3.1 Identify Pairs of Lines and Angles

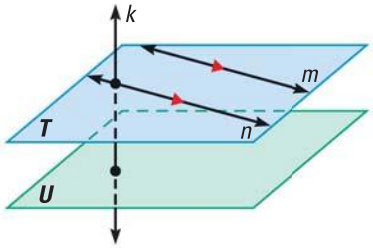
Before You identified angle pairs formed by two intersecting lines.

Now You will identify angle pairs formed by three intersecting lines.

Why? So you can classify lines in a real-world situation, as in Exs. 40–42.

Key Vocabulary
- **parallel lines**
- **skew lines**
- **parallel planes**
- **transversal**
- **corresponding angles**
- **alternate interior angles**
- **alternate exterior angles**
- **consecutive interior angles**

Two lines that do not intersect are either *parallel lines* or *skew lines*. Two lines are **parallel lines** if they do not intersect and are coplanar. Two lines are **skew lines** if they do not intersect and are not coplanar. Also, two planes that do not intersect are **parallel planes**.



Lines *m* and *n* are parallel lines ($m \parallel n$).

Lines *m* and *k* are skew lines.

Planes *T* and *U* are parallel planes ($T \parallel U$).

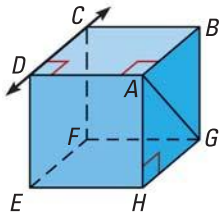
Lines *k* and *n* are intersecting lines, and there is a plane (not shown) containing them.

Small directed triangles, as shown on lines m and n above, are used to show that lines are parallel. The symbol $\parallel$ means "is parallel to," as in $m \parallel n$.

Segments and rays are parallel if they lie in parallel lines. A line is parallel to a plane if the line is in a plane parallel to the given plane. In the diagram above, line n is parallel to plane U.

EXAMPLE 1 Identify relationships in space

Think of each segment in the figure as part of a line. Which line(s) or plane(s) in the figure appear to fit the description?



a. Line(s) parallel to $\overleftrightarrow{CD}$ and containing point A

b. Line(s) skew to $\overleftrightarrow{CD}$ and containing point A

c. Line(s) perpendicular to $\overleftrightarrow{CD}$ and containing point A

d. Plane(s) parallel to plane EFG and containing point A

Solution

a. $\overleftrightarrow{AB}$, $\overleftrightarrow{HG}$, and $\overleftrightarrow{EF}$ all appear parallel to $\overleftrightarrow{CD}$, but only $\overleftrightarrow{AB}$ contains point A.

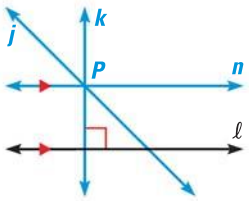
b. Both $\overleftrightarrow{AG}$ and $\overleftrightarrow{AH}$ appear skew to $\overleftrightarrow{CD}$ and contain point A.

c. $\overleftrightarrow{BC}$, $\overleftrightarrow{AD}$, $\overleftrightarrow{DE}$, and $\overleftrightarrow{FC}$ all appear perpendicular to $\overleftrightarrow{CD}$, but only $\overleftrightarrow{AD}$ contains point A.

d. Plane ABC appears parallel to plane EFG and contains point A.

PARALLEL AND PERPENDICULAR LINES Two lines in the same plane are either parallel or intersect in a point.

Through a point not on a line, there are infinitely many lines. Exactly one of these lines is parallel to the given line, and exactly one of them is perpendicular to the given line.



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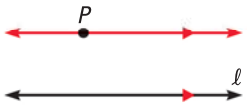
POSTULATES *For Your Notebook*

POSTULATE 13 Parallel Postulate

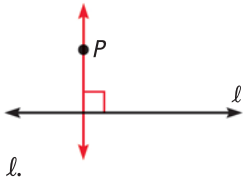
If there is a line and a point not on the line, then there is exactly one line through the point parallel to the given line.



There is exactly one line through P parallel to ℓ.

POSTULATE 14 Perpendicular Postulate

If there is a line and a point not on the line, then there is exactly one line through the point perpendicular to the given line.



There is exactly one line through P perpendicular to ℓ.

EXAMPLE 2 Identify parallel and perpendicular lines

PHOTOGRAPHY The given line markings show how the roads are related to one another.

a. Name a pair of parallel lines.

b. Name a pair of perpendicular lines.

c. Is $\overleftrightarrow{FE} \parallel \overleftrightarrow{AC}$? Explain.

