



## 13

## QUADRILATERALS

If you look around, you will find many objects bounded by four line-segments. Any surface of a book, window door, some parts of window-grill, slice of bread, the floor of your room are all examples of a closed figure bounded by four line-segments. Such a figure is called a quadrilateral.

The word quadrilateral has its origin from the two words “quadric” meaning four and “lateral” meaning sides. Thus, a quadrilateral is that geometrical figure which has four sides, enclosing a part of the plane.

In this lesson, we shall study about terms and concepts related to quadrilateral with their properties.



## OBJECTIVES

After studying this lesson, you will be able to

- describe various types of quadrilaterals viz. trapeziums, parallelograms, rectangles, rhombuses and squares;
- verify properties of different types of quadrilaterals;
- verify that in a triangle the line segment joining the mid-points of any two sides is parallel to the third side and is half of it;
- verify that the line drawn through the mid-point of a side of a triangle parallel to another side bisects the third side;
- verify that if there are three or more parallel lines and the intercepts made by them on a transversal are equal, the corresponding intercepts on any other transversal are also equal;
- verify that a diagonal of a parallelogram divides it into two triangles of equal area;
- solve problem based on starred results and direct numerical problems based on unstarred results given in the curriculum;



Notes

- prove that parallelograms on the same or equal bases and between the same parallels are equal in area;
- verify that triangles on the same or equal bases and between the same parallels are equal in area and its converse.

**EXPECTED BACKGROUND KNOWLEDGE**

- Drawing line-segments and angles of given measure.
- Drawing circles/arcs of given radius.
- Drawing parallel and perpendicular lines.
- Four fundamental operations on numbers.

**13.1 QUADRILATERAL**

Recall that if A, B, C and D are four points in a plane such that no three of them are collinear and the line segments AB, BC, CD and DA do not intersect except at their end points, then the closed figure made up of these four line segments is called a quadrilateral with vertices A, B, C and D. A quadrilateral with vertices A, B, C and D is generally denoted by quad. ABCD. In Fig. 13.1 (i) and (ii), both the quadrilaterals can be named as quad. ABCD or simply ABCD.

In quadrilateral ABCD,

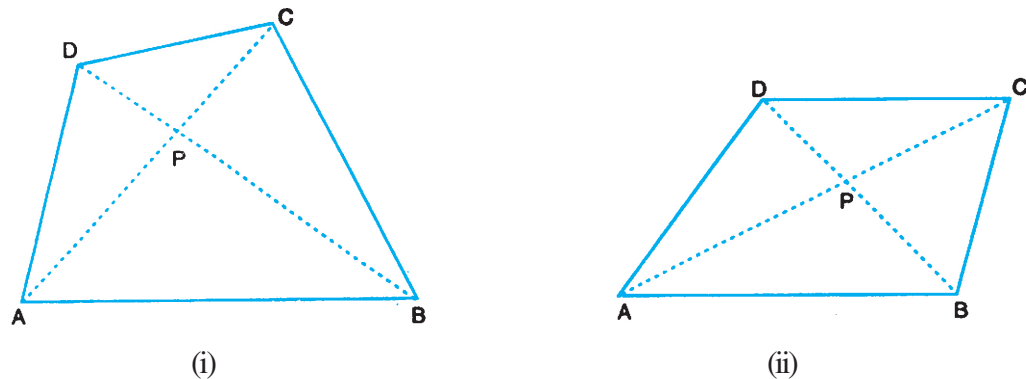


Fig. 13.1

- (i) AB and DC ; BC and AD are two pairs of opposite sides.
- (ii)  $\angle A$  and  $\angle C$  ;  $\angle B$  and  $\angle D$  are two pairs of opposite angles.
- (iii) AB and BC ; BC and CD are two pairs of consecutive or adjacent sides. Can you name the other pairs of consecutive sides?
- (iv)  $\angle A$  and  $\angle B$  ;  $\angle B$  and  $\angle C$  are two pairs of consecutive or adjacent angles. Can you name the other pairs of consecutive angles?



(v) AC and BD are the two diagonals.

In Fig. 13.2, angles denoted by 1, 2, 3 and 4 are the interior angles or the angles of the quad. ABCD. Angles denoted by 5, 6, 7 and 8 are the exterior angles of the quad. ABCD.

Measure  $\angle 1$ ,  $\angle 2$ ,  $\angle 3$  and  $\angle 4$ .

