \\
+2 & \quad +3 & \quad +4 & \quad +5
\end{align*}
\]

The numbers increase by 2, 3, 4, and 5.

**Conjecture:** The next number will increase by 6. So, it will be 15 + 6 or 21.

In Chapter 1, you learned some basic geometric concepts. These concepts can be used to make conjectures in geometry.
Lesson 2-1  Inductive Reasoning and Conjecture

**Example 2  Geometric Conjecture**

For points $P$, $Q$, and $R$, $PQ = 9$, $QR = 15$, and $PR = 12$. Make a conjecture and draw a figure to illustrate your conjecture.

**Given:** points $P$, $Q$, and $R$; $PQ = 9$, $QR = 15$, and $PR = 12$

Examine the measures of the segments.
Since $PQ + PR = QR$, the points cannot be collinear.

**Conjecture:** $P$, $Q$, and $R$ are noncollinear.

**FIND COUNTEREXAMPLES** A conjecture based on several observations may be true in most circumstances, but false in others. It takes only one false example to show that a conjecture is not true. The false example is called a **counterexample**.

**Example 3  Find a Counterexample**

**FINANCE** Find a counterexample for the following statement based on the graph.

*The rates for CDs are at least 1.5% less than the rates a year ago.*

Examine the graph. The statement is true for 6-month, 1-year, and $2\frac{1}{2}$-year CDs. However, the difference in the rate for a 5-year CD is 0.74% less, which is less than 1.5%. The statement is false for a 5-year certificate of deposit. Thus, the change in the 5-year rate is a counterexample to the original statement.

**Check for Understanding**

**Concept Check**

1. Write an example of a conjecture you have made outside of school.
2. Determine whether the following conjecture is always, sometimes, or never true based on the given information.
   **Given:** collinear points $D$, $E$, and $F$
   **Conjecture:** $DE + EF = DF$
3. **OPEN ENDED** Write a statement. Then find a counterexample for the statement.
**Guided Practice**

Make a conjecture about the next item in each sequence.

4. [Diagram of shapes]

5. $-8, -5, -2, 1, 4$

Make a conjecture based on the given information. Draw a figure to illustrate your conjecture.

6. $PQ = RS$ and $RS = TU$

7. $\overline{AB}$ and $\overline{CD}$ intersect at $P$.

Determine whether each conjecture is **true** or **false**. Give a counterexample for any false conjecture.

8. Given: $x$ is an integer.
   Conjecture: $-x$ is negative.

9. Given: $WXYZ$ is a rectangle.
   Conjecture: $WX = YZ$ and $WZ = XY$

**Application**

10. **HOUSES**  Most homes in the northern United States have roofs made with steep angles. In the warmer areas of the southern states, homes often have flat roofs. Make a conjecture about why the roofs are different.

**Practice and Apply**

Make a conjecture about the next item in each sequence.

11. [Diagram of shapes]

12. [Diagram of arrows]

13. 1, 2, 4, 8, 16

14. 4, 6, 9, 13, 18

15. $\frac{1}{3}, \frac{5}{3}, \frac{7}{3}, 3$

16. $1, \frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \frac{1}{16}$

17. 2, $-6, 18, -54$

18. $-5, 25, -125, 625$

Make a conjecture about the number of blocks in the next item of each sequence.

19. [Diagram of blocks]

20. [Diagram of blocks]

Make a conjecture based on the given information. Draw a figure to illustrate your conjecture.

21. Lines $\ell$ and $m$ are perpendicular.

22. $A(-2, -11), B(2, 1), C(5, 10)$

23. $\angle 3$ and $\angle 4$ are a linear pair.

24. $\overline{BD}$ is an angle bisector of $\angle ABC$.

25. $P(-1, 7), Q(6, -2), R(6, 5)$

26. $HIJK$ is a square.

27. $PQRS$ is a rectangle.

28. $\angle B$ is a right angle in $\triangle ABC$. 

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*For Exercises See Examples 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 See page 756.*
Determine whether each conjecture is true or false. Give a counterexample for any false conjecture.

29. Given: \( \angle 1 \) and \( \angle 2 \) are complementary angles. 
   Conjecture: \( \angle 1 \) and \( \angle 2 \) form a right angle.

30. Given: \( m + y \geq 10 \), \( y \geq 4 \) 
   Conjecture: \( m \leq 6 \)

31. Given: points \( W, X, Y, \) and \( Z \) 
   Conjecture: \( W, X, Y, \) and \( Z \) are noncollinear.

32. Given: \( A(-4, 8), B(3, 8), C(3, 5) \) 
   Conjecture: \( \triangle ABC \) is a right triangle.

33. Given: \( n \) is a real number. 
   Conjecture: \( n^2 \) is a nonnegative number.

34. Given: \( DE = EF \) 
   Conjecture: \( E \) is the midpoint of \( \overline{DF} \).

35. Given: \( JK = KL = LM = MJ \) 
   Conjecture: \( \square JKLM \) forms a square.

36. Given: noncollinear points \( R, S, \) and \( T \) 
   Conjecture: \( \overline{RS}, \overline{ST}, \) and \( \overline{RT} \) form a triangle.

37. MUSIC Many people learn to play the piano by ear. This means that they first learned how to play without reading music. What process did they use?

CHEMISTRY For Exercises 38–40, use the following information.

Hydrocarbons are molecules composed of only carbon (C) and hydrogen (H) atoms. The simplest hydrocarbons are called alkanes. The first three alkanes are shown below.

<table>
<thead>
<tr>
<th>Alkanes</th>
<th>Compound Name</th>
<th>Chemical Formula</th>
<th>Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Methane</td>
<td>( \text{CH}_4 )</td>
<td>( \text{H} - \text{C} - \text{H} )</td>
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<tr>
<td></td>
<td>Ethane</td>
<td>( \text{C}_2\text{H}_6 )</td>
<td>( \text{H} - \text{C} - \text{H} - \text{C} - \text{H} )</td>
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<tr>
<td></td>
<td>Propane</td>
<td>( \text{C}_3\text{H}_8 )</td>
<td>( \text{H} - \text{C} - \text{H} - \text{C} - \text{C} - \text{H} )</td>
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</tbody>
</table>

38. Make a conjecture about butane, which is the next compound in the group. Write its structural formula.

39. Write the chemical formula for the 7th compound in the group.

40. Develop a rule you could use to find the chemical formula of the \( n \)th substance in the alkane group.

41. CRITICAL THINKING The expression \( n^2 - n + 41 \) has a prime value for \( n = 1, n = 2, \) and \( n = 3 \). Based on this pattern, you might conjecture that this expression always generates a prime number for any positive integral value of \( n \). Try different values of \( n \) to test the conjecture. Answer true if you think the conjecture is always true. Answer false and give a counterexample if you think the conjecture is false.
42. **WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

**How can inductive reasoning help predict weather conditions?**
Include the following in your answer:
- an explanation as to how a conjecture about a weather pattern in the summer might be different from a similar weather pattern in the winter, and
- a conjecture about tomorrow’s weather based on your local weather over the past several days.

43. What is the next term in the sequence 1, 1, 2, 3, 5, 8?

A 11  B 12  C 13  D 14

44. **ALGEBRA** If the average of six numbers is 18 and the average of three of the numbers is 15, then what is the sum of the remaining three numbers?

21 45 53 63

45. Name each polygon by its number of sides and then classify it as **convex** or **concave** and **regular** or **irregular.** *(Lesson 1-6)*

46.

47.

48. **Determine whether each statement can be assumed from the figure. Explain.** *(Lesson 1-5)*

49. \( \angle KLN \) and \( \angle MNL \) are supplementary.

50. \( \angle PNL \) and \( \angle MNL \) are complementary.

51. \( \angle KLN \) and \( \angle MLN \) are supplementary.

52. \( \angle KLP \) is a right angle.

53. **Find the coordinates of the midpoint of a segment having the given endpoints.** *(Lesson 1-3)*

54. \( \overline{CD} \) for \( C(4, 1), D(-3, 7) \)

55. \( \overline{FG} \) for \( F(4, -9), G(-2, -15) \)

56. \( \overline{HJ} \) for \( H(-5, -2), J(7, 4) \)

57. \( \overline{KL} \) for \( K(8, -1.8), L(3, 6.2) \)

58. \( \overline{MN} \) for \( M(-1.5, -6), N(-4, 3) \)

59. **Find the value of the variable and \( MP \), if \( P \) is between \( M \) and \( N.** *(Lesson 1-2)*

60. \( MP = 2c, PN = 9c, PN = 63 \)

61. \( MP = 6q, PN = 6q, MN = 60 \)

62. \( MP = 4y + 3, PN = 2y, MN = 63 \)

63. \( MP = 2b - 7, PN = 8b, MN = 43 \)

64. **BASIC SKILL** Determine which values in the given replacement set make the inequality true.

65. \( x + 2 > 5 \) \{2, 3, 4, 5\}

66. \( 12 - x < 0 \) \{11, 12, 13, 14\}

67. \( 5x + 1 > 25 \) \{4, 5, 6, 7\}
Vocabulary

- statement
- truth value
- negation
- compound statement
- conjunction
- disjunction
- truth table

What You’ll Learn

- Determine truth values of conjunctions and disjunctions.
- Construct truth tables.

How does logic apply to school?

When you answer true-false questions on a test, you are using a basic principle of logic. For example, refer to the map, and answer true or false.

Raleigh is a city in North Carolina.

You know that there is only one correct answer, either true or false.

**DETERMINE TRUTH VALUES**

A statement, like the true-false example above, is any sentence that is either true or false, but not both. Unlike a conjecture, we know that a statement is either true or false. The truth or falsity of a statement is called its truth value.

Statements are often represented using a letter such as $p$ or $q$. The statement above can be represented by $p$.

$p$: Raleigh is a city in North Carolina.  **This statement is true.**

The negation of a statement has the opposite meaning as well as an opposite truth value. For example, the negation of the statement above is not $p$.

$not p$: Raleigh is not a city in North Carolina.  **In this case, the statement is false.**

**Key Concept**

**Negation**

- **Words**: If a statement is represented by $p$, then not $p$ is the negation of the statement.
- **Symbols**: $\neg p$, read not $p$

Two or more statements can be joined to form a compound statement. Consider the following two statements.

$p$: Raleigh is a city in North Carolina.
$q$: Raleigh is the capital of North Carolina.

The two statements can be joined by the word and.

$p$ and $q$: Raleigh is a city in North Carolina, and Raleigh is the capital of North Carolina.
The statement formed by joining \( p \) and \( q \) is an example of a conjunction.

**Key Concept**

- **Words** A *conjunction* is a compound statement formed by joining two or more statements with the word *and*.
- **Symbols** \( p \land q \), read *and* \( p \) and \( q \)

A conjunction is true only when both statements in it are true. Since it is true that Raleigh is in North Carolina and it is the capital, the conjunction is also true.

**Example 1** **Truth Values of Conjunctions**

Use the following statements to write a compound statement for each conjunction. Then find its truth value.

\( p: \) January 1 is the first day of the year.
\( q: \) \(-5 + 11 = -6\)
\( r: \) A triangle has three sides.

a. \( p \) and \( q \)
   - January is the first day of the year, and \(-5 + 11 = -6\).
   - \( p \) and \( q \) is false, because \( p \) is true and \( q \) is false.

b. \( r \) \& \( p \)
   - A triangle has three sides, and January 1 is the first day of the year.
   - \( r \) \& \( p \) is true, because \( r \) is true and \( p \) is true.

c. \( p \) and not \( r \)
   - January 1 is the first day of the year, and a triangle does not have three sides.
   - \( p \) and not \( r \) is false, because \( p \) is true and not \( r \) is false.

d. \( \neg q \) \& \( r \)
   - \(-5 + 11 \neq -6\), and a triangle has three sides
   - \( \neg q \) \& \( r \) is true because \( \neg q \) is true and \( r \) is true.

Statements can also be joined by the word *or*. This type of statement is a disjunction. Consider the following statements.

\( p: \) Ahmed studies chemistry.
\( q: \) Ahmed studies literature.

\( p \) or \( q \): Ahmed studies chemistry, *or* Ahmed studies literature.

**Key Concept**

- **Words** A *disjunction* is a compound statement formed by joining two or more statements with the word *or*.
- **Symbols** \( p \lor q \), read *or* \( p \) or \( q \)
A disjunction is true if at least one of the statements is true. In the case of $p$ or $q$ above, the disjunction is true if Ahmed either studies chemistry or literature or both. The disjunction is false only if Ahmed studies neither chemistry nor literature.

**Example 2 Truth Values of Disjunctions**

Use the following statements to write a compound statement for each disjunction. Then find its truth value.

$p$: $100 \div 5 = 20$
$q$: The length of a radius of a circle is twice the length of its diameter.
$r$: The sum of the measures of the legs of a right triangle equals the measure of the hypotenuse.

a. $p$ or $q$

$100 \div 5 = 20$, or the length of a radius of a circle is twice the length of its diameter.

$p$ or $q$ is true because $p$ is true. It does not matter that $q$ is false.

b. $q \lor r$

The length of a radius of a circle is twice the length of its diameter, or the sum of the measures of the legs of a right triangle equals the measure of the hypotenuse.

$q \lor r$ is false since neither statement is true.

Conjunctions can be illustrated with Venn diagrams. Refer to the statement at the beginning of the lesson. The Venn diagram at the right shows that Raleigh (R) is represented by the intersection of the set of cities in North Carolina and the set of state capitals. In other words, Raleigh must be in the set containing cities in North Carolina and in the set of state capitals.

A disjunction can also be illustrated with a Venn diagram. Consider the following statements.

$p$: Jerrica lives in a U.S. state capital.
$q$: Jerrica lives in a North Carolina city.
$p \lor q$: Jerrica lives in a U.S. state capital, or Jerrica lives in a North Carolina city.

In the Venn diagrams, the disjunction is represented by the union of the two sets. The union includes all U.S. capitals and all cities in North Carolina. The city in which Jerrica lives could be located in any of the three regions of the union.

The three regions represent

A U.S. state capitals excluding the capital of North Carolina,
B cities in North Carolina excluding the state capital, and
C the capital of North Carolina, which is Raleigh.
Venn diagrams can be used to solve real-world problems involving conjunctions and disjunctions.

Example 3 Use Venn Diagrams

RECYCLING The Venn diagram shows the number of neighborhoods that have a curbside recycling program for paper or aluminum.

![Curbside Recycling Diagram]

a. How many neighborhoods recycle both paper and aluminum?
The neighborhoods that have paper and aluminum recycling are represented by the intersection of the sets. There are 46 neighborhoods that have paper and aluminum recycling.

b. How many neighborhoods recycle paper or aluminum?
The neighborhoods that have paper or aluminum recycling are represented by the union of the sets. There are $12 + 46 + 20 = 78$ neighborhoods that have paper or aluminum recycling.

c. How many neighborhoods recycle paper and not aluminum?
The neighborhoods that have paper and not aluminum recycling are represented by the nonintersecting portion of the paper region. There are 12 neighborhoods that have paper and not aluminum recycling.

TRUTH TABLES A convenient method for organizing the truth values of statements is to use a truth table.

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<tr>
<th>Negation</th>
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<tbody>
<tr>
<td>$p$</td>
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If $p$ is a true statement, then $\sim p$ is a false statement. If $p$ is a false statement, then $\sim p$ is a true statement.

Truth tables can also be used to determine truth values of compound statements.

<table>
<thead>
<tr>
<th>Conjunction</th>
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A conjunction is true only when both statements are true.

