

## Unit 12

# SIDES AND ANGLES OF A TRIANGLE

### Student Learning Outcomes (SLOs)

After completing this unit, students will be able to:

- ◆ If two sides of a triangle are unequal in length, the longer side has an angle of greater measure opposite to it.
- ◆ If two angles of a triangle are unequal in measure, the side opposite to the greater angle is longer than the side opposite to the smaller angle.
- ◆ The sum of the lengths of any two sides of a triangle is greater than the length of the third side.
- ◆ From a point, outside a line, the perpendicular is the shortest distance from the point to the line.



## Introduction

In this unit we will study the theorems related to the sides and angles of the triangle along with their corollaries and apply them to solve the allied problems.

## 12.1 Sides and Angles of a Triangle

### Theorem 12.1.1

**Prove that:**

If two sides of a triangle are unequal in length, the longer side has an angle of greater measure opposite to it.

**Given:**

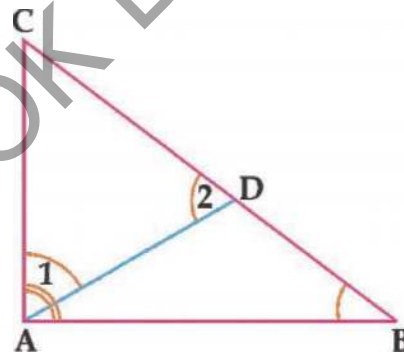
In  $\triangle ABC$ ,  $m\overline{BC} > m\overline{AC}$ .

**To Prove:**

$$m\angle A > m\angle B$$

**Construction:**

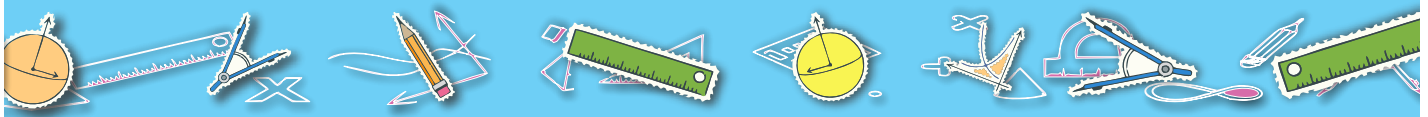
From  $\overline{BC}$  cut off  $\overline{CD} \cong \overline{AC}$ .  
Join A and D.



**Proof:**

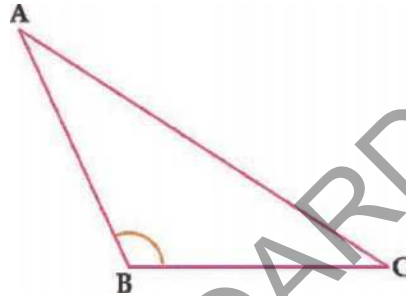
Statements	Reasons
In $\triangle ABC$ , $\overline{AC} \cong \overline{CD}$	Construction
$\therefore m\angle CAD = m\angle CDA$	Opposite sides congruent
But $\angle ABC$ is exterior angle of $\triangle ABD$	By definition of exterior angle.
$\therefore m\angle CDA > m\angle B$	Exterior angle $\angle$ is greater than non-adjacent interior angle
But $m\angle A > m\angle CAD$	$\therefore m\angle A = m\angle CAD + m\angle DAB$
$\therefore m\angle A > m\angle CDA$	$\therefore m\angle CAD = m\angle CDA$
$\therefore m\angle A > m\angle B$	Transitive property of inequality

Q.E.D.



Following example will help to understand the above theorem.

**Example:** Prove that in a scalene triangle, the angle opposite to the largest side is of measure greater than  $60^\circ$ .



**Given:**

In  $\triangle ABC$ , with,  $m\overline{AC} > m\overline{AB}$  and  $m\overline{AC} > m\overline{BC}$ .