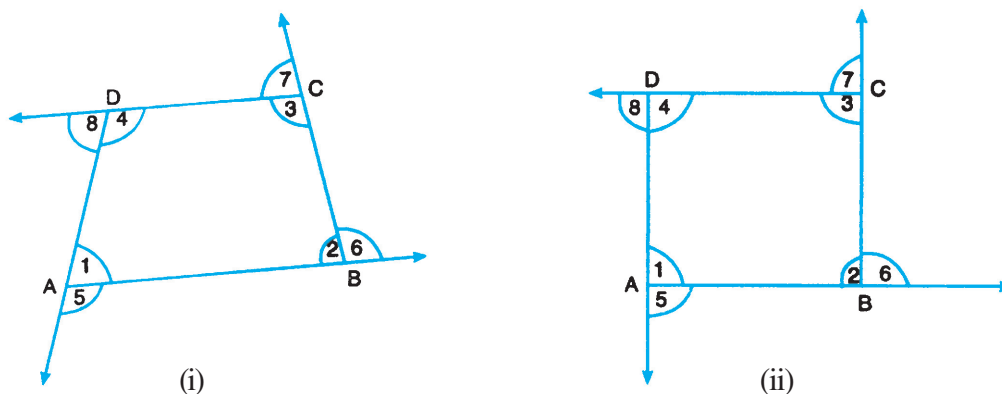


Fig. 13.2

What is the sum of these angles? You will find that  $\angle 1 + \angle 2 + \angle 3 + \angle 4 = 360^\circ$ .

i.e. sum of interior angles of a quadrilateral equals  $360^\circ$ .

Also what is the sum of exterior angles of the quadrilateral ABCD?

You will again find that  $\angle 5 + \angle 6 + \angle 7 + \angle 8 = 360^\circ$

i.e., sum of exterior angles of a quadrilateral is also  $360^\circ$ .

### 13.2 TYPES OF QUADRILATERALS

You are familiar with quadrilaterals and their different shapes. You also know how to name them. However, we will now study different types of quadrilaterals in a systematic way. A family tree of quadrilaterals is given in Fig. 13.3 below:

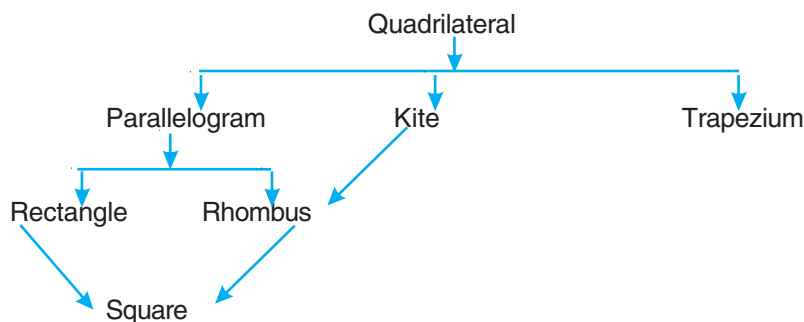


Fig. 13.3

Let us describe them one by one.

#### 1. Trapezium

A quadrilateral which has only one pair of opposite sides parallel is called a trapezium. In



Notes

Fig. 13.4 [(i) and (ii)] ABCD and PQRS are trapeziums with  $AB \parallel DC$  and  $PQ \parallel SR$  respectively.

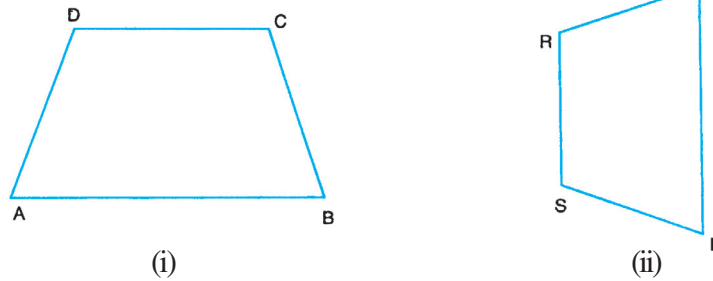


Fig. 13.4

### 2. Kite

A quadrilateral, which has two pairs of equal sides next to each other, is called a kite. Fig. 13.5 [(i) and (ii)] ABCD and PQRS are kites with adjacent sides AB and AD, BC and CD in (i) PQ and PS, QR and RS in (ii) being equal.