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<tr>
<th>Disjunction</th>
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<tbody>
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<td>$p$</td>
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A disjunction is false only when both statements are false.

You can use the truth values for negation, conjunction, and disjunction to construct truth tables for more complex compound statements.
**Example 4 Construct Truth Tables**

Construct a truth table for each compound statement.

a. \( p \land \lnot q \)
   - **Step 1** Make columns with the headings \( p, q, \lnot q, \) and \( p \land \lnot q. \)
   - **Step 2** List the possible combinations of truth values for \( p \) and \( q. \)
   - **Step 3** Use the truth values of \( q \) to determine the truth values of \( \lnot q. \)
   - **Step 4** Use the truth values for \( p \) and \( \lnot q \) to write the truth values for \( p \land \lnot q. \)

<table>
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<tr>
<th>( p )</th>
<th>( q )</th>
<th>( \lnot q )</th>
<th>( p \land \lnot q )</th>
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**b. \lnot p \lor \lnot q**

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<th>( \lnot q )</th>
<th>( \lnot p \lor \lnot q )</th>
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**c. \( (p \land q) \lor r \)**

Make columns for \( p, q, p \land q, r, \) and \( (p \land q) \lor r. \)

<table>
<thead>
<tr>
<th>( p )</th>
<th>( q )</th>
<th>( p \land q )</th>
<th>( r )</th>
<th>( (p \land q) \lor r )</th>
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**Check for Understanding**

**Concept Check**

1. **Describe** how to interpret the Venn diagram for \( p \land q. \)
2. **OPEN ENDED** Write a compound statement for each condition.
   a. a true disjunction
   b. a false conjunction
   c. a true statement that includes a negation
3. **Explain** the difference between a conjunction and a disjunction.

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**Study Tip**

**Truth Tables**

Use the Fundamental Counting Principle to determine the number of rows necessary.

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**Example 4**

Construct a truth table for each compound statement.

a. \( p \land \lnot q \)
   - **Step 1** Make columns with the headings \( p, q, \lnot q, \) and \( p \land \lnot q. \)
   - **Step 2** List the possible combinations of truth values for \( p \) and \( q. \)
   - **Step 3** Use the truth values of \( q \) to determine the truth values of \( \lnot q. \)
   - **Step 4** Use the truth values for \( p \) and \( \lnot q \) to write the truth values for \( p \land \lnot q. \)

<table>
<thead>
<tr>
<th>( p )</th>
<th>( q )</th>
<th>( \lnot q )</th>
<th>( p \land \lnot q )</th>
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**b. \lnot p \lor \lnot q**

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**c. \( (p \land q) \lor r \)**

Make columns for \( p, q, p \land q, r, \) and \( (p \land q) \lor r. \)

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<thead>
<tr>
<th>( p )</th>
<th>( q )</th>
<th>( p \land q )</th>
<th>( r )</th>
<th>( (p \land q) \lor r )</th>
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**Guided Practice**

Use the following statements to write a compound statement for each conjunction and disjunction. Then find its truth value.

- **p:** 9 + 5 = 14
- **q:** February has 30 days.
- **r:** A square has four sides.

4. **p and q**  
5. **p and r**  
6. **q \(\land\) r**  
7. **p or \(\sim q\)**  
8. **q \(\lor\) r**  
9. **\(\sim p\) \(\lor\) \(\sim r\)**

10. Copy and complete the truth table.

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<th>(p)</th>
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<th>(\sim q)</th>
<th>(p \land \sim q)</th>
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Construct a truth table for each compound statement.

11. **p \(\land\) q**  
12. **q \(\lor\) r**  
13. **\(\sim p\) \(\land\) r**  
14. \((p \lor q) \lor r\)

**Application**

**AGRICULTURE** For Exercises 15–17, refer to the Venn diagram that represents the states producing more than 100 million bushels of corn or wheat per year.

15. How many states produce more than 100 million bushels of corn?
16. How many states produce more than 100 million bushels of wheat?
17. How many states produce more than 100 million bushels of corn and wheat?

**Grain Production**

Source: U.S. Department of Agriculture

**Practice and Apply**

Use the following statements to write a compound statement for each conjunction and disjunction. Then find its truth value.

- **p:** \(\sqrt{-64} = 8\)
- **q:** An equilateral triangle has three congruent sides.
- **r:** 0 < 0
- **s:** An obtuse angle measures greater than 90° and less than 180°.

18. **p and q**  
19. **p or q**  
20. **p and r**  
21. **r and s**  
22. **q or r**  
23. **q and s**  
24. **p \(\land\) s**  
25. **q \(\land\) r**  
26. **r \(\lor\) p**  
27. **s \(\lor\) q**  
28. \((p \land q) \lor s\)  
29. **s \(\lor\) (q and r)**

Copy and complete each truth table.

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<th>(p)</th>
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32. Copy and complete the truth table.

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<th>(p ∨ q) ∧ r</th>
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</table>

Construct a truth table for each compound statement.

33. q and r
34. p or q
35. p or r
36. p and q
37. q ∧ ~r
38. ~p ∧ ~q
39. ~p ∨ (q ∧ ~r)
40. p ∨ (~q ∨ ~r)

**MUSIC** For Exercises 41–44, use the following information.

A group of 400 teens were asked what type of music they listened to. They could choose among pop, rap, and country. The results are shown in the Venn diagram.

41. How many teens said that they listened to none of these types of music?
42. How many said that they listened to all three types of music?
43. How many said that they listened to only pop and rap music?
44. How many teens said that they listened to pop, rap, or country music?

**SCHOOL** For Exercises 45–47, use the following information.

In a school of 310 students, 80 participate in academic clubs, 115 participate in sports, and 20 students participate in both.

45. Make a Venn diagram of the data.
46. How many students participate in either clubs or sports?
47. How many students do not participate in either clubs or sports?

**RESEARCH** For Exercises 48–50, use the Internet or another resource to determine whether each statement about cities in New York is true or false.

48. Albany is not located on the Hudson river.
49. Either Rochester or Syracuse is located on Lake Ontario.
50. It is false that Buffalo is located on Lake Erie.

**CRITICAL THINKING** For Exercises 51 and 52, use the following information.

All members of Team A also belong to Team B, but only some members of Team B also belong to Team C. Teams A and C have no members in common.

51. Draw a Venn diagram to illustrate the situation.
52. Which of the following statements is true?
   a. If a person is a member of Team C, then the person is not a member of Team A.
   b. If a person is not a member of Team B, then the person is not a member of Team A.
   c. No person that is a member of Team A can be a member of Team C.
53. **WRITING IN MATH**  Answer the question that was posed at the beginning of the lesson.

**How does logic apply to school?**

Include the following in your answer:
- an example of a conjunction using statements about your favorite subject and your favorite extracurricular activity, and
- a Venn diagram showing various characteristics of the members of your geometry class (for example, male/female, grade in school, and so on).

54. Which statement about \( \triangle ABC \) has the same truth value as \( AB = BC \)?

- A. \( m\angle A = m\angle C \)
- B. \( m\angle A = m\angle B \)
- C. \( AC = BC \)
- D. \( AB = AC \)

55. **ALGEBRA**  If the sum of two consecutive even integers is 78, which number is the greater of the two integers?

- A. 36
- B. 38
- C. 40
- D. 42

---

**Maintain Your Skills**

**Mixed Review**  Make a conjecture about the next item in each sequence.  *(Lesson 2-1)*

56. 3, 5, 7, 9  
57. 1, 3, 9, 27  
58. 6, 3, 3, 3
59. 17, 13, 9, 5  
60. 64, 16, 4, 1  
61. 5, 15, 45, 135

**COORDINATE GEOMETRY**  Find the perimeter of each polygon. Round answers to the nearest tenth.  *(Lesson 1-6)*

62. triangle \( \triangle ABC \) with vertices \( A(-6, 7), B(1, 3) \), and \( C(-2, -7) \)
63. square \( DEFG \) with vertices \( D(-10, -9), E(-5, -2), F(2, -7), \) and \( G(-3, -14) \)
64. quadrilateral \( HIJK \) with vertices \( H(5, -10), I(-8, -9), J(-5, -5), \) and \( K(-2, -4) \)
65. hexagon \( LMNPQR \) with vertices \( L(2, 1), M(4, 5), N(6, 4), P(7, -4), Q(5, -8), \) and \( R(3, -7) \)

Measure each angle and classify it as right, acute, or obtuse.  *(Lesson 1-4)*

66. \( \angle ABC \)
67. \( \angle DBC \)
68. \( \angle ABD \)

69. **FENCING**  Michelle wanted to put a fence around her rectangular garden. The front and back measured 35 feet each, and the sides measured 75 feet each. If she wanted to make sure that she had enough feet of fencing, how much should she buy?  *(Lesson 1-2)*

**Getting Ready for the Next Lesson**

**PREREQUISITE SKILL**  Evaluate each expression for the given values.  *(To review evaluating algebraic expressions, see page 736.)*

70. \( 5a - 2b \) if \( a = 4 \) and \( b = 3 \)
71. \( 4cd + 2d \) if \( c = 5 \) and \( d = 2 \)
72. \( 4e + 3f \) if \( e = -1 \) and \( f = -2 \)
73. \( 3g^2 + h \) if \( g = 8 \) and \( h = -8 \)
2-3 Conditional Statements

What You’ll Learn

• Analyze statements in if-then form.
• Write the converse, inverse, and contrapositive of if-then statements.

Vocabulary

• conditional statement
• if-then statement
• hypothesis
• conclusion
• related conditionals
• converse
• inverse
• contrapositive
• logically equivalent

How are conditional statements used in advertisements?

Advertisers often lure consumers into purchasing expensive items by convincing them that they are getting something for free in addition to their purchase.

If-Then Statements

The statements above are examples of conditional statements. A conditional statement is a statement that can be written in if-then form. The first example above can be rewritten to illustrate this.

If you buy a car, then you get $1500 cash back.

Key Concept

If-Then Statement

• Words An if-then statement is written in the form if \( p \), then \( q \). The phrase immediately following the word if is called the hypothesis, and the phrase immediately following the word then is called the conclusion.

• Symbols \( p \rightarrow q \), read if \( p \) then \( q \), or \( p \) implies \( q \).

Example 1 Identify Hypothesis and Conclusion

Identify the hypothesis and conclusion of each statement.

a. If points \( A \), \( B \), and \( C \) lie on line \( \ell \), then they are collinear.

If points \( A \), \( B \), and \( C \) lie on line \( \ell \), then they are collinear.

Hypothesis: points \( A \), \( B \), and \( C \) lie on line \( \ell \)
Conclusion: they are collinear

b. The Tigers will play in the tournament if they win their next game.

Hypothesis: the Tigers win their next game
Conclusion: they will play in the tournament

Identifying the hypothesis and conclusion of a statement is helpful when writing statements in if-then form.
Example 2 Write a Conditional in If-Then Form

Identify the hypothesis and conclusion of each statement. Then write each statement in if-then form.

a. An angle with a measure greater than 90 is an obtuse angle.
   Hypothesis: an angle has a measure greater than 90
   Conclusion: it is an obtuse angle
   If an angle has a measure greater than 90, then it is an obtuse angle.

b. Perpendicular lines intersect.
   Sometimes you must add information to a statement. In this case, it is necessary to know that perpendicular lines come in pairs.
   Hypothesis: two lines are perpendicular
   Conclusion: they intersect
   If two lines are perpendicular, then they intersect.

Recall that the truth value of a statement is either true or false. The hypothesis and conclusion of a conditional statement, as well as the conditional statement itself, can also be true or false.

Example 3 Truth Values of Conditionals

SCHOOL Determine the truth value of the following statement for each set of conditions.
If you get 100% on your test, then your teacher will give you an A.

a. You get 100%; your teacher gives you an A.
   The hypothesis is true since you got 100%, and the conclusion is true because the teacher gave you an A. Since what the teacher promised is true, the conditional statement is true.

b. You get 100%; your teacher gives you a B.
   The hypothesis is true, but the conclusion is false. Because the result is not what was promised, the conditional statement is false.

c. You get 98%; your teacher gives you an A.
   The hypothesis is false, and the conclusion is true. The statement does not say what happens if you do not get 100% on the test. You could still get an A. It is also possible that you get a B. In this case, we cannot say that the statement is false. Thus, the statement is true.

d. You get 85%; your teacher gives you a B.
   As in part c, we cannot say that the statement is false. Therefore, the conditional statement is true.

The resulting truth values in Example 3 can be used to create a truth table for conditional statements. Notice that a conditional statement is true in all cases except where the hypothesis is true and the conclusion is false.

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</table>
**Key Concept**

<table>
<thead>
<tr>
<th>Related Conditionals</th>
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<tbody>
<tr>
<td><strong>Statement</strong></td>
</tr>
<tr>
<td><strong>Conditional</strong></td>
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<tr>
<td><strong>Converse</strong></td>
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<tr>
<td><strong>Inverse</strong></td>
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<tr>
<td><strong>Contrapositive</strong></td>
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</table>

If a given conditional is true, the converse and inverse are not necessarily true. However, the contrapositive of a true conditional is always true, and the contrapositive of a false conditional is always false. Likewise, the converse and inverse of a conditional are either both true or both false.

Statements with the same truth values are said to be **logically equivalent**. So, a conditional and its contrapositive are logically equivalent as are the converse and inverse of a conditional. These relationships are summarized below.

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<tr>
<th>$p$</th>
<th>$q$</th>
<th>Conditional $p \rightarrow q$</th>
<th>Converse $q \rightarrow p$</th>
<th>Inverse $\sim p \rightarrow \sim q$</th>
<th>Contrapositive $\sim q \rightarrow \sim p$</th>
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</table>

**Contrapositive**
The relationship of the truth values of a conditional and its contrapositive is known as the Law of Contrapositive.

**Example 4**

Write the converse, inverse, and contrapositive of the statement *Linear pairs of angles are supplementary*. Determine whether each statement is true or false. If a statement is false, give a counterexample.

First, write the conditional in if-then form.

**Conditional:** If two angles form a linear pair, then they are supplementary.
- The conditional statement is true.

Write the converse by switching the hypothesis and conclusion of the conditional.

**Converse:** If two angles are supplementary, then they form a linear pair. The converse is false. $\angle ABC$ and $\angle PQR$ are supplementary, but are not a linear pair.

Write the inverse by switching the hypothesis and conclusion of the conditional.

**Inverse:** If two angles do not form a linear pair, then they are not supplementary. The inverse is false. $\angle ABC$ and $\angle PQR$ do not form a linear pair, but they are supplementary.

The contrapositive is the negation of the hypothesis and conclusion of the converse.

**Contrapositive:** If two angles are not supplementary, then they do not form a linear pair. The contrapositive is true.
Identify the hypothesis and conclusion of each statement.
16. If \( 2x + 6 = 10 \), then \( x = 2 \).
17. If you are a teenager, then you are at least 13 years old.
18. If you have a driver’s license, then you are at least 16 years old.
19. If three points lie on a line, then they are collinear.
20. “If a man hasn’t discovered something that he will die for, he isn’t fit to live.” (Martin Luther King, Jr., 1963)
21. If the measure of an angle is between 0 and 90, then the angle is acute.

Write each statement in if-then form.
22. Get a free visit with a one-year fitness plan.
23. Math teachers love to solve problems.
24. “I think, therefore I am.” (Descartes)
25. Adjacent angles have a common side.
26. Vertical angles are congruent.
27. Equiangular triangles are equilateral.
Determine the truth value of the following statement for each set of conditions.

If you are over 18 years old, then you vote in all elections.