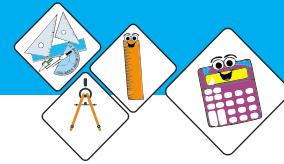
**To Prove:**

$$m\angle B > 60^\circ$$

**Proof:**

Statements	Reasons
In $\triangle ABC$ .	
We have, $m\angle B > m\angle C$	$m\overline{AC} > m\overline{AB}$ } Given
and $m\angle B > m\angle A$	$m\overline{AC} > m\overline{BC}$ }
but, $m\angle A + m\angle B + m\angle C = 180^\circ$	$\angle A, \angle B$ and $\angle C$ are the angles of the $\triangle ABC$ .
$\therefore m\angle B + m\angle B + m\angle B > 180^\circ$	$m\angle B > m\angle C$ and $m\angle B > m\angle A$
i.e. $3m\angle B > 180^\circ$	By addition
$= m\angle B > \frac{180^\circ}{3}$	Dividing both sides by 3
Thus, $m\angle B > 60^\circ$	

Q.E.D



### Theorem 12.1.2

Prove that if two angles of a triangle are unequal in measure, the side opposite to the greater angle is longer than the side opposite to the smaller angle.

**Given:**

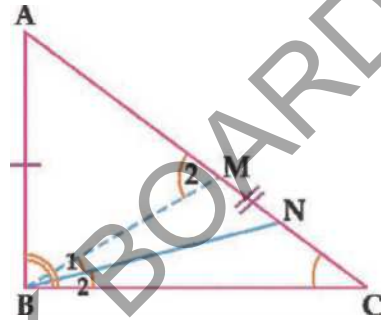
In  $\triangle ABC$ ,  $m\angle B > m\angle C$

**To Prove:**

$m\overline{AC} > m\overline{AB}$

**Construction:**

Make  $\angle ABM \cong \angle C$ . Draw  $\overline{BN}$ , the bisector of  $\angle MBC$ , i.e.  $m\angle 1 = m\angle 2$ .



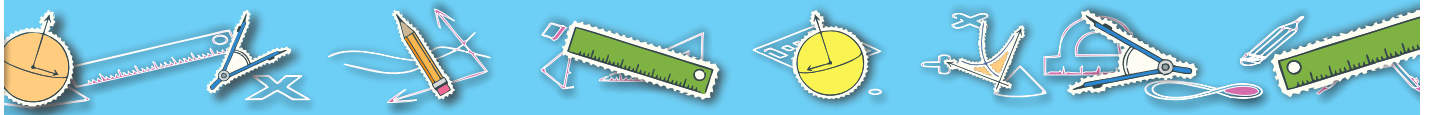
**Proof:**

Statements	Reasons
$\angle ANB$ is the exterior $\angle$ of $\triangle CBN$	By definition of exterior $\angle$
$\therefore m\angle ANB = m\angle C + m\angle 2$	
$= m\angle C + m\angle 1$	$\therefore m\angle 2 = m\angle 1$ (Construction)
$= m\angle ABM + m\angle 1$	$\therefore m\angle C = m\angle ABM$ (Construction)
$= m\angle ABN$	By angle addition postulate
$\therefore \overline{AB} \cong \overline{AN}$	$\therefore m\angle ANB = m\angle ABN$ (Proved above)
$\therefore m\overline{AC} > m\overline{AB}$	$\therefore m\overline{AC} > m\overline{AN}$

Q.E.D

**Corollaries:**

1. The hypotenuse of a right angle is longer than each of the other two sides.
2. In an obtuse angled triangle, the side opposite to the obtuse angle is longer than each of the other two sides.



**Theorem 12.1.3**

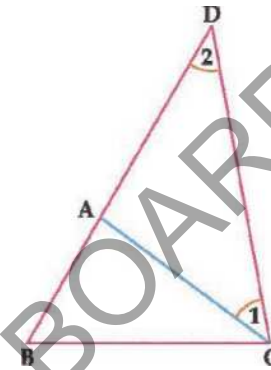
The sum of the lengths of any two sides of a triangle is greater than the length of the third side.