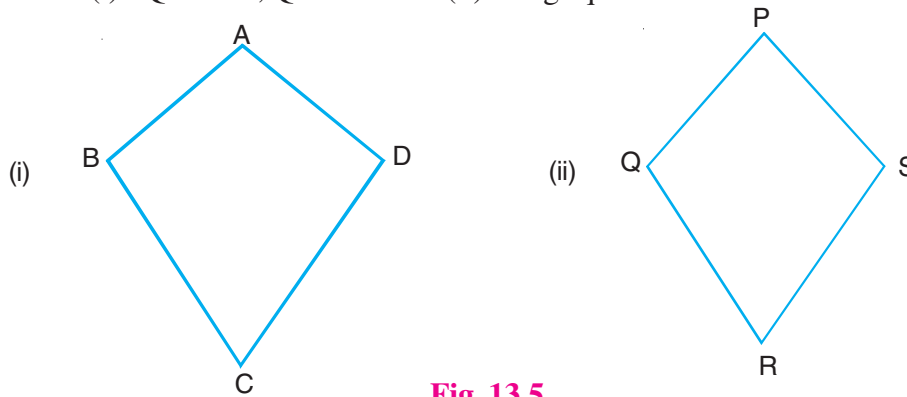


Fig. 13.5

### 3. Parallelogram

A quadrilateral which has both pairs of opposite sides parallel, is called a parallelogram. In Fig. 13.6 [(i) and (ii)] ABCD and PQRS are parallelograms with  $AB \parallel DC$ ,  $AD \parallel BC$  and  $PQ \parallel SR$ ,  $SP \parallel RQ$ . These are denoted by  $\parallel^{\text{gm}} ABCD$  (Parallelogram ABCD) and  $\parallel^{\text{gm}} PQRS$  (Parallelogram PQRS).

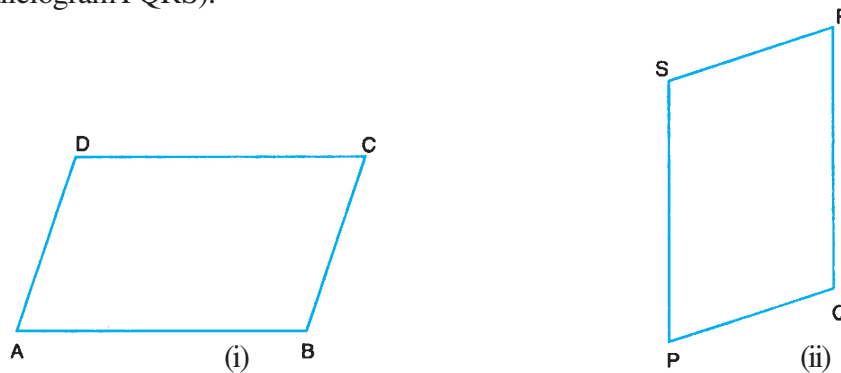


Fig. 13.6



Notes

#### 4. Rhombus

A rhombus is a parallelogram in which any pair of adjacent sides is equal.

In Fig. 13.7 ABCD is a rhombus.

You may note that ABCD is a parallelogram with  $AB = BC = CD = DA$  i.e., each pair of adjacent sides being equal.

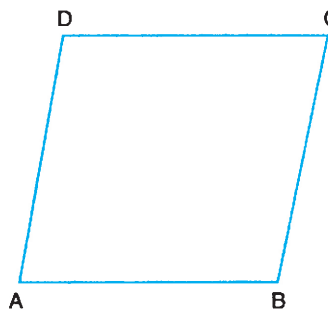


Fig. 13.7

#### 5. Rectangle

A parallelogram one of whose angles is a right angle is called a rectangle.

In Fig. 13.8, ABCD is a rectangle in which  $AB \parallel DC$ ,  $AD \parallel BC$  and  $\angle A = \angle B = \angle C = \angle D = 90^\circ$ .

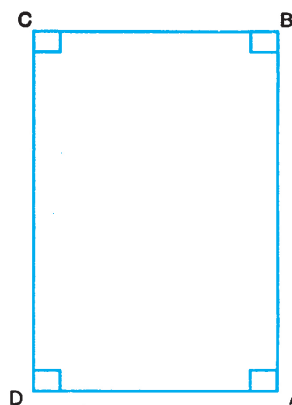
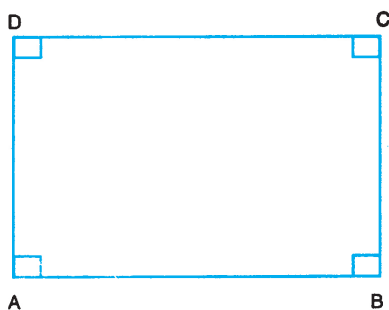


Fig. 13.8

#### 6. Square

A square is a rectangle, with a pair of adjacent sides equal.

In other words, a parallelogram having all sides equal and each angle a right angle is called a square.

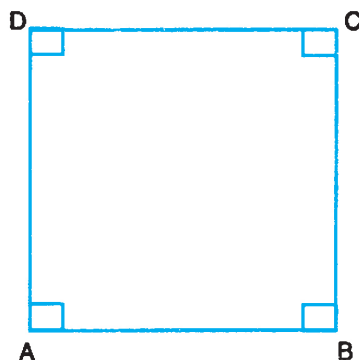


Fig. 13.9



Notes

In Fig. 13.9, ABCD is a square in which  $AB \parallel DC$ ,  $AD \parallel BC$ , and  $AB = BC = CD = DA$  and  $\angle A = \angle B = \angle C = \angle D = 90^\circ$ .

Let us take some examples to illustrate different types of quadrilaterals.