28. You are 19 years old and you vote.
29. You are 16 years old and you vote.
30. You are 21 years old and do not vote.
31. You are 17 years old and do not vote.
32. Your sister is 21 years old and votes.
33. Your dad is 45 years old and does not vote.

In the figure, \( P, Q, \) and \( R \) are collinear, \( P \) and \( A \) lie in plane \( M \), and \( Q \) and \( B \) lie in plane \( N \). Determine the truth value of each statement.

34. \( P, Q, \) and \( R \) lie in plane \( M \).
35. \( \overline{QB} \) lies in plane \( N \).
36. \( Q \) lies in plane \( M \).
37. \( P, Q, A, \) and \( B \) are coplanar.
38. \( \overline{AP} \) contains \( Q \).
39. Planes \( M \) and \( N \) intersect at \( \overline{RQ} \).

Write the converse, inverse, and contrapositive of each conditional statement. Determine whether each related conditional is true or false. If a statement is false, find a counterexample.

40. If you live in Dallas, then you live in Texas.
41. If you exercise regularly, then you are in good shape.
42. The sum of two complementary angles is 90.
43. All rectangles are quadrilaterals.
44. All right angles measure 90.
45. Acute angles have measures less than 90.

**SEASONS** For Exercises 46 and 47, use the following information.

Due to the movement of Earth around the sun, summer days in Alaska have more hours of daylight than darkness, and winter days have more hours of darkness than daylight.

46. Write two true conditional statements in if-then form for summer days and winter days in Alaska.
47. Write the converse of the two true conditional statements. State whether each is true or false. If a statement is false, find a counterexample.

48. **CRITICAL THINKING** Write a false conditional statement. Is it possible to insert the word not into your conditional to make it true? If so, write the true conditional.

49. **WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

**How are conditional statements used in advertisements?**

Include the following in your answer:

- an example of a conditional statement in if-then form, and
- an example of a conditional statement that is not in if-then form.
50. Which statement has the same truth value as the following statement?
   If Ava and Willow are classmates, then they go to the same school.
   
   - (A) If Ava and Willow go to the same school, then they are classmates.
   - (B) If Ava and Willow are not classmates, then they do not go to the same school.
   - (C) If Ava and Willow do not go to the same school, then they are not classmates.
   - (D) If Ava and Willow go to the same school, then they are not classmates.

51. **ALGEBRA** In a history class with 32 students, the ratio of girls to boys is 5 to 3. How many more girls are there than boys?
   
   28 1 2 20

Maintain Your Skills

- Use the following statements to write a compound statement for each conjunction and disjunction. Then find its truth value. (Lesson 2-2)

  - \( p \): George Washington was the first president of the United States.
  - \( q \): A hexagon has five sides.
  - \( r \): \( \frac{60}{11547} \times \frac{11549}{18} \)

- Make a conjecture based on the given information. Draw a figure to illustrate your conjecture. (Lesson 2-1)

58. \( ABCD \) is a rectangle.
59. In \( \triangle FGH \), \( \angle F = 45 \), \( \angle G = 67 \), \( \angle H = 68 \).
60. \( J(-3, 2), K(1, 8), L(5, 2) \)

Use the Distance Formula to find the distance between each pair of points. (Lesson 1-3)

62. \( C(-2, -1), D(0, 3) \)
63. \( J(-3, 5), K(1, 0) \)
64. \( P(-3, -1), Q(2, -3) \)
65. \( R(1, -7), S(-4, 3) \)

**PREREQUISITE SKILL** Identify the operation used to change Equation (1) to Equation (2). (To review solving equations, see pages 737 and 738.)

66. (1) \( 3x + 4 = 5x - 8 \)  
   (2) \( 3x = 5x - 12 \)
67. (1) \( \frac{1}{2}(a - 5) = 12 \)  
   (2) \( a - 5 = 24 \)
68. (1) \( 8p = 24 \)  
   (2) \( p = 3 \)

Practice Quiz 1

**Lessons 2-1 through 2-3**

Determine whether each conjecture is **true** or **false**. Give a counterexample for any false conjecture. (Lesson 2-1)

1. Given: \( WX = XY \)
   Conjecture: \( W, X, \) and \( Y \) are collinear.
2. Given: \( \angle 1 \) and \( \angle 2 \) are complementary.
   \( \angle 2 \) and \( \angle 3 \) are complementary.
   Conjecture: \( m\angle 1 = m\angle 3 \)

Construct a truth table for each compound statement. (Lesson 2-2)

3. \( \sim p \land q \)
4. \( p \lor (q \land r) \)

5. Write the converse, inverse, and contrapositive of the following conditional statement. Determine whether each related conditional is **true** or **false**. If a statement is false, find a counterexample. (Lesson 2-3)
   If two angles are adjacent, then the angles have a common vertex.
Biconditional Statements

Ashley began a new summer job, earning $10 an hour. If she works over 40 hours a week, she earns time and a half, or $15 an hour. If she earns $15 an hour, she has worked over 40 hours a week.

\( p: \) Ashley earns $15 an hour
\( q: \) Ashley works over 40 hours a week

\( p \rightarrow q: \) If Ashley earns $15 an hour, she has worked over 40 hours a week.
\( q \rightarrow p: \) If Ashley works over 40 hours a week, she earns $15 an hour.

In this case, both the conditional and its converse are true. The conjunction of the two statements is called a **biconditional**.

### Key Concept

**Biconditional Statement**

- **Words** A biconditional statement is the conjunction of a conditional and its converse.
- **Symbols** \((p \rightarrow q) \land (q \rightarrow p)\) is written \((p \leftrightarrow q)\) and read \(p\) if and only if \(q\).

*If and only if* can be abbreviated *iff*.

So, the biconditional statement is as follows.

\( p \leftrightarrow q: \) Ashley earns $15 an hour if and only if she works over 40 hours a week.

### Examples

Write each biconditional as a conditional and its converse. Then determine whether the biconditional is **true** or **false**. If false, give a counterexample.

**a.** Two angle measures are complements if and only if their sum is 90.
- **Conditional:** If two angle measures are complements, then their sum is 90.
- **Converse:** If the sum of two angle measures is 90, then they are complements. Both the conditional and the converse are true, so the biconditional is true.

**b.** \( x > 9 \text{ iff } x > 0 \)
- **Conditional:** If \( x > 9 \), then \( x > 0 \).
- **Converse:** If \( x > 0 \), then \( x > 9 \).
  - The conditional is true, but the converse is not. Let \( x = 2 \). Then \( 2 > 0 \) but \( 2 \not> 9 \).
  - So, the biconditional is false.

### Reading to Learn

Write each biconditional as a conditional and its converse. Then determine whether the biconditional is **true** or **false**. If false, give a counterexample.

1. A calculator will run if and only if it has batteries.
2. Two lines intersect if and only if they are not vertical.
3. Two angles are congruent if and only if they have the same measure.
4. \( 3x - 4 = 20 \text{ iff } x = 7 \).
5. A line is a segment bisector if and only if it intersects the segment at its midpoint.
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LAW OF SYLLOGISM  Another law of logic is the Law of Syllogism. It is similar to the Transitive Property of Equality.

### Key Concept

**Law of Syllogism**

- **Words**  
  If \( p \rightarrow q \) and \( q \rightarrow r \) are true, then \( p \rightarrow r \) is also true.

- **Symbols**  
  \((p \rightarrow q) \land (q \rightarrow r) \rightarrow (p \rightarrow r)\)

### Example 2  
**Determine Valid Conclusions From Two Conditionals**

**CHEMISTRY**  
Use the Law of Syllogism to determine whether a valid conclusion can be reached from each set of statements.

**a.** (1) If the symbol of a substance is Pb, then it is lead.
(2) The atomic number of lead is 82.

Let \( p \), \( q \), and \( r \) represent the parts of the statement.

- \( p \): the symbol of a substance is Pb
- \( q \): it is lead
- \( r \): the atomic number is 82

Statement (1): \( p \rightarrow q \)
Statement (2): \( q \rightarrow r \)

Since the given statements are true, use the Law of Syllogism to conclude \( p \rightarrow r \).

That is, *If the symbol of a substance is Pb, then its atomic number is 82.*

**b.** (1) Water can be represented by \( \text{H}_2\text{O} \).
(2) Hydrogen (H) and oxygen (O) are in the atmosphere.

There is no valid conclusion. While both statements are true, the conclusion of each statement is not used as the hypothesis of the other.

### Example 3  
**Analyze Conclusions**

Determine whether statement (3) follows from statements (1) and (2) by the Law of Detachment or the Law of Syllogism. If it does, state which law was used. If it does not, write invalid.

**a.** (1) Vertical angles are congruent.
(2) If two angles are congruent, then their measures are equal.
(3) If two angles are vertical, then their measures are equal.

- \( p \): two angles are vertical
- \( q \): they are congruent
- \( r \): their measures are equal

Statement (3) is a valid conclusion by the Law of Syllogism.

**b.** (1) If a figure is a square, then it is a polygon.
(2) Figure A is a polygon.
(3) Figure A is a square.

Statement (1) is true, but statement (3) does not follow from statement (2). Not all polygons are squares. Statement (3) is invalid.
1. **OPEN ENDED** Write an example to illustrate the correct use of the Law of Detachment.

2. **Explain** how the Transitive Property of Equality is similar to the Law of Syllogism.

3. **FIND THE ERROR** An article in a magazine states that if you get seasick, then you will get dizzy. It also says that if you get seasick, you will get an upset stomach. Suzanne says that this means that if you get dizzy, then you will get an upset stomach. Lakeisha says that she is wrong. Who is correct? Explain.

4. Given: \( \angle A \) and \( \angle B \) are vertical angles.
   Conclusion: \( \angle A \equiv \angle B \)

5. Given: \( \angle C \equiv \angle D \)
   Conclusion: \( \angle C \) and \( \angle D \) are vertical angles.

Use the Law of Syllogism to determine whether a valid conclusion can be reached from each set of statements. If a valid conclusion is possible, write it. If not, write **no conclusion**.

6. If you are 18 years old, you are in college.
   You are in college.

7. The midpoint divides a segment into two congruent segments.
   If two segments are congruent, then their measures are equal.

Determine whether statement (3) follows from statements (1) and (2) by the Law of Detachment or the Law of Syllogism. If it does, state which law was used. If it does not, write **invalid**.

8. (1) If Molly arrives at school at 7:30 A.M., she will get help in math.
   (2) If Molly gets help in math, then she will pass her math test.
   (3) If Molly arrives at school at 7:30 A.M., then she will pass her math test.

9. (1) Right angles are congruent.
   (2) \( \angle X \equiv \angle Y \)
   (3) \( \angle X \) and \( \angle Y \) are right angles.

**Application** **INSURANCE** For Exercises 10 and 11, use the following information.
An insurance company advertised the following monthly rates for life insurance.

<table>
<thead>
<tr>
<th>If you are a:</th>
<th>Premium for $30,000 Coverage</th>
<th>Premium for $50,000 Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female, age 35</td>
<td>$14.35</td>
<td>$19.00</td>
</tr>
<tr>
<td>Male, age 35</td>
<td>$16.50</td>
<td>$21.63</td>
</tr>
<tr>
<td>Female, age 45</td>
<td>$21.63</td>
<td>$25.85</td>
</tr>
<tr>
<td>Male, age 45</td>
<td>$23.75</td>
<td>$28.90</td>
</tr>
</tbody>
</table>

10. If Ann is 35 years old and she wants to purchase $30,000 of insurance from this company, then what is her premium?

11. If Terry paid $21.63 for life insurance, can you conclude that Terry is 35? Explain.
Practice and Apply

For Exercises 12–19, determine whether the stated conclusion is valid based on the given information. If not, write invalid. Explain your reasoning.

If two numbers are odd, then their sum is even.

12. Given: The sum of two numbers is 22.
   Conclusion: The two numbers are odd.

13. Given: The numbers are 5 and 7.
   Conclusion: The sum is even.

14. Given: 11 and 23 are added together.
   Conclusion: The sum of 11 and 23 is even.

15. Given: The numbers are 2 and 6.
   Conclusion: The sum is odd.

If three points are noncollinear, then they determine a plane.

   Conclusion: A, B, and C determine a plane.

17. Given: E, F, and G lie in plane M.
   Conclusion: E, F, and G are noncollinear.

18. Given: P and Q lie on a line.
   Conclusion: P and Q determine a plane.

19. Given: \( \triangle XYZ \)
   Conclusion: X, Y, and Z determine a plane.

Use the Law of Syllogism to determine whether a valid conclusion can be reached from each set of statements. If a valid conclusion is possible, write it. If not, write no conclusion.

20. If you spend money on it, then it is a business.
   If you spend money on it, then it is fun.

21. If the measure of an angle is less than 90, then it is acute.
   If an angle is acute, then it is not obtuse.

22. If \( X \) is the midpoint of segment \( YZ \), then \( YX = XZ \).
   If the measures of two segments are equal, then they are congruent.

23. If two lines intersect to form a right angle, then they are perpendicular.
   Lines \( \ell \) and \( m \) are perpendicular.

Determine whether statement (3) follows from statements (1) and (2) by the Law of Detachment or the Law of Syllogism. If it does, state which law was used. If it does not, write invalid.

24. (1) In-line skaters live dangerously.
   (2) If you live dangerously, then you like to dance.
   (3) If you are an in-line skater, then you like to dance.

25. (1) If the measure of an angle is greater than 90, then it is obtuse.
   (2) \( m\angle ABC > 90 \)
   (3) \( \angle ABC \) is obtuse.

26. (1) Vertical angles are congruent.
   (2) \( \angle 3 \equiv \angle 4 \)
   (3) \( \angle 3 \) and \( \angle 4 \) are vertical angles.

27. (1) If an angle is obtuse, then it cannot be acute.
   (2) \( \angle A \) is obtuse.
   (3) \( \angle A \) cannot be acute.
Determine whether statement (3) follows from statements (1) and (2) by the Law of Detachment or the Law of Syllogism. If it does, state which law was used. If it does not, write invalid.

28. (1) If you drive safely, then you can avoid accidents.
   (2) Tika drives safely.
   (3) Tika can avoid accidents.

29. (1) If you are a customer, then you are always right.
   (2) If you are a teenager, then you are always right.
   (3) If you are a teenager, then you are a customer.

30. **LITERATURE** John Steinbeck, a Pulitzer Prize winning author, lived in Monterey, California, for part of his life. In 1945, he published the book, *Cannery Row*, about many of his local working-class heroes from Monterey. If you visited Cannery Row in Monterey during the 1940s, then you could hear the grating noise of the fish canneries. Write a valid conclusion to the following hypothesis.

   *If John Steinbeck lived in Monterey in 1941.*, . . .

31. **SPORTS** In the 2002 Winter Olympics, Canadian speed skater Catriona Le May Doan won her second Olympic title in 500-meter speed skating. Ms. Doan was in the last heat for the second round of that race. Use the two true conditional statements to reach a valid conclusion about Ms. Doan’s 2002 competition.

   (1) If Catriona Le May Doan skated her second 500 meters in 37.45 seconds, then she would beat the time of Germany’s Monique Garbrecht-Enfeldt.
   (2) If Ms. Doan beat the time of Monique Garbrecht-Enfeldt, then she would win the race.

32. **CRITICAL THINKING** An advertisement states that “If you like to ski, then you’ll love Snow Mountain Resort.” Stacey likes to ski, but when she went to Snow Mountain Resort, she did not like it very much. If you know that Stacey saw the ad, explain how her reasoning was flawed.