Niagara Falls, New York

Solution

a. $\overleftrightarrow{MD} \parallel \overleftrightarrow{FE}$ **b.** $\overleftrightarrow{MD} \perp \overleftrightarrow{BF}$

c. $\overleftrightarrow{FE}$ is not parallel to $\overleftrightarrow{AC}$, because $\overleftrightarrow{MD}$ is parallel to $\overleftrightarrow{FE}$ and by the Parallel Postulate there is exactly one line parallel to $\overleftrightarrow{FE}$ through M.

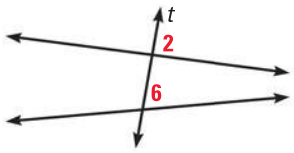
GUIDED PRACTICE for Examples 1 and 2

1. Look at the diagram in Example 1. Name the lines through point H that appear skew to $\overleftrightarrow{CD}$.
2. In Example 2, can you use the Perpendicular Postulate to show that $\overleftrightarrow{AC}$ is *not* perpendicular to $\overleftrightarrow{BF}$? *Explain* why or why not.

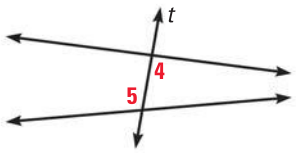
ANGLES AND TRANSVERSALS A **transversal** is a line that intersects two or more coplanar lines at different points.

KEY CONCEPT *For Your Notebook*

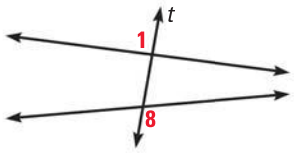
Angles Formed by Transversals



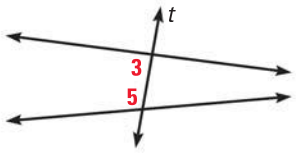
Two angles are **corresponding angles** if they have corresponding positions. For example, $\angle 2$ and $\angle 6$ are above the lines and to the right of the transversal t.



Two angles are **alternate interior angles** if they lie between the two lines and on opposite sides of the transversal.



Two angles are **alternate exterior angles** if they lie outside the two lines and on opposite sides of the transversal.



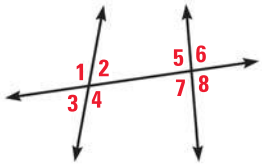
Two angles are **consecutive interior angles** if they lie between the two lines and on the same side of the transversal.

READ VOCABULARY
Another name for consecutive interior angles is **same-side interior angles**.

EXAMPLE 3 Identify angle relationships

Identify all pairs of angles of the given type.

a. Corresponding **b.** Alternate interior
c. Alternate exterior **d.** Consecutive interior



Solution

a. $\angle 1$ and $\angle 5$
$\angle 2$ and $\angle 6$
$\angle 3$ and $\angle 7$
$\angle 4$ and $\angle 8$

b. $\angle 2$ and $\angle 7$
$\angle 4$ and $\angle 5$

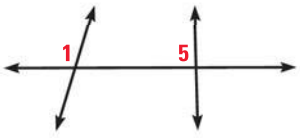
c. $\angle 1$ and $\angle 8$
$\angle 3$ and $\angle 6$

d. $\angle 2$ and $\angle 5$
$\angle 4$ and $\angle 7$

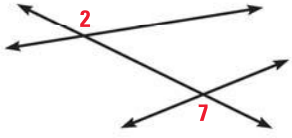
GUIDED PRACTICE for Example 3

Classify the pair of numbered angles.

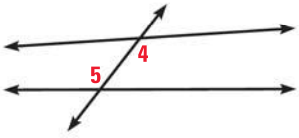
3.



4.



5.



3.1 EXERCISES

HOMEWORK KEY

○ = **WORKED-OUT SOLUTIONS** on p. WS1 for Exs. 11, 25, and 35

★ = **STANDARDIZED TEST PRACTICE** Exs. 2, 28, 36, 37, and 39

SKILL PRACTICE

1. **VOCABULARY** Copy and complete: A line that intersects two other lines is a ___?___.

2. ★ **WRITING** A table is set for dinner. Can the legs of the table and the top of the table lie in parallel planes? *Explain* why or why not.