**Given:** $\triangle ABC$ **To Prove:**

- i)  $m\overline{AB} + m\overline{AC} > m\overline{BC}$
- ii)  $m\overline{AB} + m\overline{BC} > m\overline{CA}$
- iii)  $m\overline{AC} + m\overline{BC} > m\overline{AB}$

**Construction:**

Produce  $\overrightarrow{BA}$  to D, making  $\overline{AD} \cong \overline{AC}$ . Draw  $\overline{DC}$

**Proof:**

Statements	Reasons
In $\triangle ADC$ , $\overline{AD} \cong \overline{AC}$	Construction
$\therefore m\angle 1 = m\angle 2$	Angles opposite to congruent sides
But $m\angle BCD > m\angle 1$	$m\angle BCD = m\angle BCA + m\angle 1$
$\therefore m\angle BCD > m\angle 2$	Transitive property of inequality
$\therefore$ In $\triangle BDC$ , $m\overline{BD} > m\overline{BC}$	Greater angle has greater side opposite to it.
But $m\overline{BD} = m\overline{AB} + m\overline{AD}$	By construction
$= m\overline{AB} + m\overline{AC}$	
$\therefore m\overline{AB} + m\overline{AC} > m\overline{BC}$	Putting value of $\overline{BD}$
Similarly, we can prove that:	
$m\overline{AB} + m\overline{BC} > m\overline{AC}$	
and $m\overline{BC} + m\overline{AC} > m\overline{AB}$	By the above process

**Q.E.D**

The following example will help to understand the above theorem.



**Example 01** Which of the following sets of lengths of the sides form a triangle:

- (i) 3 cm, 4 cm and 5 cm                      (ii) 4 cm, 5 cm and 4.5 cm  
(iii) 60 mm, 80 mm and 10 cm            (iv) 3 cm, 4 cm and 10 cm

**Solution:**

- (i) 3 cm, 4 cm and 5 cm  
Since,  $3 + 4 > 5$ ,  $3 + 5 > 4$  and  $4 + 5 > 3$   
 $\therefore$  the sum of the two sides is greater than the 3<sup>rd</sup> side.  
Thus, the given set of lengths form a triangle.
- (ii) 4 cm, 5 cm and 4.5 cm  
Since,  $4 + 5 > 4.5$ ,  $5 + 4.5 > 4$  and  $4.5 + 4 > 4.5$   
Thus, the given set of lengths form a triangle.
- (iii) 60 mm, 80 mm and 10 cm  
Since,  $10 \text{ mm} = 1 \text{ cm}$  so,  $60 \text{ mm} = 6 \text{ cm}$  and  $80 \text{ mm} = 8 \text{ cm}$   
Now,  $6 + 8 > 10$ ,  $6 + 10 > 8$  and also  $8 + 10 > 6$   
Thus, the given set of lengths form a triangle.

**Example 02** By using the idea of the above theorem decide, which of the following sets of lengths of the sides form a triangle:

- (i) 2 cm, 4 cm and 7 cm                      (ii) 5.5 cm, 5 cm and 9.5 cm

**Solution:**

- (i) 2 cm, 4 cm and 7 cm  
Since,  $2 + 4 < 7$ ,  $4 + 7 > 2$  and  $7 + 2 > 4$   
Thus, this type of set of lengths cannot form a triangle.
- (ii) 5.5 cm, 5 cm and 9.5 cm  
Since,  $5.5 + 5 > 9.5$ ,  $5 + 9.5 > 5.5$  and  $9.5 + 5.5 > 5$   
Thus, the given set of lengths form a triangle.

 **Activity**

If  $a = 3 \text{ cm}$   
 $b = 4 \text{ cm}$   
 $c = 5 \text{ cm}$   
then  $\Delta ABC$  can be formed or not.



**Theorem 12.1.4:** Prove that:

From a point, outside a line, the perpendicular is the shortest distance from the point to the line.