33. **WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

   **How does deductive reasoning apply to health?**

   Include the following in your answer:

   • an explanation of how doctors may use deductive reasoning to prescribe medicine, and
   • an example of a doctor’s uses of deductive reasoning to diagnose an illness, such as strep throat or chickenpox.

34. Based on the following statements, which statement must be true?
   I If Yasahiro is an athlete and he gets paid, then he is a professional athlete.
   II Yasahiro is not a professional athlete.
   III Yasahiro is an athlete.
   A Yasahiro is an athlete and he gets paid.
   B Yasahiro is a professional athlete or he gets paid.
   C Yasahiro does not get paid.
   D Yasahiro is not an athlete.
35. **ALGEBRA** At a restaurant, a diner uses a coupon for 15% off the cost of one meal. If the diner orders a meal regularly priced at $16 and leaves a tip of 20% of the discounted meal, how much does she pay in total?  

- **A** $15.64  
- **B** $16.32  
- **C** $16.80  
- **D** $18.72

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**Maintain Your Skills**

**Mixed Review**  
**ADVERTISING** For Exercises 36–38, use the following information. *(Lesson 2-3)*  
Advertising writers frequently use if-then statements to relay a message and promote their product. An ad for a type of Mexican food reads, *If you’re looking for a fast, easy way to add some fun to your family’s menu, try Casa Fiesta.*

36. Write the converse of the conditional.

37. What do you think the advertiser wants people to conclude about Casa Fiesta products?

38. Does the advertisement say that Casa Fiesta adds fun to your family’s menu?

**Construct a truth table for each compound statement.** *(Lesson 2-2)*  
39. $q \land r$

40. $\sim p \lor r$

41. $p \land (q \lor r)$

42. $p \lor (\sim q \land r)$

For Exercises 43–47, refer to the figure at the right. *(Lesson 1-5)*

43. Which angle is complementary to $\angle FDG$?

44. Name a pair of vertical angles.

45. Name a pair of angles that are noncongruent and supplementary.

46. Identify $\angle FDH$ and $\angle CDH$ as congruent, adjacent, vertical, complementary, supplementary, and/or a linear pair.

47. Can you assume that $\overline{DC} \cong \overline{CK}$? Explain.

**Use the Pythagorean Theorem to find the distance between each pair of points.** *(Lesson 1-3)*

48. $A(1, 5), B(-2, 9)$

49. $C(-4, -2), D(2, 6)$

50. $F(7, 4), G(1, 0)$

51. $M(-5, 0), N(4, 7)$

For Exercises 52–55, draw and label a figure for each relationship. *(Lesson 1-1)*

52. $\overline{FG}$ lies in plane $M$ and contains point $H$.

53. Lines $r$ and $s$ intersect at point $W$.

54. Line $\ell$ contains $P$ and $Q$, but does not contain $R$.

55. Planes $A$ and $B$ intersect in line $n$.

**PREREQUISITE SKILL** Write what you can assume about the segments or angles listed for each figure. *(To review information from figures, see Lesson 1-5.)*

56. $\overline{AM}, \overline{CM}, \overline{CN}, \overline{BN}$

57. $\angle 1, \angle 2$

58. $\angle 4, \angle 5, \angle 6$
Matrix Logic

Deductive reasoning can be used in problem-solving situations. One method of solving problems uses a table. This method is called **matrix logic**.

**Example**

**GEOLOGY** On a recent test, Rashaun was given five different mineral samples to identify, along with the chart at right. Rashaun observed the following.

- Sample C is brown.
- Samples B and E are harder than glass.
- Samples D and E are red.

Identify each of the samples.

Make a table to organize the information. Mark each false condition with an X and each true condition with a ✓. The first observation is that Sample C is brown. Only one of the minerals, biotite, is brown, so place a check in the box that corresponds to biotite and Sample C. Then place an X in each of the other boxes in the same column and row.

The second observation is that Samples B and E are harder than glass. Place an X in each box for minerals that are softer than glass. The third observation is that Samples D and E are red. Mark the boxes accordingly. Notice that Sample E has an X in all but one box. Place a check mark in the remaining box, and an X in all other boxes in that row.

Then complete the table. Sample A is Halite, Sample B is Feldspar, Sample C is Biotite, Sample D is Hematite, and Sample E is Jaspar.

**Exercises**

1. Nate, John, and Nick just began after-school jobs. One works at a veterinarian’s office, one at a computer store, and one at a restaurant. Nate buys computer games on the way to work. Nick is allergic to cat hair. John receives free meals at his job. Who works at which job?

2. Six friends live in consecutive apartments on the same side of their apartment building. Anita lives in apartment C. Kelli’s apartment is just past Scott’s. Anita’s closest neighbors are Eric and Ava. Scott’s apartment is not A through D. Eric’s apartment is before Ava’s. If Roberto lives in one of the apartments, who lives in which apartment?
What You’ll Learn

- Identify and use basic postulates about points, lines, and planes.
- Write paragraph proofs.

Vocabulary

- postulate
- axiom
- theorem
- proof
- paragraph proof
- informal proof

How were postulates used by the founding fathers of the United States?

U.S. Supreme Court Justice William Douglas stated “The First Amendment makes confidence in the common sense of our people and in the maturity of their judgment the great postulate of our democracy.” The writers of the constitution assumed that citizens would act and speak with common sense and maturity. Some statements in geometry also must be assumed or accepted as true.

POINTS, LINES, AND PLANES

In geometry, a postulate, or axiom, is a statement that describes a fundamental relationship between the basic terms of geometry. Postulates are accepted as true. The basic ideas about points, lines, and planes can be stated as postulates.

Postulates

2.1 Through any two points, there is exactly one line.
2.2 Through any three points not on the same line, there is exactly one plane.

Example 1 Points and Lines

COMPUTERS

Jessica is setting up a network for her father’s business. There are five computers in his office. Each computer needs to be connected to every other computer. How many connections does Jessica need to make?

Explore

There are five computers, and each is connected to four others.

Plan

Draw a diagram to illustrate the solution.

Solve

Let noncollinear points \( A, B, C, D, \) and \( E \) represent the five computers. Connect each point with every other point. Then, count the number of segments.

Between every two points there is exactly one segment. So, the connection between computer \( A \) and computer \( B \) is the same as the connection between computer \( B \) and computer \( A \). For the five points, ten segments can be drawn.

Examine

\( AB, AC, AD, AE, BC, BD, BE, CD, CE, \) and \( DE \) each represent a connection between two computers. So there will be ten connections among the five computers.
There are other postulates that are based on relationships among points, lines, and planes.

**Postulates**

2.3 A line contains at least two points.
2.4 A plane contains at least three points not on the same line.
2.5 If two points lie in a plane, then the entire line containing those points lies in that plane.
2.6 If two lines intersect, then their intersection is exactly one point.
2.7 If two planes intersect, then their intersection is a line.

**Example 2 Use Postulates**

Determine whether each statement is always, sometimes, or never true. Explain.

a. If points $A$, $B$, and $C$ lie in plane $M$, then they are collinear.
   Sometimes; $A$, $B$, and $C$ do not necessarily have to be collinear to lie in plane $M$.

b. There is exactly one plane that contains noncollinear points $P$, $Q$, and $R$.
   Always; Postulate 2.2 states that through any three noncollinear points, there is exactly one plane.

c. There are at least two lines through points $M$ and $N$.
   Never; Postulate 2.1 states that through any two points, there is exactly one line.

**PARAGRAPH PROOFS**

Undefined terms, definitions, postulates, and algebraic properties of equality are used to prove that other statements or conjectures are true. Once a statement or conjecture has been shown to be true, it is called a **theorem**, and it can be used like a definition or postulate to justify that other statements are true.

You will study and use various methods to verify or prove statements and conjectures in geometry. A **proof** is a logical argument in which each statement you make is supported by a statement that is accepted as true. One type of proof is called a **paragraph proof** or **informal proof**. In this type of proof, you write a paragraph to explain why a conjecture for a given situation is true.

**Key Concept**

Five essential parts of a good proof:

- State the theorem or conjecture to be proven.
- List the given information.
- If possible, draw a diagram to illustrate the given information.
- State what is to be proved.
- Develop a system of deductive reasoning.

In Lesson 1-2, you learned the relationship between segments formed by the midpoint of a segment. This statement can be proven, and the result stated as a theorem.
Theorem 2.8
Once a conjecture has been proven true, it can be stated as a theorem and used in other proofs. The conjecture in Example 3 is known as the Midpoint Theorem.

Write a Paragraph Proof

Given that \( M \) is the midpoint of \( PQ \), write a paragraph proof to show that \( PM \cong MQ \).

**Given:** \( M \) is the midpoint of \( PQ \).

**Prove:** \( PM \cong MQ \).

From the definition of midpoint of a segment, \( PM = MQ \). This means that \( PM \) and \( MQ \) have the same measure. By the definition of congruence, if two segments have the same measure, then they are congruent. Thus, \( PM \cong MQ \).

Once a conjecture has been proven true, it can be stated as a theorem and used in other proofs. The conjecture in Example 3 is known as the Midpoint Theorem.

**Theorem 2.8**

Midpoint Theorem  If \( M \) is the midpoint of \( AB \), then \( AM \cong MB \).

Check for Understanding

**Concept Check**
1. Explain how deductive reasoning is used in a proof.
2. **OPEN ENDED** Draw figures to illustrate Postulates 2.6 and 2.7.
3. List the types of reasons that can be used for justification in a proof.

**Guided Practice**
Determine the number of segments that can be drawn connecting each pair of points.

4. 

5. 

6. Determine whether the following statement is always, sometimes, or never true. Explain.
   The intersection of three planes is two lines.

**In the figure, \( BD \) and \( BR \) are in plane \( T \), and \( W \) is on \( BD \). State the postulate or definition that can be used to show each statement is true.**

7. \( B, D, \) and \( W \) are collinear.
8. \( E, B, \) and \( R \) are coplanar.
9. \( R \) and \( W \) are collinear.

**10. PROOF** In the figure at the right, \( P \) is the midpoint of \( QR \) and \( ST \), and \( QR \cong ST \). Write a paragraph proof to show that \( PQ = PT \).

**Application**
11. **DANCING** Six students are participating in a dance to celebrate the opening of a new community center. The students, each connected to each of the other students with wide colored ribbons, will move in a circular motion. How many ribbons are needed?
Determine the number of segments that can be drawn connecting each pair of points.

12.  13.  

14.  15.  

Determine whether the following statements are always, sometimes, or never true. Explain.

16. Three points determine a plane.
17. Points \(G\) and \(H\) are in plane \(X\). Any point collinear with \(G\) and \(H\) is in plane \(X\).
18. The intersection of two planes can be a point.
19. Points \(S\), \(T\), and \(U\) determine three lines.
20. Points \(A\) and \(B\) lie in at least one plane.
21. If line \(\ell\) lies in plane \(P\) and line \(m\) lies in plane \(Q\), then lines \(\ell\) and \(m\) lie in plane \(R\).

In the figure at the right, \(\overrightarrow{AC}\) and \(\overrightarrow{BD}\) lie in plane \(J\) and \(\overrightarrow{BY}\) and \(\overrightarrow{CX}\) lie in plane \(K\).
State the postulate that can be used to show each statement is true.

22. \(C\) and \(D\) are collinear.
23. \(\overleftrightarrow{AB}\) lies in plane \(K\).
24. Points \(A\), \(C\), and \(X\) are coplanar.
25. \(\overrightarrow{AD}\) lies in plane \(J\).
26. \(X\) and \(Y\) are collinear.
27. Points \(Y\), \(D\), and \(C\) are coplanar.

28. **Proof** Point \(C\) is the midpoint of \(\overrightarrow{AB}\) and \(B\) is the midpoint of \(\overrightarrow{CD}\). Prove that \(\overrightarrow{AC} \cong \overrightarrow{BD}\).

29. **Models** Faith’s teacher asked her to make a figure showing the number of lines and planes formed from four points that are noncollinear and noncoplanar. Faith decided to make a mobile of straws, pipe cleaners, and colored sheets of tissue paper. She plans to glue the paper to the straws and connect the straws together to form a group of connected planes. How many planes and lines will she have?

30. **Careers** Many professions use deductive reasoning and paragraph proofs. For example, a police officer uses deductive reasoning investigating a traffic accident and then writes the findings in a report. List a profession, and describe how it can use paragraph proofs.
31. **CRITICAL THINKING** You know that three noncollinear points lie in a single plane. In Exercise 29, you found the number of planes defined by four noncollinear points. What are the least and greatest number of planes defined by five noncollinear points?

32. **WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

**How are postulates used in literature?**

Include the following in your answer:

- an example of a postulate in historic United States’ documents, and
- an example of a postulate in mathematics.

33. Which statement cannot be true?

(A) A plane can be determined using three noncollinear points.
(B) Two lines intersect at exactly one point.
(C) At least two lines can contain the same two points.
(D) A midpoint divides a segment into two congruent segments.

34. **ALGEBRA** For all values of $x$, 

\[
(8x^4 - 2x^2 + 3x - 5) - (2x^4 + x^3 + 3x + 5) =
\]

(A) $6x^4 - x^3 - 2x^2 - 10$. 
(B) $6x^4 - 3x^2 + 6x - 10$. 
(C) $6x^4 + x^3 - 2x^2 + 6x$. 
(D) $6x^4 - 3x^2$.

---

**Maintain Your Skills**

**Mixed Review**

35. Determine whether statement (3) follows from statements (1) and (2) by the Law of Detachment or the Law of Syllogism. If it does, state which law was used. If it does not, write *invalid*.  *(Lesson 2-4)*

(1) Part-time jobs require 20 hours of work per week.
(2) Jamie has a part-time job.
(3) Jamie works 20 hours per week.

Write the converse, inverse, and contrapositive of each conditional statement. Determine whether each related conditional is *true* or *false*. If a statement is false, find a counterexample.  *(Lesson 2-3)*

36. If you have access to the Internet at your house, then you have a computer.
37. If $\triangle ABC$ is a right triangle, one of its angle measures is greater than 90.

38. **BIOLOGY** Use a Venn diagram to illustrate the following statement.

*If an animal is a butterfly, then it is an arthropod.*  *(Lesson 2-2)*

Use the Distance Formula to find the distance between each pair of points.  *(Lesson 1-3)*

39. $D(3, 3), F(4, -1)$
40. $M(0, 2), N(-5, 5)$
41. $P(-8, 2), Q(1, -3)$
42. $R(-5, 12), S(2, 1)$

---

**Getting Ready for the Next Lesson**

**PREREQUISITE SKILL** Solve each equation.  *(To review solving equations, see pages 737 and 738.)*

43. $m - 17 = 8$
44. $3y = 57$
45. $\frac{y}{6} + 12 = 14$
46. $-t + 3 = 27$
47. $8n - 39 = 41$
48. $-6x + 33 = 0$

www.geometryonline.com/self_check_quiz
### Vocabulary
- deductive argument
- two-column proof
- formal proof

### What You’ll Learn
- Use algebra to write two-column proofs.
- Use properties of equality in geometry proofs.

### How is mathematical evidence similar to evidence in law?
Lawyers develop their cases using logical arguments based on evidence to lead a jury to a conclusion favorable to their case. At the end of a trial, a lawyer will make closing remarks summarizing the evidence and testimony that they feel proves their case. These closing arguments are similar to a proof in mathematics.

### ALGEBRAIC PROOF
Algebra is a system with sets of numbers, operations, and properties that allow you to perform algebraic operations.