**Example 13.1:** In Fig 13.10, PQR is a triangle. S and T are two points on the sides PQ and PR respectively such that  $ST \parallel QR$ . Name the type of quadrilateral STRQ so formed.

**Solution:** Quadrilateral STRQ is a trapezium, because  $ST \parallel QR$ .

**Example 13.2:** The three angles of a quadrilateral are  $100^\circ$ ,  $50^\circ$  and  $70^\circ$ . Find the measure of the fourth angle.

**Solution:** We know that the sum of the angles of a quadrilateral is  $360^\circ$ .

$$\text{Then } 100^\circ + 50^\circ + 70^\circ + x^\circ = 360^\circ$$

$$220^\circ + x^\circ = 360^\circ$$

$$x = 140$$

Hence, the measure of fourth angle is  $140^\circ$ .

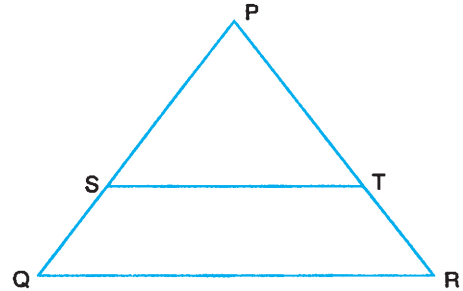


Fig. 13.10



CHECK YOUR PROGRESS 13.1

1. Name each of the following quadrilaterals.



(i)



(ii)



(iii)



(iv)



(v)



(vi)

Fig. 13.10



2. State which of the following statements are correct ?
  - (i) Sum of interior angles of a quadrilateral is  $360^\circ$ .
  - (ii) All rectangles are squares,
  - (iii) A rectangle is a parallelogram.
  - (iv) A square is a rhombus.
  - (v) A rhombus is a parallelogram.
  - (vi) A square is a parallelogram.
  - (vii) A parallelogram is a rhombus.
  - (viii) A trapezium is a parallelogram.
  - (ix) A trapezium is a rectangle.
  - (x) A parallelogram is a trapezium.
3. In a quadrilateral, all its angles are equal. Find the measure of each angle.
4. The angles of a quadrilateral are in the ratio 5:7:7: 11. Find the measure of each angle.
5. If a pair of opposite angles of a quadrilateral are supplementary, what can you say about the other pair of angles?

### 13.3 PROPERTIES OF DIFFERENT TYPES OF QUADRILATERALS

#### 1. Properties of a Parallelogram

We have learnt that a parallelogram is a quadrilateral with both pairs of opposite sides parallel. Now let us establish some relationship between sides, angles and diagonals of a parallelogram.

Draw a pair of parallel lines  $l$  and  $m$  as shown in Fig. 13.12. Draw another pair of parallel lines  $p$  and  $q$  such that they intersect  $l$  and  $m$ . You observe that a parallelogram  $ABCD$  is formed. Join  $AC$  and  $BD$ . They intersect each other at  $O$ .



Notes

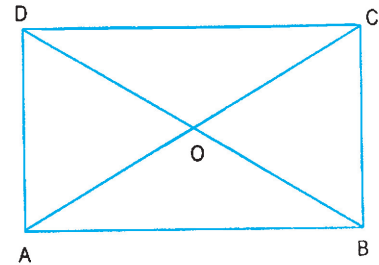
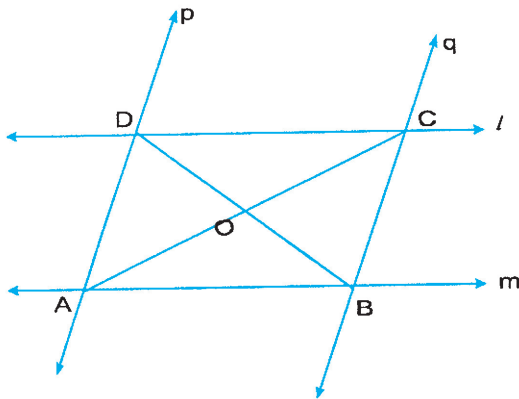


Fig. 13.12

Now measure the sides AB, BC, CD and DA. What do you find?

You will find that  $AB = DC$  and  $BC = AD$ .

Also measure  $\angle ABC$ ,  $\angle BCD$ ,  $\angle CDA$  and  $\angle DAB$ .

What do you find?

You will find that  $\angle DAB = \angle BCD$  and  $\angle ABC = \angle CDA$

Again, Measure OA, OC, OB and OD.

What do you find?

You will find that  $OA = OC$  and  $OB = OD$

Draw another parallelogram and repeat the activity. You will find that

**The opposite sides of a parallelogram are equal.**

**The opposite angles of a parallelogram are equal.**

**The diagonals of a parallelogram bisect each other.**

The above mentioned properties of a parallelogram can also be verified by Cardboard model which is as follows:

Let us take a cardboard. Draw any parallelogram ABCD on it. Draw its diagonal AC as shown in Fig 13.13 Cut the parallelogram ABCD from the cardboard. Now cut this parallelogram along the diagonal AC. Thus, the parallelogram has been divided into two parts and each part is a triangle.