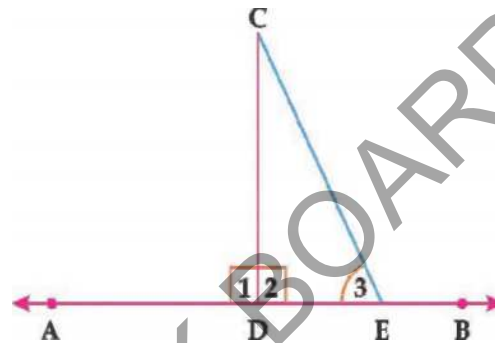
**Given:**

From a point C,  $\overline{CD}$  is drawn perpendicular to AB meeting it in D and  $\overline{CE}$  is any other segment meeting AB in E.

**To Prove:**

$$m\overline{CD} < m\overline{CE}$$

**Proof:**



Statements	Reasons
$\angle 1$ is an exterior $\angle$ of $\triangle CDE$	By definition of exterior $\angle$
$\therefore m\angle 1 > m\angle 3$	Exterior $\angle$ is greater than opposite interior $\angle$
$\therefore m\angle 2 > m\angle 3$	$m\angle 1 = m\angle 2$ (right $\angle$ s)
$\therefore m\overline{CE} > m\overline{CD}$	Side opposite to greater angle
Similarly, it can be proved that $m\overline{CD}$ is less than any other segment drawn from C to AB	By the above process

Q.E.D

**Corollaries:**

- The distance between a line and point (on a line) is zero.

Exercise 12.1

1. O is an interior point of the  $\Delta ABC$ .

Show that:  $m\overline{OA} + m\overline{OB} + m\overline{OC} > \frac{1}{2}(m\overline{AB} + m\overline{BC} + m\overline{CA})$ .

2. In  $\Delta ABC$ ,  $m\angle B = 70^\circ$  and  $m\angle C = 45^\circ$ . Which of the sides of the triangle is longest?
3. In  $\Delta ABC$ ,  $m\angle A = 55^\circ$  and  $m\angle B = 65^\circ$ , which of the side of the triangle is smallest?

Review Exercise 12

1. Tick (✓) True or False from the following statements.

- (i) Sum of the two sides of a triangle is greater than the third side. T/F
- (ii) The difference of two sides of a triangle is larger than the third side. T/F
- (iii) Exterior point of a line is the coincident or that line. T/F
- (iv) In a right angled triangle the largest angle is of  $100^\circ$ . T/F
- (v) A perpendicular on a line always makes an angle of  $90^\circ$ . T/F

2. Fill in the blanks to make the sentences true sentences.

- (i) In any right angled triangle, \_\_\_\_\_ is the longest side of the triangle.
- (ii) In a right angled triangle, sum of the measures of the sides containing right angles is \_\_\_\_\_ than the measure of the hypotenuse.
- (iii) In  $\Delta ABC$ ,  $m\angle A = 50^\circ$  and  $m\angle B = 30^\circ$ . Side \_\_\_\_\_ will be longer than its other sides.
- (iv) Length of diagonal of any quadrilateral is \_\_\_\_\_ than the sum of the measures of its two adjacent sides.



3. Tick (✓) the correct answer.

- (i) Measure of one side of an equilateral triangle is 6 cm, then the length of its median is \_\_\_\_\_ 9cm.
- a) less than                                  b) greater than  
c) equal to                                    d) none of the above
- (ii) Perimeter of a rectangle is 22cm, then the length of its diagonal is \_\_\_\_\_ 11cm.
- a) equal to                                    b) greater than  
c) less than                                    d) none of the above

 **Summary**

- ◆ If two sides of a triangle are unequal in length, the longer side has an angle of greater measure opposite to it.
- ◆ If two angles of a triangle are unequal in measure, the side opposite to the greater angle is longer than the side opposite to the smaller angle.
- ◆ The sum of the lengths of any two sides of a triangle is greater than the length of the third side.
- ◆ From a point, outside a line, the perpendicular is the shortest distance from the point to the line.