<table>
<thead>
<tr>
<th>Concept Summary</th>
<th>Properties of Equality for Real Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflexive Property</td>
<td>For every number $a$, $a = a$.</td>
</tr>
<tr>
<td>Symmetric Property</td>
<td>For all numbers $a$ and $b$, if $a = b$, then $b = a$.</td>
</tr>
<tr>
<td>Transitive Property</td>
<td>For all numbers $a$, $b$, and $c$, if $a = b$ and $b = c$, then $a = c$.</td>
</tr>
<tr>
<td>Addition and Subtraction Properties</td>
<td>For all numbers $a$, $b$, and $c$, if $a = b$, then $a + c = b + c$ and $a - c = b - c$.</td>
</tr>
<tr>
<td>Multiplication and Division Properties</td>
<td>For all numbers $a$, $b$, and $c$, if $a = b$, then $a \cdot c = b \cdot c$ and if $c \neq 0$, $\frac{a}{c} = \frac{b}{c}$.</td>
</tr>
<tr>
<td>Substitution Property</td>
<td>For all numbers $a$ and $b$, if $a = b$, then $a$ may be replaced by $b$ in any equation or expression</td>
</tr>
<tr>
<td>Distributive Property</td>
<td>For all numbers $a$, $b$, and $c$, $a(b + c) = ab + ac$.</td>
</tr>
</tbody>
</table>

The properties of equality can be used to justify each step when solving an equation. A group of algebraic steps used to solve problems form a **deductive argument**.

### Example 1  Verify Algebraic Relationships
Solve $3(x - 2) = 42$.

<table>
<thead>
<tr>
<th>Algebraic Steps</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>$3(x - 2) = 42$</td>
<td>Original equation</td>
</tr>
<tr>
<td>$3x - 6 = 42$</td>
<td>Distributive Property</td>
</tr>
<tr>
<td>$3x - 6 + 6 = 42 + 6$</td>
<td>Addition Property</td>
</tr>
<tr>
<td>$3x = 48$</td>
<td>Substitution Property</td>
</tr>
<tr>
<td>$\frac{3x}{3} = \frac{48}{3}$</td>
<td>Division Property</td>
</tr>
<tr>
<td>$x = 16$</td>
<td>Substitution Property</td>
</tr>
</tbody>
</table>
Example 1 is a proof of the conditional statement \( 5x + 3(x - 2) = 42 \), then \( x = 6 \). Notice that the column on the left is a step-by-step process that leads to a solution. The column on the right contains the reason for each statement.

In geometry, a similar format is used to prove conjectures and theorems. A two-column proof, or formal proof, contains statements and reasons organized in two columns. In a two-column proof, each step is called a statement, and the properties that justify each step are called reasons.

Example 2  Write a Two-Column Proof

Write a two-column proof.

a. If \( 3\left( \frac{x}{2} - \frac{5}{2} \right) = 1 \), then \( x = 2 \)

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( 3\left( \frac{x}{2} - \frac{5}{2} \right) = 1 )</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. ( 3x - 3\left( \frac{5}{2} \right) = 1 )</td>
<td>2. Distributive Property</td>
</tr>
<tr>
<td>3. ( 3x - 5 = 1 )</td>
<td>3. Substitution</td>
</tr>
<tr>
<td>4. ( 3x - 5 + 5 = 1 + 5 )</td>
<td>4. Addition Property</td>
</tr>
<tr>
<td>5. ( 3x = 6 )</td>
<td>5. Substitution</td>
</tr>
<tr>
<td>6. ( \frac{3x}{3} = \frac{6}{3} )</td>
<td>6. Division Property</td>
</tr>
<tr>
<td>7. ( x = 2 )</td>
<td>7. Substitution</td>
</tr>
</tbody>
</table>

b. Given: \( \frac{7}{2} - n = 4 - \frac{1}{2}n \)

Prove: \( n = -1 \)

Proof:

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( \frac{7}{2} - n = 4 - \frac{1}{2}n )</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. ( 2\left( \frac{7}{2} - n \right) = 2\left( 4 - \frac{1}{2}n \right) )</td>
<td>2. Multiplication Property</td>
</tr>
<tr>
<td>3. ( 7 - 2n = 8 - n )</td>
<td>3. Distributive Property</td>
</tr>
<tr>
<td>4. ( 7 - 2n + n = 8 - n + n )</td>
<td>4. Addition Property</td>
</tr>
<tr>
<td>5. ( 7 = 8 )</td>
<td>5. Substitution</td>
</tr>
<tr>
<td>6. ( 7 - n = 8 )</td>
<td>6. Subtraction Property</td>
</tr>
<tr>
<td>7. ( -n = 1 )</td>
<td>7. Substitution</td>
</tr>
<tr>
<td>8. ( \frac{-n}{-1} = \frac{1}{-1} )</td>
<td>8. Division Property</td>
</tr>
<tr>
<td>9. ( n = -1 )</td>
<td>9. Substitution</td>
</tr>
</tbody>
</table>

GEOMETRIC PROOF  Since geometry also uses variables, numbers, and operations, many of the properties of equality used in algebra are also true in geometry. For example, segment measures and angle measures are real numbers, so properties from algebra can be used to discuss their relationships. Some examples of these applications are shown below.

<table>
<thead>
<tr>
<th>Property</th>
<th>Segments</th>
<th>Angles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflexive</td>
<td>( AB = AB )</td>
<td>( m\angle 1 = m\angle 1 )</td>
</tr>
<tr>
<td>Symmetric</td>
<td>If ( AB = CD ), then ( CD = AB ).</td>
<td>If ( m\angle 1 = m\angle 2 ), then ( m\angle 2 = m\angle 1 ).</td>
</tr>
<tr>
<td>Transitive</td>
<td>If ( AB = CD ) and ( CD = EF ), then ( AB = EF ).</td>
<td>If ( m\angle 1 = m\angle 2 ) and ( m\angle 2 = m\angle 3 ), then ( m\angle 1 = m\angle 3 ).</td>
</tr>
</tbody>
</table>

www.geometryonline.com/extra_examples
Example 3  Justify Geometric Relationships

Multiple-Choice Test Item

If \( AB \cong CD \), and \( CD \cong EF \), then which of the following is a valid conclusion?

I  \( AB = CD \) and \( CD = EF \)
II  \( AB \cong EF \)
III  \( AB = EF \)

(A) I only    (B) I and II
(C) I and III  (D) I, II, and III

Read the Test Item

Determine whether the statements are true based on the given information.

Solve the Test Item

Statement I:
Examine the given information, \( AB \cong CD \) and \( CD \cong EF \). From the definition of congruent segments, if \( AB \cong CD \) and \( CD \cong EF \), then \( AB = CD \) and \( CD = EF \). Thus, Statement I is true.

Statement II:
By the definition of congruent segments, if \( AB = EF \), then \( AB \cong EF \).
Statement II is true also.

Statement III:
If \( AB = CD \) and \( CD = EF \), then \( AB = EF \) by the Transitive Property.
Thus, Statement III is true.

Because Statements I, II, and III are true, choice D is correct.

In Example 3, each conclusion was justified using a definition or property. This process is used in geometry to verify and prove statements.

Example 4  Geometric Proof

TIME  On a clock, the angle formed by the hands at 2:00 is a 60° angle. If the angle formed at 2:00 is congruent to the angle formed at 10:00, prove that the angle at 10:00 is a 60° angle.

Given:  \( m\angle 2 = 60 \)
\( \angle 2 \cong \angle 10 \)
Prove:  \( m\angle 10 = 60 \)

Proof:

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( m\angle 2 = 60 ) ( \angle 2 \cong \angle 10 )</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. ( m\angle 2 = m\angle 10 )</td>
<td>2. Definition of congruent angles</td>
</tr>
<tr>
<td>3. ( 60 = m\angle 10 )</td>
<td>3. Substitution</td>
</tr>
<tr>
<td>4. ( m\angle 10 = 60 )</td>
<td>4. Symmetric Property</td>
</tr>
</tbody>
</table>
State the property that justifies each statement.

14. If \( \frac{m}{H} + H11028 \) and \( \frac{m}{H} = H11005 \), then \( \frac{m}{H} = H11028 \).

15. If \( HJ + 5 = 20 \), then \( HJ = 15 \).

16. If \( XY + 20 = YW \) and \( XY + 20 = DT \), then \( YW = DT \).

17. If \( m\angle 1 + m\angle 2 = 90 \) and \( m\angle 2 = m\angle 3 \), then \( m\angle 1 + m\angle 3 = 90 \).

18. If \( \frac{1}{2}AB = \frac{1}{2}EF \), then \( AB = EF \).

19. \( AB = AB \)
20. If \(2 \left( x - \frac{3}{2} \right) = 5\), which property can be used to support the statement \(2x - 3 = 5\)?

21. Which property allows you to state \(m \angle 4 = m \angle 5\), if \(m \angle 4 = 35\) and \(m \angle 5 = 35\)?

22. If \(\frac{1}{2} AB = \frac{1}{2} CD\), which property can be used to justify the statement \(AB = CD\)?

23. Which property could be used to support the statement \(EF = JK\), given that 
   \(EF = GH\) and \(GH = JK\)?

Complete each proof.

24. Given: \(\frac{3x + 5}{2} = 7\)
   Prove: \(x = 3\)

   Proof:
   
<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (\frac{3x + 5}{2} = 7)</td>
<td>a. ?</td>
</tr>
<tr>
<td>c. (3x + 5 = 14)</td>
<td>c. ?</td>
</tr>
<tr>
<td>d. (3x = 9)</td>
<td>d. ?</td>
</tr>
<tr>
<td>e. ?</td>
<td>e. Div. Prop.</td>
</tr>
</tbody>
</table>

25. Given: \(2x - 7 = \frac{1}{3}x - 2\)
   Prove: \(x = 3\)

   Proof:
   
<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ?</td>
<td>a. Given</td>
</tr>
<tr>
<td>c. (6x - 21 = x - 6)</td>
<td>c. ?</td>
</tr>
<tr>
<td>e. (5x = 15)</td>
<td>e. ?</td>
</tr>
</tbody>
</table>

PROOF Write a two-column proof.

26. If \(4 - \frac{1}{2}a = \frac{7}{2} - a\), then \(a = -1\).

27. If \(-2y + \frac{3}{2} = 8\), then \(y = \frac{-13}{4}\).

28. If \(-\frac{1}{2}m = 9\), then \(m = -18\).

29. If \(5 - \frac{2}{3}z = 1\), then \(z = 6\).

30. If \(XZ = ZY\), \(XZ = 4x + 1\), and \(ZY = 6x - 13\), then \(x = 7\).

31. If \(m \angle ACB = m \angle ABC\), then \(m \angle XCA = m \angle YBA\).

32. PHYSICS Kinetic energy is the energy of motion. The formula for kinetic energy is \(E_k = h \cdot f + W\), where \(h\) represents Planck’s Constant, \(f\) represents the frequency of its photon, and \(W\) represents the work function of the material being used. Solve this formula for \(f\) and justify each step.
33. **GARDENING** Areas in the southwest and southeast have cool but mild winters. In these areas, many people plant pansies in October so that they have flowers outside year-round. In the arrangement of pansies shown, the walkway divides the two sections of pansies into four beds that are the same size. If $m\angle ACB = m\angle DCE$, what could you conclude about the relationship among $\angle ACB$, $\angle DCE$, $\angle ECF$, and $\angle ACG$?

34. **CRITICAL THINKING** For Exercises 34 and 35, use the following information. Below is a family tree of the Gibbs family. Clara, Carol, Cynthia, and Cheryl are all daughters of Lucy. Because they are sisters, they have a transitive and symmetric relationship. That is, Clara is a sister of Carol, Carol is a sister of Cynthia, so Clara is a sister of Cynthia.

![Family Tree](image)

What other relationships in a family have reflexive, symmetric, or transitive relationships? Explain why. Remember that the child or children of each person are listed beneath that person’s name. Consider relationships such as first cousin, ancestor or descendent, aunt or uncle, sibling, or any other relationship.

35. Construct your family tree on one or both sides of your family and identify the reflexive, symmetric, or transitive relationships.

36. **WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

How is mathematical evidence similar to evidence in law?

Include the following in your answer:

- a description of how evidence is used to influence jurors’ conclusions in court, and
- a description of the evidence used to make conclusions in mathematics.

37. In $\triangle PQR$, $m\angle P = m\angle Q$ and $m\angle R = 2(m\angle Q)$. Find $m\angle P$ if $m\angle P + m\angle Q + m\angle R = 180$.

   - **A** 30
   - **B** 45
   - **C** 60
   - **D** 90

38. **ALGEBRA** If 4 more than $x$ is 5 less than $y$, what is $x$ in terms of $y$?

   - **A** $y - 1$
   - **B** $y - 9$
   - **C** $y + 9$
   - **D** $y - 5$
39. **CONSTRUCTION** There are four buildings on the Medfield High School Campus, no three of which stand in a straight line. How many sidewalks need to be built so that each building is directly connected to every other building? *(Lesson 2-5)*

Determine whether the stated conclusion is valid based on the given information. If not, write invalid. Explain your reasoning. *A number is divisible by 3 if it is divisible by 6.* *(Lesson 2-4)*

40. Given: 24 is divisible by 6. Conclusion: 24 is divisible by 3.
41. Given: 27 is divisible by 3. Conclusion: 27 is divisible by 6.
42. Given: 85 is not divisible by 3. Conclusion: 85 is not divisible by 6.

Write each statement in if-then form. *(Lesson 2-3)*

43. “Happy people rarely correct their faults.” *(La Rochefoucauld)*
44. “If you don’t know where you are going, you will probably end up somewhere else.” *(Laurence Peters)*
45. “A champion is afraid of losing.” *(Billie Jean King)*
46. “If we would have new knowledge, we must get a whole new world of questions.” *(Susanne K. Langer)*

Find the precision for each measurement. *(Lesson 1-2)*

47. 13 feet 48. 5.9 meters 49. 74 inches 50. 3.1 kilometers

**PREREQUISITE SKILL** Find the measure of each segment. *(To review segment measures, see Lesson 1-2.)*

51. \(KL\) 52. \(QS\) 53. \(WZ\)

In the figure at the right, \(A, B,\) and \(C\) are collinear. Points \(A, B,\) \(C,\) and \(D\) lie in plane \(N.\) State the postulate or theorem that can be used to show each statement is true. *(Lesson 2-5)*

2. \(A, B,\) and \(D\) determine plane \(N.\)
3. \(BE\) intersects \(AC\) at \(B.\)
4. \(\ell\) lies in plane \(N.\)
5. **PROOF** If \(2(n - 3) + 5 = 3(n - 1),\) prove that \(n = 2.\) *(Lesson 2-6)*
Proving Segment Relationships

What You’ll Learn

• Write proofs involving segment addition.
• Write proofs involving segment congruence.

How can segment relationships be used for travel?

When leaving San Diego, the pilot said that the flight would be about 360 miles to Phoenix before continuing on to Dallas. When the plane left Phoenix, the pilot said that the flight would be flying about 1070 miles to Dallas.

SEGMENT ADDITION In Lesson 1-2, you measured segments with a ruler by placing the mark for zero on one endpoint, then finding the distance to the other endpoint. This illustrates the Ruler Postulate.

Postulate 2.8

Ruler Postulate The points on any line or line segment can be paired with real numbers so that, given any two points \( A \) and \( B \) on a line, \( A \) corresponds to zero, and \( B \) corresponds to a positive real number.

![Diagram of Ruler Postulate]

The Ruler Postulate can be used to further investigate line segments.