In other words, you get two triangles,  $\triangle ABC$  and  $\triangle ADC$ . Now place  $\triangle ADC$  on  $\triangle ABC$  in such a way that the vertex D falls on the vertex B and the side CD falls along the side AB.



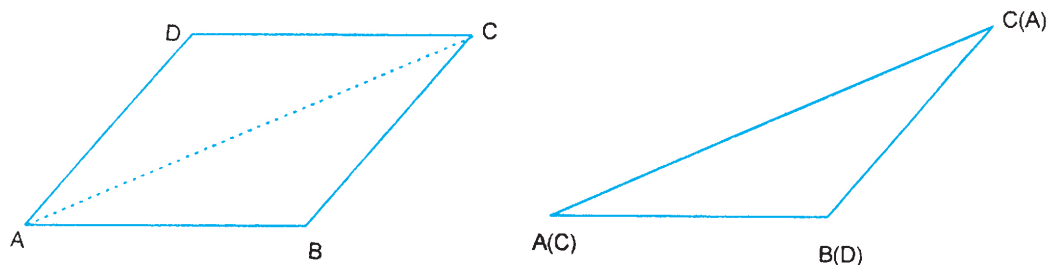


Fig. 13.13

Where does the point C fall?

Where does the point A fall?

You will observe that  $\triangle ADC$  will coincide with  $\triangle ABC$ . In other words  $\triangle ABC \cong \triangle ADC$ . Also  $AB = CD$  and  $BC = AD$  and  $\angle B = \angle D$ .

You may repeat this activity by taking some other parallelograms, you will always get the same results as verified earlier, thus, proving the above two properties of the parallelogram.

Now you can prove the third property of the parallelogram, i.e., the diagonals of a parallelogram bisect each other.

Again take a thin cardboard. Draw any parallelogram PQRS on it. Draw its diagonals

PR and QS which intersect each other at O as shown in Fig. 13.14. Now cut the parallelogram PQRS.

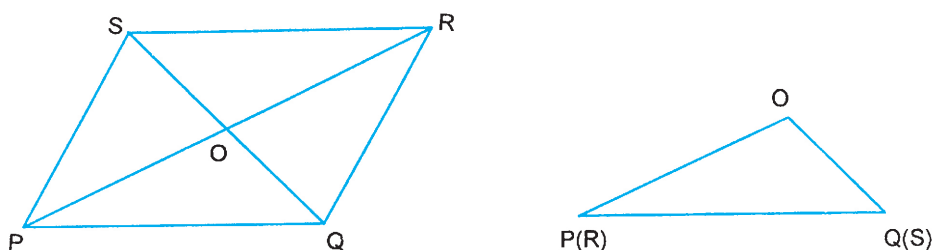


Fig. 13.14

Also cut  $\triangle POQ$  and  $\triangle ROS$ .

Now place  $\triangle ROS$  and  $\triangle POQ$  in such a way that the vertex R coincides with the vertex P and RO coincides with the side PO.

Where does the point S fall?

Where does the side OS fall?

Is  $\triangle ROS \cong \triangle POQ$ ? Yes, it is.



## Notes

So, what do you observe?

We find that  $RO = PO$  and  $OS = OQ$

You may also verify this property by taking another pair of triangles i.e.  $\triangle POS$  and  $\triangle ROQ$ . You will again arrive at the same result.

You may also verify the following properties which are the converse of the properties of a parallelogram verified earlier.

**A quadrilateral is a parallelogram if its opposite sides are equal.**

**A quadrilateral is a parallelogram if its opposite angles are equal.**

**A quadrilateral is a parallelogram if its diagonals bisect each other.**

## 2. Properties of a Rhombus

In the previous section we have defined a rhombus. We know that a rhombus is a parallelogram in which a pair of adjacent sides is equal. In Fig. 13.15, ABCD is a rhombus.

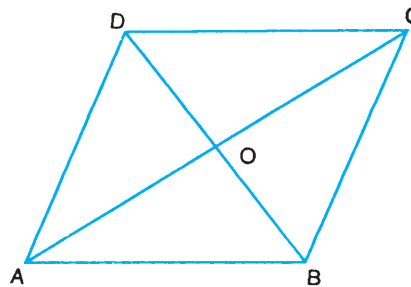


Fig. 13.15

Thus, ABCD is a parallelogram with  $AB = BC$ . Since every rhombus is a parallelogram, therefore all the properties of a parallelogram are also true for rhombus, i.e.