EXAMPLE 1 on p. 147 for Exs. 3–6

IDENTIFYING RELATIONSHIPS **Think of each segment in the diagram as part of a line. Which line(s) or plane(s) contain point *B* and appear to fit the description?**

3. Line(s) parallel to $\overleftrightarrow{CD}$

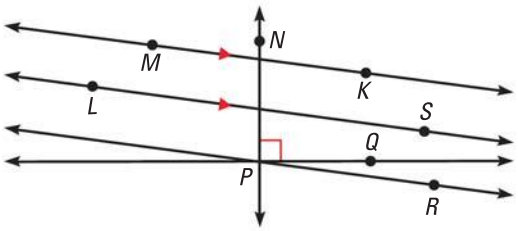
4. Line(s) perpendicular to $\overleftrightarrow{CD}$

5. Line(s) skew to $\overleftrightarrow{CD}$

6. Plane(s) parallel to plane *CDH*

EXAMPLE 2 on p. 148 for Exs. 7–10

PARALLEL AND PERPENDICULAR LINES **Use the markings in the diagram.**



7. Name a pair of parallel lines.

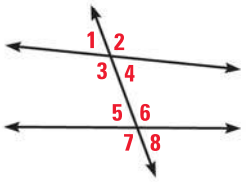
8. Name a pair of perpendicular lines.

9. Is $\overleftrightarrow{PN} \parallel \overleftrightarrow{KM}$? *Explain.*

10. Is $\overleftrightarrow{PR} \perp \overleftrightarrow{NP}$? *Explain.*

EXAMPLE 3 on p. 149 for Exs. 11–15

ANGLE RELATIONSHIPS **Identify all pairs of angles of the given type.**



11. Corresponding

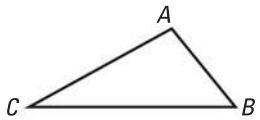
12. Alternate interior

13. Alternate exterior

14. Consecutive interior

15. **ERROR ANALYSIS** *Describe* and correct the error in saying that $\angle 1$ and $\angle 8$ are corresponding angles in the diagram for Exercises 11–14.

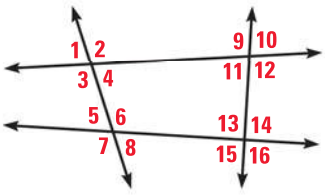
APPLYING POSTULATES **How many lines can be drawn that fit each description? Copy the diagram and sketch all the lines.**



16. Lines through *B* and parallel to $\overleftrightarrow{AC}$

17. Lines through *A* and perpendicular to $\overleftrightarrow{BC}$

USING A DIAGRAM **Classify the angle pair as *corresponding*, *alternate interior*, *alternate exterior*, or *consecutive interior* angles.**



18. $\angle 5$ and $\angle 1$

19. $\angle 11$ and $\angle 13$

20. $\angle 6$ and $\angle 13$

21. $\angle 10$ and $\angle 15$

22. $\angle 2$ and $\angle 11$

23. $\angle 8$ and $\angle 4$

ANALYZING STATEMENTS **Copy and complete the statement with *sometimes*, *always*, or *never*. Sketch examples to *justify* your answer.**

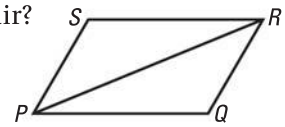
24. If two lines are parallel, then they are __?__ coplanar.

25. If two lines are not coplanar, then they __?__ intersect.

26. If three lines intersect at one point, then they are __?__ coplanar.

27. If two lines are skew to a third line, then they are __?__ skew to each other.

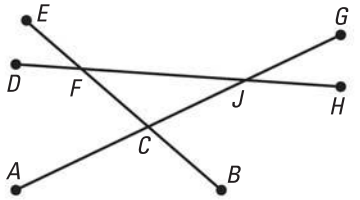
28. ★ **MULTIPLE CHOICE** $\angle RPQ$ and $\angle PRS$ are what type of angle pair?



Ⓐ Corresponding Ⓑ Alternate interior

Ⓒ Alternate exterior Ⓓ Consecutive interior

ANGLE RELATIONSHIPS **Copy and complete the statement. List all possible correct answers.**



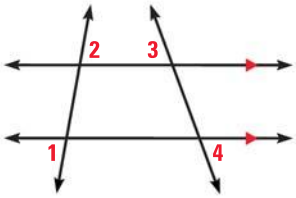
29. $\angle BCG$ and __?__ are corresponding angles.

30. $\angle BCG$ and __?__ are consecutive interior angles.

31. $\angle FCJ$ and __?__ are alternate interior angles.

32. $\angle FCA$ and __?__ are alternate exterior angles.