Geometry Software Investigation

Adding Segment Measures

Construct a Figure

• Use The Geometer’s Sketchpad to construct \( \overline{AC} \).
• Place point \( B \) on \( \overline{AC} \).
• Find \( AB \), \( BC \), and \( AC \).

Analyze the Model

1. What is the sum \( AB + BC \)?
2. Move \( B \). Find \( AB \), \( BC \) and \( AC \). What is the sum of \( AB + BC \)?
3. Repeat moving \( B \), measuring the segments, and finding the sum \( AB + BC \) three times. Record your results.

Make a Conjecture

4. What is true about the relationship of \( AB \), \( BC \), and \( AC \)?
5. Is it possible to place \( B \) on \( \overline{AC} \) so that this relationship is not true?
Examine the measures \( AB \), \( BC \), and \( AC \) in the Geometry Activity. Notice that wherever \( B \) is placed between \( A \) and \( C \), \( AB + BC = AC \). This suggests the following postulate.

**Postulate 2.9**

**Segment Addition Postulate**  If \( B \) is between \( A \) and \( C \), then \( AB + BC = AC \).

If \( AB + BC = AC \), then \( B \) is between \( A \) and \( C \).

---

**Example 1**  
**Proof With Segment Addition**

Prove the following.

**Given:** \( PQ = RS \)

**Prove:** \( PR = QS \)

**Proof:**

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( PQ = RS )</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. ( PQ + QR = QR + RS )</td>
<td>2. Addition Property</td>
</tr>
<tr>
<td>3. ( PQ + QR = PR ) ( QR + RS = QS )</td>
<td>3. Segment Addition Postulate</td>
</tr>
<tr>
<td>4. ( PR = QS )</td>
<td>4. Substitution</td>
</tr>
</tbody>
</table>

---

**SEGMENT CONGRUENCE**  In Lesson 2-5, you learned that once a theorem is proved, it can be used in proofs of other theorems. One theorem we can prove is similar to properties of equality from algebra.

**Theorem 2.2**  
**Segment Congruence**

Congruence of segments is reflexive, symmetric, and transitive.

**Reflexive Property** \( \overline{AB} \equiv \overline{AB} \)

**Symmetric Property** If \( \overline{AB} \equiv \overline{CD} \), then \( \overline{CD} \equiv \overline{AB} \).

**Transitive Property** If \( \overline{AB} \equiv \overline{CD} \), and \( \overline{CD} \equiv \overline{EF} \), then \( \overline{AB} \equiv \overline{EF} \).

You will prove the first two properties in Exercises 10 and 24.

**Proof**  
**Transitive Property of Congruence**

**Given:** \( \overline{MN} \equiv \overline{PQ} \) \( \overline{PQ} \equiv \overline{RS} \)

**Prove:** \( \overline{MN} \equiv \overline{RS} \)

**Proof:**

**Method 1**  Paragraph Proof

Since \( \overline{MN} \equiv \overline{PQ} \) and \( \overline{PQ} \equiv \overline{RS} \), \( MN = PQ \) and \( PQ = RS \) by the definition of congruent segments. By the Transitive Property of Equality, \( MN = RS \). Thus, \( \overline{MN} \equiv \overline{RS} \) by the definition of congruent segments.
Method 2 Two-Column Proof

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $MN \cong PQ$, $PQ \cong RS$</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. $MN = PQ$, $PQ = RS$</td>
<td>2. Definition of congruent segments</td>
</tr>
<tr>
<td>3. $MN = RS$</td>
<td>3. Transitive Property</td>
</tr>
<tr>
<td>4. $MN \cong RS$</td>
<td>4. Definition of congruent segments</td>
</tr>
</tbody>
</table>

The theorems about segment congruence can be used to prove segment relationships.

**Example 2** Proof With Segment Congruence

Prove the following.

**Given:** $JK \cong KL$, $HJ \cong GH$, $KL \cong HJ$

**Prove:** $GH \cong JK$

**Proof:**

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $JK \cong KL$, $KL \cong HJ$</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. $KL \cong HJ$</td>
<td>2. Transitive Property</td>
</tr>
<tr>
<td>3. $HJ \cong GH$</td>
<td>3. Given</td>
</tr>
<tr>
<td>4. $JK \cong GH$</td>
<td>4. Transitive Property</td>
</tr>
<tr>
<td>5. $GH \cong JK$</td>
<td>5. Symmetric Property</td>
</tr>
</tbody>
</table>

**Concept Check**

1. Choose two cities from a United States road map. Describe the distance between the cities using the Reflexive Property.
2. **OPEN ENDED** Draw three congruent segments, and illustrate the Transitive Property using these segments.
3. Describe how to determine whether a point $B$ is between points $A$ and $C$.

**Guided Practice**

Justify each statement with a property of equality or a property of congruence.

4. $XY \cong XY$
5. If $GH \cong MN$, then $MN \cong GH$.
6. If $AB = AC + CB$, then $AB - AC = CB$.

7. Copy and complete the proof.

**Given:** $PQ \cong RS$, $QS \cong ST$

**Prove:** $PS \cong RT$

**Proof:**

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. $?$, $?$</td>
<td>a. Given</td>
</tr>
<tr>
<td>b. $PQ = RS$, $QS = ST$</td>
<td>b. $?$</td>
</tr>
<tr>
<td>c. $PS = PQ + QS$, $RT = RS + ST$</td>
<td>c. $?$</td>
</tr>
<tr>
<td>d. $?$</td>
<td>d. Addition Property</td>
</tr>
<tr>
<td>e. $?$</td>
<td>e. Substitution</td>
</tr>
<tr>
<td>f. $PS \cong RT$</td>
<td>f. $?$</td>
</tr>
</tbody>
</table>

www.geometryonline.com/extra_examples
Practice and Apply

Justify each statement with a property of equality or a property of congruence.

12. If $JK \equiv LM$, then $LM \equiv JK$.
13. If $AB = 14$ and $CD = 14$, then $AB = CD$.
14. If $W, X,$ and $Y$ are collinear, in that order, then $WY = WX + XY$.
15. If $MN \equiv PQ$ and $PQ \equiv RS$, then $MN \equiv RS$.
16. If $EF = TU$ and $GH = VW$, then $EF + GH = TU + VW$.
17. If $JK + MN = JK + QR$, then $MN = QR$.

18. Copy and complete the proof.

Given: $AD \equiv CE$, $DB \equiv EB$  
Prove: $AB \equiv CB$  
Proof:

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ?</td>
<td>a. Given</td>
</tr>
<tr>
<td>b. $AD = CE$, $DB = EB$</td>
<td>b. ?</td>
</tr>
<tr>
<td>c. $AD + DB = CE + EB$</td>
<td>c. ?</td>
</tr>
<tr>
<td>d. ?</td>
<td>d. Segment Addition Postulate</td>
</tr>
<tr>
<td>e. $AB = CB$</td>
<td>e. ?</td>
</tr>
<tr>
<td>f. $AB \equiv CB$</td>
<td>f. ?</td>
</tr>
</tbody>
</table>

19. If $XY \equiv WZ$ and $WZ \equiv AB$, then $XY \equiv AB$.

20. If $AB \equiv AC$ and $PC \equiv QB$, then $AP \equiv AQ$.
21. Copy and complete the proof.

Given: \( WY \cong ZX \)
\( A \) is the midpoint of \( WY \).
\( A \) is the midpoint of \( ZX \).

Prove: \( WA \cong ZA \)

Proof:

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. ( WY \cong ZX )</td>
<td>a. ?</td>
</tr>
<tr>
<td>( A ) is the midpoint of ( WY ).</td>
<td>( A ) is the midpoint of ( ZX ).</td>
</tr>
<tr>
<td>b. ( WY = ZX )</td>
<td>b. ?</td>
</tr>
<tr>
<td>c. ?</td>
<td>c. Definition of midpoint</td>
</tr>
<tr>
<td>d. ( WY = WA + AY, ZX = ZA + AX )</td>
<td>d. ?</td>
</tr>
<tr>
<td>e. ( WA + AY = ZA + AX )</td>
<td>e. ?</td>
</tr>
<tr>
<td>f. ( WA + WA = ZA + ZA )</td>
<td>f. ?</td>
</tr>
<tr>
<td>g. ( 2WA = 2ZA )</td>
<td>g. ?</td>
</tr>
<tr>
<td>h. ?</td>
<td>h. Division Property</td>
</tr>
<tr>
<td>i. ( WA \cong ZA )</td>
<td>i. ?</td>
</tr>
</tbody>
</table>

22. If \( LM \cong PN \) and \( XM \cong XN \), then \( LX \cong PX \).

23. If \( AB = BC \), then \( AC = 2BC \).

24. Reflexive Property of Congruence (Theorem 2.2)

25. DESIGN The front of a building has a triangular window. If \( AB \cong DE \) and \( C \) is the midpoint of \( BD \), prove that \( AC \cong CE \).

26. LIGHTING The light fixture in Gerrard Hall of the University of North Carolina is shown at the right. If \( AB \cong EF \) and \( BC \cong DE \), prove that \( AC \cong DF \).

27. CRITICAL THINKING Given that \( LN \cong RT \), \( RT \cong QO \), \( LQ \cong NO \), \( MP \cong NO \), \( S \) is the midpoint of \( RT \), \( M \) is the midpoint of \( LN \), and \( P \) is the midpoint of \( QO \), list three statements that you could prove using the postulates, theorems, and definitions that you have learned.
28. **WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

**How can segment relationships be used for travel?**

Include the following in your answer:
- an explanation of how a passenger can use the distances the pilot announced to find the total distance from San Diego to Dallas, and
- an explanation of why the Segment Addition Postulate may or may not be useful when traveling.

29. If $P$ is the midpoint of $BC$ and $Q$ is the midpoint of $AD$, what is $PQ$?

   - **A** $\frac{1}{2}$  
   - **B** $1$  
   - **C** $2$  
   - **D** $2\frac{1}{2}$

30. **GRID IN** A refreshment stand sells a large tub of popcorn for twice the price of a box of popcorn. If 60 tubs were sold for a total of $150 and the total popcorn sales were $275, how many boxes of popcorn were sold?

**Maintain Your Skills**

**Mixed Review** State the property that justifies each statement. *(Lesson 2-6)*

31. If $m\angle P + m\angle Q = 110$ and $m\angle R = 110$, then $m\angle P + m\angle Q = m\angle R$.
32. If $x(y + z) = a$, then $xy + xz = a$.
33. If $n - 17 = 39$, then $n = 56$.
34. If $cv = md$ and $md = 15$, then $cv = 15$.

**Determine whether the following statements are always, sometimes, or never true. Explain.** *(Lesson 2-5)*

35. A midpoint divides a segment into two noncongruent segments.
36. Three lines intersect at a single point.
37. The intersection of two planes forms a line.
38. Three single points determine three lines.
39. If the perimeter of rectangle $ABCD$ is 44 centimeters, find $x$ and the dimensions of the rectangle. *(Lesson 1-6)*

**Getting Ready for the Next Lesson** **PREREQUISITE SKILL** Find $x$.

*(To review complementary and supplementary angles, see Lesson 1-5.)*

40.  
41.  
42.  
43.  
44.  
45.
What You’ll Learn
- Write proofs involving supplementary and complementary angles.
- Write proofs involving congruent and right angles.

How do scissors illustrate supplementary angles?

Notice that when a pair of scissors is opened, the angle formed by the two blades, \( \angle 1 \), and the angle formed by a blade and a handle, \( \angle 2 \), are a linear pair. Likewise, the angle formed by a blade and a handle, \( \angle 2 \), and the angle formed by the two handles, \( \angle 3 \), also forms a linear pair.

SUPPLEMENTARY AND COMPLEMENTARY ANGLES

Recall that when you measure angles with a protractor, you position the protractor so that one of the rays aligns with zero degrees and then determine the position of the second ray. This illustrates the Protractor Postulate.

Postulate 2.10

Protractor Postulate

Given \( \overline{AB} \) and a number \( r \) between 0 and 180, there is exactly one ray with endpoint \( A \), extending on either side of \( \overline{AB} \), such that the measure of the angle formed is \( r \).

In Lesson 2-7, you learned about the Segment Addition Postulate. A similar relationship exists between the measures of angles.

Postulate 2.11

Angle Addition Postulate

If \( R \) is in the interior of \( \angle PQS \), then \( m\angle PQR + m\angle RQS = m\angle PQS \).

If \( m\angle PQR + m\angle RQS = m\angle PQS \), then \( R \) is in the interior of \( \angle PQS \).

Example 1

Angle Addition

The Grand Union Flag at the left contains several angles.

If \( m\angle ABD = 44 \) and \( m\angle ABC = 88 \), find \( m\angle DBC \).

\[
\begin{align*}
44 + m\angle DBC &= 88 \\
m\angle DBC &= 44
\end{align*}
\]

The Grand Union Flag at the left contains several angles.
The Angle Addition Postulate can be used with other angle relationships to provide additional theorems relating to angles.

### Theorems

#### 2.3 Supplement Theorem
If two angles form a linear pair, then they are supplementary angles.

- **Diagram:**
  - Angles 1 and 2 form a linear pair.
  - $m\angle 1 + m\angle 2 = 180$

#### 2.4 Complement Theorem
If the noncommon sides of two adjacent angles form a right angle, then the angles are complementary angles.

- **Diagram:**
  - Angles 1 and 2 form a right angle.
  - $m\angle 1 + m\angle 2 = 90$

You will prove Theorems 2.3 and 2.4 in Exercises 10 and 11.

#### Supplementary Angles

If $\angle 1$ and $\angle 2$ form a linear pair and $m\angle 2 = 67$, find $m\angle 1$.

- **Solution:**
  - $m\angle 1 + m\angle 2 = 180$ Suppose Theorem
  - $m\angle 1 + 67 = 180$ Substitution Property
  - $m\angle 1 = 113$ Subtraction Property

---

### CONGRUENT AND RIGHT ANGLES

The properties of algebra that applied to the congruence of segments and the equality of their measures also hold true for the congruence of angles and the equality of their measures.

#### Theorem 2.5

Congruence of angles is reflexive, symmetric, and transitive.

- Reflexive Property: $\angle 1 \equiv \angle 1$
- Symmetric Property: If $\angle 1 \equiv \angle 2$, then $\angle 2 \equiv \angle 1$.
- Transitive Property: If $\angle 1 \equiv \angle 2$, and $\angle 2 \equiv \angle 3$, then $\angle 1 \equiv \angle 3$.

You will prove the Reflexive and Transitive Properties of Angle Congruence in Exercises 26 and 27.

#### Proof of Symmetric Property of Congruence

**Given:** $\angle A \equiv \angle B$

**Prove:** $\angle B \equiv \angle A$

**Paragraph Proof:**

We are given $\angle A \equiv \angle B$. By the definition of congruent angles, $m\angle A = m\angle B$.

Using the Symmetric Property, $m\angle B = m\angle A$. Thus, $\angle B \equiv \angle A$ by the definition of congruent angles.

Algebraic properties can be applied to prove theorems for congruence relationships involving supplementary and complementary angles.
### Theorems

#### 2.6 Angles supplementary to the same angle or to congruent angles are congruent.

**Abbreviation:** \( \triangle \) suppl. to same \( \angle \)

or \( \cong \) \( \triangle \) \( \cong \).

**Example:** If \( m\angle 1 + m\angle 2 = 180 \) and \( m\angle 2 + m\angle 3 = 180 \), then \( \angle 1 \cong \angle 3 \).

#### 2.7 Angles complementary to the same angle or to congruent angles are congruent.

**Abbreviation:** \( \triangle \) compl. to same \( \angle \)

or \( \cong \) \( \triangle \) \( \cong \).