- (i) Opposite sides are equal,  
i.e.,  $AB = DC$  and  $AD = BC$
- (ii) Opposite angles are equal,  
i.e.,  $\angle A = \angle C$  and  $\angle B = \angle D$
- (iii) Diagonals bisect each other  
i.e.,  $AO = OC$  and  $DO = OB$

Since adjacent sides of a rhombus are equal and by the property of a parallelogram opposite sides are equal. Therefore,

$$AB = BC = CD = DA$$



Thus, all the sides of a rhombus are equal. Measure  $\angle AOD$  and  $\angle BOC$ .

What is the measures of these angles?

You will find that each of them equals  $90^\circ$

Also  $\angle AOB = \angle COD$  (Each pair is a vertically opposite angles)

and  $\angle BOC = \angle DOA$

$\therefore \angle AOB = \angle COD = \angle BOC = \angle DOA = 90^\circ$

Thus, the diagonals of a rhombus bisect each other at right angles.

You may repeat this experiment by taking different rhombuses, you will find in each case, the diagonals of a rhombus bisect each other.

Thus, we have the following properties of a rhombus.

**All sides of a rhombus are equal**

**Opposite angles of a rhombus are equal**

**The diagonals of a rhombus bisect each other at right angles.**

### 3. Properties of a Rectangle

We know that a rectangle is a parallelogram one of whose angles is a right angle. Can you say whether a rectangle possesses all the properties of a parallelogram or not?

Yes it possesses. Let us study some more properties of a rectangle.

Draw a parallelogram ABCD in which  $\angle B = 90^\circ$ .

Join AC and BD as shown in the Fig. 13.16

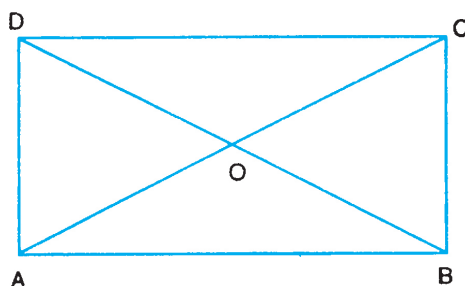


Fig. 13.16

Measure  $\angle BAD$ ,  $\angle BCD$  and  $\angle ADC$ , what do you find?

What are the measures of these angles?

The measure of each angle is  $90^\circ$ . Thus, we can conclude that

$$\angle A = \angle B = \angle C = \angle D = 90^\circ$$



## Notes

i.e., each angle of a rectangle measures  $90^\circ$ . Now measure the diagonals AC and BD. Do you find that  $AC = BD$ .

Now, measure AO, OC, BO and OD.

You will find that  $AO = OC$  and  $BO = OD$ .

Draw some more rectangles of different dimensions. Label them again by ABCD. Join AC and BD in each case. Let them intersect each other at O. Also measure AO, OC and BO, OD for each rectangle. In each case you will find that

The diagonals of a rectangle are equal and they bisect each other. Thus, we have the following properties of a rectangle;

**The opposite sides of a rectangle are equal**

**Each angle of a rectangle is a right-angle.**

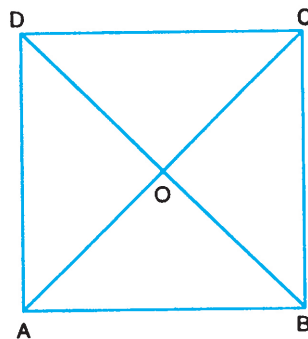
**The diagonals of a rectangle are equal.**

**The diagonals of a rectangle bisect each other.**

#### 4. Properties of a Square

You know that a square is a rectangle, with a pair of adjacent sides equal. Now, can you conclude from definition of a square that a square is a rectangle and possesses all the properties of a rectangle? Yes it is. Let us now study some more properties of a square.

Draw a square ABCD as shown in Fig. 13.17.



**Fig 13.17**

Since ABCD is a rectangle, therefore we have

- (i)  $AB = DC$ ,  $AD = BC$
- (ii)  $\angle A = \angle B = \angle C = \angle D = 90^\circ$
- (iii)  $AC = BD$  and  $AO = OC$ ,  $BO = OD$



But in a square we have  $AB = AD$

∴ By property (i) we have

$$AB = AD = CD = BC.$$

Since a square is also a rhombus. Therefore, we conclude that the diagonals AC and BD of a square bisect each other at right angles.

Thus, we have the following properties of a square.