33. **CHALLENGE** Copy the diagram at the right and extend the lines.



a. Measure $\angle 1$ and $\angle 2$.

b. Measure $\angle 3$ and $\angle 4$.

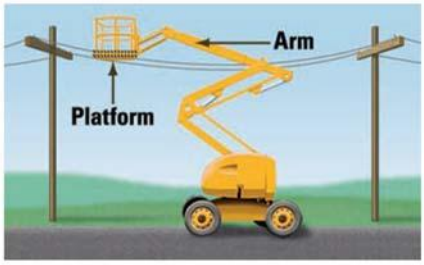
c. Make a conjecture about alternate exterior angles formed when parallel lines are cut by transversals.

PROBLEM SOLVING

EXAMPLE 2 on p. 148 for Exs. 34–35

CONSTRUCTION **Use the picture of the cherry-picker for Exercises 34 and 35.**

34. Is the platform *perpendicular*, *parallel*, or *skew* to the ground?



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35. Is the arm *perpendicular*, *parallel*, or *skew* to a telephone pole?

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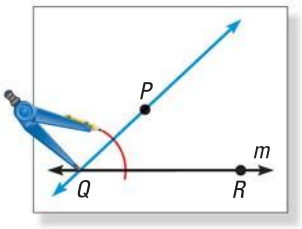
36. ★ **OPEN-ENDED MATH** *Describe* two lines in your classroom that are parallel, and two lines that are skew.

37. ★ **MULTIPLE CHOICE** What is the best description of the horizontal bars in the photo?

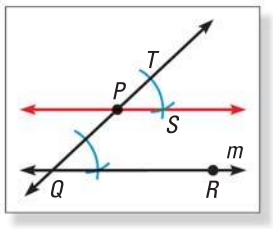
Ⓐ Parallel Ⓑ Perpendicular

Ⓒ Skew Ⓓ Intersecting

38. **CONSTRUCTION** Use these steps to construct a line through a given point P that is parallel to a given line m.



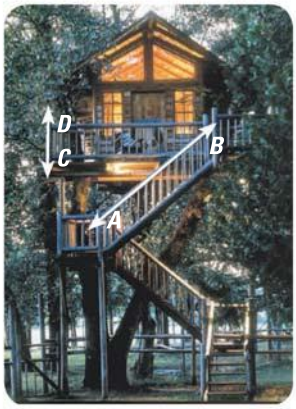
STEP 1 Draw points Q and R on m. Draw $\overleftrightarrow{PQ}$. Draw an arc with the compass point at Q so it crosses $\overleftrightarrow{QP}$ and $\overleftrightarrow{QR}$.



STEP 2 Copy $\angle PQR$ on $\overleftrightarrow{QP}$. Be sure the two angles are corresponding. Label the new angle $\angle TPS$. Draw $\overleftrightarrow{PS}$. $\overleftrightarrow{PS} \parallel \overleftrightarrow{QR}$.

39. ★ **SHORT RESPONSE** Two lines are cut by a transversal. Suppose the measure of a pair of alternate interior angles is 90°. *Explain* why the measure of all four interior angles must be 90°.

TREE HOUSE In Exercises 40–42, use the photo to decide whether the statement is *true* or *false*.



40. The plane containing the floor of the tree house is parallel to the ground.

41. All of the lines containing the railings of the staircase, such as $\overleftrightarrow{AB}$, are skew to the ground.

42. All of the lines containing the *balusters*, such as $\overleftrightarrow{CD}$, are perpendicular to the plane containing the floor of the tree house.

CHALLENGE **Draw the figure described.**

43. Lines ℓ and m are skew, lines ℓ and n are skew, and lines m and n are parallel.

44. Line ℓ is parallel to plane A, plane A is parallel to plane B, and line ℓ is not parallel to plane B.

MIXED REVIEW

Use the Law of Detachment to make a valid conclusion. *(p. 87)*

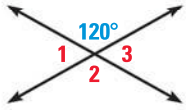
45. If the measure of an angle is less than 90°, then the angle is acute. The measure of $\angle A$ is 46°.

46. If a food has less than 140 milligrams of sodium per serving, then it is low sodium. A serving of soup has 90 milligrams of sodium per serving.

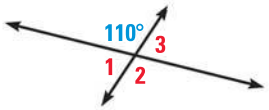
PREVIEW
Prepare for Lesson 3.2 in Exs. 47–49.

Find the measure of each numbered angle. *(p. 124)*

47.



48.



49.