**Example:** If \( m\angle 1 + m\angle 2 = 90 \) and \( m\angle 2 + m\angle 3 = 90 \), then \( \angle 1 \cong \angle 3 \).

You will prove Theorem 2.6 in Exercise 6.

### Proof

**Theorem 2.7**

**Given:** \( \angle 1 \) and \( \angle 3 \) are complementary. 
\( \angle 2 \) and \( \angle 3 \) are complementary.

**Prove:** \( \angle 1 \cong \angle 2 \)

#### Proof:

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( \angle 1 ) and ( \angle 3 ) are complementary. ( \angle 2 ) and ( \angle 3 ) are complementary.</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. ( m\angle 1 + m\angle 3 = 90 ) ( m\angle 2 + m\angle 3 = 90 )</td>
<td>2. Definition of complementary angles</td>
</tr>
<tr>
<td>3. ( m\angle 1 + m\angle 3 = m\angle 2 + m\angle 3 )</td>
<td>3. Substitution</td>
</tr>
<tr>
<td>4. ( m\angle 3 = m\angle )</td>
<td>4. Reflective Property</td>
</tr>
<tr>
<td>5. ( m\angle 1 = m\angle 2 )</td>
<td>5. Subtraction Property</td>
</tr>
<tr>
<td>6. ( \angle 1 \cong \angle 2 )</td>
<td>6. Definition of congruent angles</td>
</tr>
</tbody>
</table>

### Example 3 Use Supplementary Angles

In the figure, \( \angle 1 \) and \( \angle 2 \) form a linear pair and \( \angle 2 \) and \( \angle 3 \) form a linear pair. Prove that \( \angle 1 \) and \( \angle 3 \) are congruent.

**Given:** \( \angle 1 \) and \( \angle 2 \) form a linear pair. 
\( \angle 2 \) and \( \angle 3 \) form a linear pair.

**Prove:** \( \angle 1 \cong \angle 3 \)

#### Proof:

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( \angle 1 ) and ( \angle 2 ) form a linear pair. ( \angle 2 ) and ( \angle 3 ) form a linear pair.</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. ( \angle 1 ) and ( \angle 2 ) are supplementary. ( \angle 2 ) and ( \angle 3 ) are supplementary.</td>
<td>2. Supplement Theorem</td>
</tr>
<tr>
<td>3. ( \angle 1 \cong \angle 3 )</td>
<td>3. ( \triangle ) suppl. to same ( \angle ) or ( \cong ) ( \triangle ) ( \cong ).</td>
</tr>
</tbody>
</table>
Note that in Example 3, $\angle 1$ and $\angle 3$ are vertical angles. The conclusion in the example is a proof for the following theorem.

**Theorem 2.8**

**Vertical Angles Theorem** If two angles are vertical angles, then they are congruent.

**Abbreviation:** Vert. $\angle$ are $\cong$.

$\angle 1 \cong \angle 3$ and $\angle 2 \cong \angle 4$

---

**Example 4** **Vertical Angles**

If $\angle 1$ and $\angle 2$ are vertical angles and $m\angle 1 = x$ and $m\angle 2 = 228 - 3x$, find $m\angle 1$ and $m\angle 2$.

\[
\angle 1 \cong \angle 2 \\
m\angle 1 = m\angle 2 \\
x = 228 - 3x \\
4x = 228 \\
x = 57 \\
m\angle 1 = x \\
m\angle 2 = m\angle 1 \\
= 57 \\
= 57
\]

The theorems you have learned can be applied to right angles. You can create right angles and investigate congruent angles by paper folding.

---

**Geometry Activity**

**Right Angles**

**Make a Model**

- Fold the paper so that one corner is folded downward.
- Fold along the crease so that the top edge meets the side edge.
- Unfold the paper and measure each of the angles formed.
- Repeat the activity three more times.

**Analyze the Model**

1. What do you notice about the lines formed?
2. What do you notice about each pair of adjacent angles?
3. What are the measures of the angles formed?

**Make a Conjecture**

4. What is true about perpendicular lines?
5. What is true about all right angles?

The following theorems support the conjectures you made in the Geometry Activity.
Theorems

- **Theorems**
- **Right Angles**

2.9 Perpendicular lines intersect to form four right angles.
2.10 All right angles are congruent.
2.11 Perpendicular lines form congruent adjacent angles.
2.12 If two angles are congruent and supplementary, then each angle is a right angle.
2.13 If two congruent angles form a linear pair, then they are right angles.

Check for Understanding

**Concept Check**

1. **FIND THE ERROR** Tomas and Jacob wrote equations involving the angle measures shown.

   **Tomas**
   \[ \angle ABE + \angle EBC = \angle ABC \]

   **Jacob**
   \[ \angle ABE + \angle FBC = \angle ABC \]

   Who is correct? Explain your reasoning.

2. **OPEN ENDED** Draw three congruent angles. Use these angles to illustrate the Transitive Property for angle congruence.

**Guided Practice**

Find the measure of each numbered angle.

3. \( \angle 1 = 65 \)  
4. \( \angle 6 \) and \( \angle 8 \) are complementary.  
   \[ m\angle 8 = 47 \]

5. \( m\angle 11 = x - 4 \), \( m\angle 12 = 2x - 5 \)

6. **PROOF** Copy and complete the proof of Theorem 2.6.

   **Given:** \( \angle 1 \) and \( \angle 2 \) are supplementary.  
   \( \angle 3 \) and \( \angle 4 \) are supplementary.  
   \( \angle 1 \equiv \angle 4 \)

   **Prove:** \( \angle 2 \equiv \angle 3 \)

   **Proof:**

   **Statements**
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>a. ( \angle 1 ) and ( \angle 2 ) are supplementary. ( \angle 3 ) and ( \angle 4 ) are supplementary. ( \angle 1 \equiv \angle 4 )</td>
</tr>
<tr>
<td>b. ( m\angle 1 + m\angle 2 = 180 ) ( m\angle 3 + m\angle 4 = 180 )</td>
</tr>
<tr>
<td>c. ( m\angle 1 + m\angle 2 = m\angle 3 + m\angle 4 )</td>
</tr>
<tr>
<td>d. ( m\angle 1 = m\angle 4 )</td>
</tr>
<tr>
<td>e. ( m\angle 2 = m\angle 3 )</td>
</tr>
<tr>
<td>f. ( \angle 2 \equiv \angle 3 )</td>
</tr>
</tbody>
</table>
7. **PROOF** Write a two-column proof.
   **Given:** VX bisects \( \angle WVY \).
   VY bisects \( \angle XVZ \).
   **Prove:** \( \angle WVX \cong \angle YVZ \)

Determine whether the following statements are **always**, **sometimes**, or **never** true.
8. Two angles that are nonadjacent are _?_ vertical.
9. Two angles that are congruent are _?_ complementary to the same angle.

**PROOF** Write a proof for each theorem.
10. Supplement Theorem
11. Complement Theorem

**APPLICATION** For Exercises 12–15, use the following information.
\( \angle 1 \) and \( \angle X \) are complementary,
\( \angle 2 \) and \( \angle X \) are complementary,
\( m \angle 1 = 2n + 2 \), and \( m \angle 2 = n + 32 \).
12. Find \( n \).
13. Find \( m \angle 1 \).
14. What is \( m \angle 2 \)?
15. Find \( m \angle X \).

**PRACTICE AND APPLY** Find the measure of each numbered angle.
16. \( m \angle 2 = 67 \)
17. \( m \angle 3 = 38 \)
18. \( \angle 7 \) and \( \angle 8 \) are complementary. \( \angle 5 \cong \angle 8 \)
   and \( m \angle 6 = 29 \).
19. \( m \angle 9 = 2x - 4 \),
   \( m \angle 10 = 2x + 4 \)
20. \( m \angle 11 = 4x \),
   \( m \angle 12 = 2x - 6 \)
21. \( m \angle 13 = 2x + 94 \),
   \( m \angle 14 = 7x + 49 \)
22. \( m \angle 15 = x \),
   \( m \angle 16 = 6x - 290 \)
23. \( m \angle 17 = 2x + 7 \),
   \( m \angle 18 = x + 30 \)
24. \( m \angle 19 = 100 + 20x \),
   \( m \angle 20 = 20x \)
25. Prove that congruence of angles is reflexive.
26. Write a proof of the Transitive Property of Angle Congruence.

Determine whether the following statements are always, sometimes, or never true.
27. Two angles that are complementary ____ form a right angle.
28. Two angles that are vertical are ____ nonadjacent.
29. Two angles that form a right angle are ____ complementary.
30. Two angles that form a linear pair are ____ congruent.
31. Two angles that are supplementary are ____ congruent.
32. Two angles that form a linear pair are ____ supplementary.

PROOF Use the figure to write a proof of each theorem.
33. Theorem 2.9
34. Theorem 2.10
35. Theorem 2.11
36. Theorem 2.12
37. Theorem 2.13

PROOF Write a two-column proof.
38. Given: \( \angle ABD \cong \angle YXZ \)
   Prove: \( \angle CBD \cong \angle WXZ \)
39. Given: \( m\angle RSW = m\angle TSU \)
   Prove: \( m\angle RST = m\angle WSU \)

40. RIVERS Tributaries of rivers sometimes form a linear pair of angles when they meet the main river. The Yellowstone River forms the linear pair \( \angle 1 \) and \( \angle 2 \) with the Missouri River. If \( m\angle 1 \) is 28, find \( m\angle 2 \).

41. HIGHWAYS Near the city of Hopewell, Virginia, Route 10 runs perpendicular to Interstate 95 and Interstate 295. Show that the angles at the intersections of Route 10 with Interstate 95 and Interstate 295 are congruent.

42. CRITICAL THINKING What conclusion can you make about the sum of \( m\angle 1 \) and \( m\angle 4 \) if \( m\angle 1 = m\angle 2 \) and \( m\angle 3 = m\angle 4 \)? Explain.
43. **WRITING IN MATH** Answer the question that was posed at the beginning of the lesson.

How do scissors illustrate supplementary angles?
Include the following in your answer:
• a description of the relationship among \( \angle 1, \angle 2, \) and \( \angle 3, \)
• an example of another way that you can tell the relationship between \( \angle 1 \) and \( \angle 3, \)
• an explanation of whether this relationship is the same for two angles complementary to the same angle.

44. The measures of two complementary angles are in the ratio 4:1. What is the measure of the smaller angle?
- **A** 15
- **B** 18
- **C** 24
- **D** 36

45. **ALGEBRA** \( T \) is the set of all positive numbers \( n \) such that \( n \leq 50 \) and \( \sqrt{n} \) is an integer. What is the median of the members of set \( T? \)
- **A** 4
- **B** 16
- **C** 20
- **D** 25

46. **PROOF** Write a two-column proof. \( (\text{Lesson 2-7}) \)

**Given:**
\( G \) is between \( F \) and \( H. \)
\( H \) is between \( G \) and \( J. \)

**Prove:** \( FG + GJ = FH + HJ \)

47. **PROOF** \( X \) is the midpoint of \( \overline{WY}. \)

**Prove:** \( WX + YZ = XZ \)

48. **PHOTOGRAPHY** Film is fed through a camera by gears that catch the perforation in the film. The distance from the left edge of the film, \( A, \) to the right edge of the image, \( C, \) is the same as the distance from the left edge of the image, \( B, \) to the right edge of the film, \( D. \) Show that the two perforated strips are the same width. \( (\text{Lesson 2-6}) \)

For Exercises 49–55, refer to the figure at the right. \( (\text{Lesson 1-4}) \)
49. Name two angles that have \( N \) as a vertex.
50. If \( MQ \) bisects \( \angle PMN, \) name two congruent angles.
51. Name a point in the interior of \( \angle LMQ. \)
52. List all the angles that have \( O \) as the vertex.
53. Does \( \angle QML \) appear to be acute, obtuse, right, or straight?
54. Name a pair of opposite rays.
55. List all the angles that have \( MN \) as a side.
Exercises  Choose the correct term to complete each sentence.
1. A (counterexample, conjecture) is an educated guess based on known information.
2. The truth or falsity of a statement is called its (conclusion, truth value).
3. Two or more statements can be joined to form a (conditional, compound) statement.
4. A conjunction is a compound statement formed by joining two or more statements using (or, and).
5. The phrase immediately following the word if in a conditional statement is called the (hypothesis, conclusion).
6. The (inverse, converse) is formed by exchanging the hypothesis and the conclusion.
7. (Theorems, Postulates) are accepted as true without proof.
8. A paragraph proof is a (an) (informal proof, formal proof).

Lesson-by-Lesson Review

2-1  Inductive Reasoning and Conjecture

Concept Summary
- Conjectures are based on observations and patterns.
- Counterexamples can be used to show that a conjecture is false.

Example
Given that points \( P, Q, \) and \( R \) are collinear, determine whether the conjecture that \( Q \) is between \( P \) and \( R \) is true or false. If the conjecture is false, give a counterexample.

In the figure, \( R \) is between \( P \) and \( Q \). Since we can find a counterexample, the conjecture is false.

Exercises  Make a conjecture based on the given information. Draw a figure to illustrate your conjecture.  See Example 2 on page 63.
9. \( \angle A \) and \( \angle B \) are supplementary.
10. \( X, Y, \) and \( Z \) are collinear and \( XY = YZ \).
11. In quadrilateral \( LMNO, LM = LO = MN = NO \), and \( \angle L = 90 \).
2-2 Logic

**Concept Summary**
- The negation of a statement has the opposite truth value of the original statement.
- Venn diagrams and truth tables can be used to determine the truth values of statements.

**Example**
Use the following statements to write a compound statement for each conjunction. Then find its truth value.

\[ p: \sqrt{15} = 5 \quad q: \text{The measure of a right angle equals 90.} \]

a. \( p \land q \)
   \( \sqrt{15} = 5, \) and the measure of a right angle equals 90.
   \( p \) and \( q \) is false because \( p \) is false and \( q \) is true.

b. \( p \lor q \)
   \( \sqrt{15} = 5, \) or the measure of a right angle equals 90.
   \( p \lor q \) is true because \( q \) is true. It does not matter that \( p \) is false.

**Exercises**
Use the following statements to write a compound statement for each conjunction. Then find its truth value.  
See Examples 1 and 2 on pages 68 and 69.

\[ p: -1 > 0 \quad q: \text{In a right triangle with right angle } C, a^2 + b^2 = c^2. \quad r: \text{The sum of the measures of two supplementary angles is 180.} \]

12. \( p \land q \)
13. \( q \lor r \)
14. \( r \land p \)
15. \( p \lor (q \land r) \)
16. \( q \lor (p \land r) \)
17. \( (q \land r) \lor p \)

2-3 Conditional Statements

**Concept Summary**
- Conditional statements are written in if-then form.
- Form the converse, inverse, and contrapositive of an if-then statement by using negations and by exchanging the hypothesis and conclusion.

**Example**
Identify the hypothesis and conclusion of the statement The intersection of two planes is a line. Then write the statement in if-then form.

Hypothesis: two planes intersect
Conclusion: their intersection is a line
If two planes intersect, then their intersection is a line.

**Exercises**
Write the converse, inverse, and contrapositive of each conditional statement. Determine whether each related conditional is true or false. If a statement is false, find a counterexample.  
See Example 4 on page 77.

18. If an angle measure equals 120, then the angle is obtuse.
19. If the month is March, then it has 31 days.
20. If an ordered pair for a point has 0 for its \( x \)-coordinate, then the point lies on the \( y \)-axis.
Determine the truth value of the following statement for each set of conditions.