**All the sides of a square are equal**

**Each of the angles measures  $90^\circ$ .**

**The diagonals of a square are equal.**

**The diagonals of a square bisect each other at right angles.**

Let us study some examples to illustrate the above properties:

**Example 13.3:** In Fig. 13.17, ABCD is a parallelogram. If  $\angle A = 80^\circ$ , find the measures of the remaining angles

**Solution:** As ABCD is a parallelogram.

$$\angle A = \angle C \text{ and } \angle B = \angle D$$

It is given that

$$\angle A = 80^\circ$$

$$\therefore \angle C = 80^\circ$$

$$\therefore AB \parallel DC$$

$$\therefore \angle A + \angle D = 180^\circ$$

$$\therefore \angle D = (180 - 80)^\circ = 100^\circ$$

$$\therefore \angle B = \angle D = 100^\circ$$

$$\text{Hence } \angle C = 80^\circ, \angle B = 100^\circ \text{ and } \angle D = 100^\circ$$

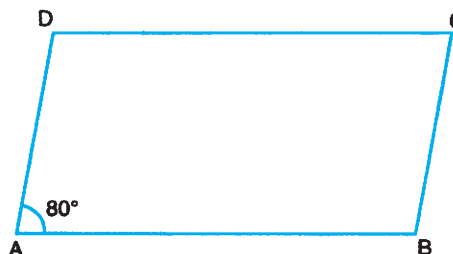


Fig 13.18

**Example 13.4:** Two adjacent angles of a rhombus are in the ratio 4 : 5. Find the measure of all its angles.

**Solution:** Since opposite sides of a rhombus are parallel, the sum of two adjacent angles of a rhombus is  $180^\circ$ .

Let the measures of two angles be  $4x^\circ$  and  $5x^\circ$ ,

$$\text{Therefore, } 4x + 5x = 180$$

$$\text{i.e. } 9x = 180$$



Notes

$$x = 20$$

∴ The two measures of angles are  $80^\circ$  and  $100^\circ$ .

i.e.  $\angle A = 80^\circ$  and  $\angle B = 100^\circ$

Since  $\angle A = \angle C \Rightarrow \angle C = 100^\circ$

Also,  $\angle B = \angle D \Rightarrow \angle D = 100^\circ$

Hence, the measures of angles of the rhombus are  $80^\circ, 100^\circ, 80^\circ$  and  $100^\circ$ .

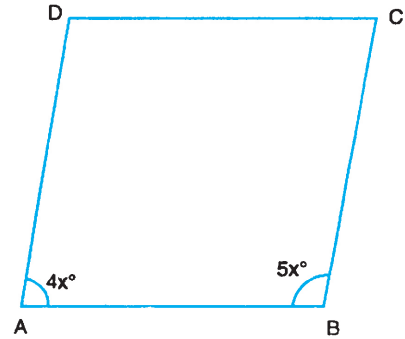


Fig 13.19

**Example 13.5:** One of the diagonals of a rhombus is equal to one of its sides. Find the angles of the rhombus.

**Solution:** Let in rhombus, ABCD,

$$AB = AD = BD$$

∴  $\triangle ABD$  is an equilateral triangle.

∴  $\angle DAB = \angle 1 = \angle 2 = 60^\circ$  ....(1)

Similarly  $\angle BCD = \angle 3 = \angle 4 = 60^\circ$  ....(2)

Also from (1) and (2)

$$\angle ABC = \angle B = \angle 1 + \angle 3 = 60^\circ + 60^\circ = 120^\circ$$

$$\angle ADC = \angle D = \angle 2 + \angle 4 = 60^\circ + 60^\circ = 120^\circ$$

Hence,  $\angle A = 60^\circ, \angle B = 120^\circ, \angle C = 60^\circ$  and  $\angle D = 120^\circ$

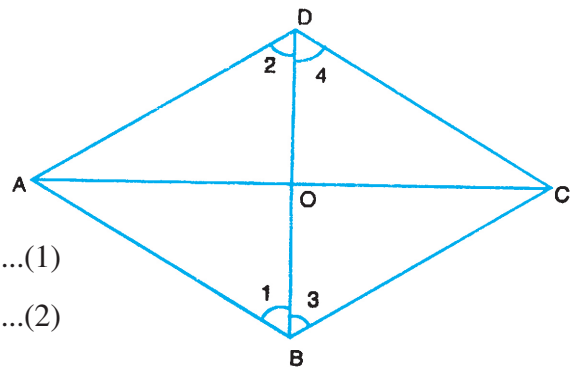


Fig 13.20

**Example 13.6:** The diagonals of a rhombus ABCD intersect at O. If  $\angle ADC = 120^\circ$  and  $OD = 6$  cm, find

- (a)  $\angle OAD$
- (b) side AB
- (c) perimeter of the rhombus ABCD

**Solution:** (a) Given that

$$\angle ADC = 120^\circ$$

i.e.  $\angle ADO + \angle ODC = 120^\circ$

But  $\angle ADO = \angle ODC$  ( $\triangle AOD \cong \triangle COD$ )

∴  $2\angle ADO = 120^\circ$

i.e.  $\angle ADO = 60^\circ$  ... (i)