If the temperature is at most 0°C, then water freezes.  See Example 3 on page 76.

21. The temperature is −10°C, and water freezes.
22. The temperature is 15°C, and water freezes.
23. The temperature is −2°C, and water does not freeze.
24. The temperature is 30°C, and water does not freeze.

\[ \text{Example} \]

Deductive Reasoning

Concept Summary

- The Law of Detachment and the Law of Syllogism can be used to determine the truth value of a compound statement.

Use the Law of Syllogism to determine whether a valid conclusion can be reached from the following statements.

(1) If a body in our solar system is the Sun, then it is a star.
(2) Stars are in constant motion.

\[ p: \text{a body in our solar system is the Sun} \]
\[ q: \text{it is a star} \]
\[ r: \text{stars are in constant motion} \]

Statement (1): \( p \rightarrow q \)  
Statement (2): \( q \rightarrow r \)

Since the given statements are true, use the Law of Syllogism to conclude \( p \rightarrow r \). That is, If a body in our solar system is the Sun, then it is in constant motion.

Exercises  Determine whether the stated conclusion is valid based on the given information. If not, write invalid. Explain your reasoning.  See Example 1 on page 82.

If two angles are adjacent, then they have a common vertex.

25. Given: \( \angle 1 \) and \( \angle 2 \) are adjacent angles.
   Conclusion: \( \angle 1 \) and \( \angle 2 \) have a common vertex.
26. Given: \( \angle 3 \) and \( \angle 4 \) have a common vertex.
   Conclusion: \( \angle 3 \) and \( \angle 4 \) are adjacent angles.

Determine whether statement (3) follows from statements (1) and (2) by the Law of Detachment or the Law of Syllogism. If it does, state which law was used. If it does not follow, write invalid.  See Example 3 on page 83.

27. (1) If a student attends North High School, then the student has an ID number.
    (2) Josh Michael attends North High School.
    (3) Josh Michael has an ID number.
28. (1) If a rectangle has four congruent sides, then it is a square.
    (2) A square has diagonals that are perpendicular.
    (3) A rectangle has diagonals that are perpendicular.
29. (1) If you like pizza with everything, then you’ll like Cardo’s Pizza.
    (2) If you like Cardo’s Pizza, then you are a pizza connoisseur.
    (3) If you like pizza with everything, then you are a pizza connoisseur.
Postulates and Paragraph Proofs

Concept Summary

- Use undefined terms, definitions, postulates, and theorems to prove that statements and conjectures are true.

Example

Determine whether the following statement is always, sometimes, or never true. Explain. Two points determine a line.

According to a postulate relating to points and lines, two points determine a line. Thus, the statement is always true.

Exercises

Determine whether the following statements are always, sometimes, or never true. Explain. See Example 2 on page 90.

30. The intersection of two lines can be a line.
31. If \( P \) is the midpoint of \( XY \), then \( XP = PY \).
32. If \( MX = MY \), then \( M \) is the midpoint of \( XY \).
33. Three points determine a line.
34. Points \( Q \) and \( R \) lie in at least one plane.
35. If two angles are right angles, they are adjacent.
36. An angle is congruent to itself.
37. Vertical angles are adjacent.
38. PROOF Write a paragraph proof to prove that if \( M \) is the midpoint of \( AB \) and \( Q \) is the midpoint of \( AM \), then \( AQ = \frac{1}{4} AB \).

Algebraic Proof

Concept Summary

- The properties of equality used in algebra can be applied to the measures of segments and angles to verify and prove statements.

Example

Given: \( 2x + 6 = 3 + \frac{5}{3}x \)
Prove: \( x = -9 \)
Proof:

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ( 2x + 6 = 3 + \frac{5}{3}x )</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. ( 3(2x + 6) = 3 \left( 3 + \frac{5}{3}x \right) )</td>
<td>2. Multiplication Property</td>
</tr>
<tr>
<td>3. ( 6x + 18 = 9 + 5x )</td>
<td>3. Distributive Property</td>
</tr>
<tr>
<td>4. ( 6x + 18 - 5x = 9 + 5x - 5x )</td>
<td>4. Subtraction Property</td>
</tr>
<tr>
<td>5. ( x + 18 = 9 )</td>
<td>5. Substitution</td>
</tr>
<tr>
<td>6. ( x + 18 - 18 = 9 - 18 )</td>
<td>6. Subtraction Property</td>
</tr>
<tr>
<td>7. ( x = -9 )</td>
<td>7. Substitution</td>
</tr>
</tbody>
</table>
Exercises  State the property that justifies each statement.  See Example 1 on page 94.

39. If $3(x + 2) = 6$, then $3x + 6 = 6$.
40. If $10x = 20$, then $x = 2$.
41. If $AB + 20 = 45$, then $AB = 25$.
42. If $3 = CD$ and $CD = XY$, then $3 = XY$.

PROOF  Write a two-column proof.  See Examples 2 and 4 on pages 95 and 96.

43. If $5 = 2 - \frac{1}{2}x$, then $x = -6$.
44. If $x - 1 = \frac{x - 10}{-2}$, then $x = 4$.
45. If $AC = AB$, $AC = 4x + 1$, and $AB = 6x - 13$, then $x = 7$.
46. If $MN = PQ$ and $PQ = RS$, then $MN = RS$.

**2-7 Proving Segment Relationships**

See pages 101–106.

**Concept Summary**

- Use properties of equality and congruence to write proofs involving segments.

**Example**  Write a two-column proof.

**Given:**  $QT = RT$, $TS = TP$

**Prove:**  $QS = RP$

**Proof:**

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. $QT = RT$, $TS = TP$</td>
<td>1. Given</td>
</tr>
<tr>
<td>2. $QT + TS = RT + TS$</td>
<td>2. Addition Property</td>
</tr>
<tr>
<td>3. $QT + TS = RT + TP$</td>
<td>3. Substitution</td>
</tr>
<tr>
<td>4. $QT + TS = QS$, $RT + TP = RP$</td>
<td>4. Segment Addition Postulate</td>
</tr>
<tr>
<td>5. $QS = RP$</td>
<td>5. Substitution</td>
</tr>
</tbody>
</table>

**Exercises**  Justify each statement with a property of equality or a property of congruence.  See Example 1 on page 102.

47. $PS = PS$

48. If $XY = OP$, then $OP = XY$.

49. If $AB - 8 = CD - 8$, then $AB = CD$.

50. If $EF = GH$ and $GH = LM$, then $EF = LM$.

51. If $2(XY) = AB$, then $XY = \frac{1}{2}(AB)$.

52. If $AB = CD$, then $AB + BC = CD + BC$. 

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53. Given: \(BC = EC, CA = CD\)
Prove: \(BA = DE\)

54. Given: \(AB = CD\)
Prove: \(AC = BD\)

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**2-8**

Proving Angle Relationships

**Concept Summary**
- The properties of equality and congruence can be applied to angle relationships.

**Example**

Find the measure of each numbered angle.
\(m\angle 1 = 55\), since \(\angle 1\) is a vertical angle to the \(55^\circ\) angle.
\(\angle 2\) and the \(55^\circ\) angle form a linear pair.

\[55 + m\angle 2 = 180\]  \(\text{Def. of supplementary } \angle\)
\[m\angle 2 = 125\]  \(\text{Subtract 55 from each side.}\)

**Exercises**

55. \(m\angle 6\)
56. \(m\angle 7\)
57. \(m\angle 8\)

58. **PROOF** Copy and complete the proof.

Given: \(\angle 1\) and \(\angle 2\) form a linear pair.
\(m\angle 2 = 2(m\angle 1)\)
Prove: \(m\angle 1 = 60\)
Proof:

<table>
<thead>
<tr>
<th>Statements</th>
<th>Reasons</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. (\angle 1) and (\angle 2) form a linear pair.</td>
<td>a. ?</td>
</tr>
<tr>
<td>b. (\angle 1) and (\angle 2) are supplementary.</td>
<td>b. ?</td>
</tr>
<tr>
<td>c. ?</td>
<td>c. Definition of supplementary angles</td>
</tr>
<tr>
<td>d. (m\angle 2 = 2(m\angle 1))</td>
<td>d. ?</td>
</tr>
<tr>
<td>e. ?</td>
<td>e. Substitution</td>
</tr>
<tr>
<td>f. ?</td>
<td>f. Substitution</td>
</tr>
<tr>
<td>g. [\frac{3(m\angle 1)}{3} = \frac{180}{3}]</td>
<td>g. ?</td>
</tr>
<tr>
<td>h. ?</td>
<td>h. Substitution</td>
</tr>
</tbody>
</table>
Vocabulary and Concepts

1. Explain the difference between formal and informal proofs.
2. Explain how you can prove that a conjecture is false.
3. Describe the parts of a two-column proof.

Skills and Applications

Determine whether each conjecture is true or false. Explain your answer and give a counterexample for any false conjecture.

4. Given: \( \angle A \cong \angle B \)
   Conjecture: \( \angle B \cong \angle A \)

5. Given: \( y \) is a real number
   Conjecture: \( -y > 0 \)

6. Given: \( 3a^2 = 48 \)
   Conjecture: \( a = 4 \)

Use the following statements to write a compound statement for each conjunction or disjunction. Then find its truth value.

7. \( p \) and \( q \)
   \( p: -3 > 2 \quad q: 3x = 12 \) when \( x = 4 \)

8. \( p \) or \( q \)
   \( r: \) An equilateral triangle is also equiangular.

9. \( p \lor (q \land r) \)

Identify the hypothesis and conclusion of each statement and write each statement in if-then form. Then write the converse, inverse, and contrapositive of each conditional.

10. An apple a day keeps the doctor away.
11. A rolling stone gathers no moss.

12. Determine whether statement (3) follows from statements (1) and (2) by the Law of Detachment or the Law of Syllogism. If it does, state which law was used. If it does not, write invalid.
   (1) Perpendicular lines intersect.
   (2) Lines \( m \) and \( n \) are perpendicular.
   (3) Lines \( m \) and \( n \) intersect.

13. \( \angle 1 \)
14. \( \angle 2 \)
15. \( \angle 3 \)

16. Write a two-column proof.
   If \( y = 4x + 9 \) and \( x = 2 \), then \( y = 17 \).

17. Write a paragraph proof.
   Given: \( AM = CN, MB = ND \)
   Prove: \( AB = CD \)

18. ADVERTISING Identify the hypothesis and conclusion of the following statement, then write it in if-then form. Hard working people deserve a great vacation.

19. STANDARDIZED TEST PRACTICE If two planes intersect, their intersection can be
   I a line.
   II three noncollinear points.
   III two intersecting lines.
   A I only
   B II only
   C III only
   D I and II only

www.geometryonline.com/chapter_test
1. Arrange the numbers $|−7|, \frac{1}{7}, \sqrt{7}, −7^2$ in order from least to greatest. **(Prerequisite Skill)**

- **A** $|−7|, \sqrt{7}, \frac{1}{7}, −7^2$
- **B** $−7^2, |−7|, \frac{1}{7}, \sqrt{7}$
- **C** $|−7|, \frac{1}{7}, \sqrt{7}, −7^2$
- **D** $−7^2, \frac{1}{7}, \sqrt{7}, |−7|$

2. Points $A$ and $B$ lie on the line $y = 2x − 3$. Which of the following are coordinates of a point noncollinear with $A$ and $B$? **(Lesson 1-1)**

- **A** $(7, 11)$
- **B** $(4, 5)$
- **C** $(-2, −10)$
- **D** $(-5, −13)$

3. Dana is measuring distance on a map. Which of the following tools should Dana use to make the most accurate measurement? **(Lesson 1-2)**

- **A** centimeter ruler
- **B** protractor
- **C** yardstick
- **D** calculator

4. Point $E$ is the midpoint of $DF$. If $DE = 8x − 3$ and $EF = 3x + 7$, what is $x$? **(Lesson 1-3)**

- **A** 1
- **B** 2
- **C** 4
- **D** 13

5. What is the relationship between $\angle ACF$ and $\angle DCF$? **(Lesson 1-6)**

- **A** complementary angles
- **B** congruent angles
- **C** supplementary angles
- **D** vertical angles

6. Which of the following is an example of inductive reasoning? **(Lesson 2-1)**

- **A** Carlos learns that the measures of all acute angles are less than 90. He conjectures that if he sees an acute angle, its measure will be less than 90.
- **B** Carlos reads in his textbook that the measure of all right angles is 90. He conjectures that the measure of each right angle in a square equals 90.
- **C** Carlos measures the angles of several triangles and finds that their measures all add up to 180. He conjectures that the sum of the measures of the angles in any triangle is always 180.
- **D** Carlos knows that the sum of the measures of the angles in a square is always 360. He conjectures that if he draws a square, the sum of the measures of the angles will be 360.

7. Which of the following is the contrapositive of the statement If Rick buys hamburgers for lunch, then Denzel buys French fries and a large soda? **(Lesson 2-2)**

- **A** If Denzel does not buy French fries and a large soda, then Rick does not buy hamburgers for lunch.
- **B** If Rick does not buy hamburgers for lunch, then Denzel does not buy French fries and a large soda.
- **C** If Denzel buys French fries and a large soda, then Rick buys hamburgers for lunch.
- **D** If Rick buys hamburgers for lunch, then Denzel does not buy French fries and a large soda.

8. Which property could justify the first step in solving $3 \times \frac{14x + 6}{8} = 18$? **(Lesson 2-5)**

- **A** Division Property of Equality
- **B** Substitution Property of Equality
- **C** Addition Property of Equality
- **D** Transitive Property of Equality
9. Two cheerleaders stand at opposite corners of a football field. What is the shortest distance between them, to the nearest yard? (Lesson 1-3)

10. Consider the conditional If I call in sick, then I will not get paid for the day. Based on the original conditional, what is the name of the conditional If I do not call in sick, then I will get paid for the day? (Lesson 2-2)

11. Examine the following statements.
   
   p: Martina drank a cup of soy milk.
   q: A cup is 8 ounces.
   r: Eight ounces of soy milk contains 300 milligrams of calcium.

   Using the Law of Syllogism, how many milligrams of calcium did Martina get from drinking a cup of soy milk? (Lesson 2-4)

12. In the following proof, what property justifies statement c? (Lesson 2-7)

   Given: \( \overline{AC} \cong \overline{MN} \)
   
   Prove: \( AB + BC = MN \)

   Proof:
   
   Statements | Reasons
   --- | ---
   a. \( \overline{AC} \cong \overline{MN} \) | a. Given
   b. \( AC = MN \) | b. Definition of congruent segments
   c. \( AC = AB + BC \) | c. ?
   d. \( AC + BC = MN \) | d. Substitution

13. In any right triangle, the sum of the squares of the lengths of the legs equals the square of the length of the hypotenuse. From a single point in her yard, Marti measures and marks distances of 18 feet and 24 feet for two sides of her garden. Explain how Marti can ensure that the two sides of her garden form a right angle. (Lesson 1-3)

14. A farmer needs to make a 100-square-foot rectangular enclosure for her chickens. She wants to save money by purchasing the least amount of fencing possible to enclose the area. (Lesson 1-4)

   a. What whole-number dimensions, to the nearest yard, will require the least amount of fencing?
   
   b. Explain your procedure for finding the dimensions that will require the least amount of fencing.
   
   c. Explain how the amount of fencing required to enclose the area changes as the dimensions change.

15. Given: \( \angle 1 \) and \( \angle 3 \) are vertical angles. \( m\angle 1 = 3x + 5, m\angle 3 = 2x + 8 \)

   Prove: \( m\angle 1 = 14 \) (Lesson 2-8)