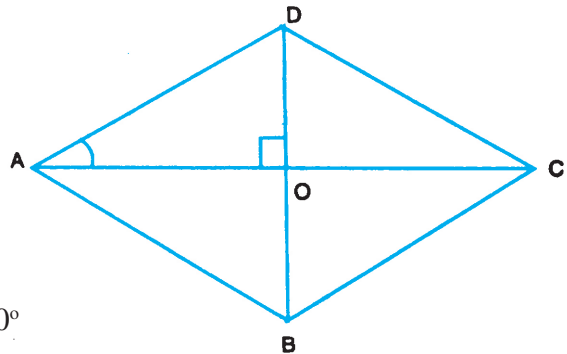


Fig 13.21



Also, we know that the diagonals of a rhombus bisect each other at  $90^\circ$ .

$$\therefore \angle DOA = 90^\circ \quad \dots(\text{ii})$$

Now, in  $\triangle DOA$

$$\angle ADO + \angle DOA + \angle OAD = 180^\circ$$

From (i) and (ii), we have

$$60^\circ + 90^\circ + \angle OAD = 180^\circ$$

$$\Rightarrow \angle OAD = 30^\circ$$

(b) Now,  $\angle DAB = 60^\circ$  [since  $\angle OAD = 30^\circ$ , similarly  $\angle OAB = 30^\circ$ ]

$\therefore \triangle DAB$  is an equilateral triangle.

$$OD = 6 \text{ cm} \quad [\text{given}]$$

$$\Rightarrow OD + OB = BD$$

$$6 \text{ cm} + 6 \text{ cm} = BD$$

$$\Rightarrow BD = 12 \text{ cm}$$

$$\text{so, } AB = BD = AD = 12 \text{ cm}$$

$$AB = 12 \text{ cm}$$

(c) Now Perimeter =  $4 \times \text{side}$

$$= (4 \times 12) \text{ cm}$$

$$= 48 \text{ cm}$$

Hence, the perimeter of the rhombus = 48 cm.



### CHECK YOUR PROGRESS 13.2

1. In a parallelogram ABCD,  $\angle A = 62^\circ$ . Find the measures of the other angles.
2. The sum of the two opposite angles of a parallelogram is  $150^\circ$ . Find all the angles of the parallelogram.
3. In a parallelogram ABCD,  $\angle A = (2x + 10)^\circ$  and  $\angle C = (3x - 20)^\circ$ . Find the value of  $x$ .
4. ABCD is a parallelogram in which  $\angle DAB = 70^\circ$  and  $\angle CBD = 55^\circ$ . Find  $\angle CDB$  and  $\angle ADB$ .
5. ABCD is a rhombus in which  $\angle ABC = 58^\circ$ . Find the measure of  $\angle ACD$ .



Notes

6. In Fig. 13.22, the diagonals of a rectangle PQRS intersect each other at O. If  $\angle ROQ = 40^\circ$ , find the measure of  $\angle OPS$ .

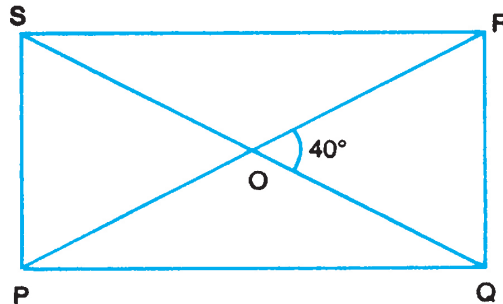


Fig 13.22

7. AC is one diagonal of a square ABCD. Find the measure of  $\angle CAB$ .

### 13.4 MID POINT THEOREM

Draw any triangle ABC. Find the mid points of side AB and AC. Mark them as D and E respectively. Join DE, as shown in Fig. 13.23.

Measure BC and DE.

What relation do you find between the length of BC and DE?

Of course, it is  $DE = \frac{1}{2} BC$

Again, measure  $\angle ADE$  and  $\angle ABC$ .

Are these angles equal?

Yes, they are equal. You know that these angles make a pair of corresponding angles. You know that when a pair of corresponding angles are equal, the lines are parallel

$$\therefore DE \parallel BC$$

You may repeat this experiment with another two or three triangles and naming each of them as triangle ABC and the mid point as D and E of sides AB and AC respectively.

You will always find that  $DE = \frac{1}{2} BC$  and  $DE \parallel BC$ .

Thus, we conclude that

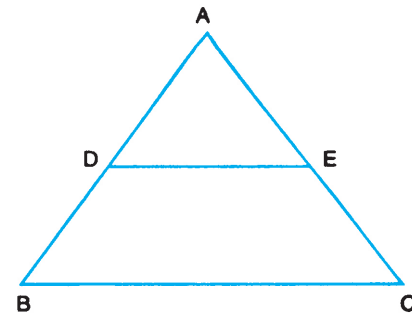


Fig 13.23





Notes

**In a triangle the line-segment joining the mid points of any two sides is parallel to the third side and is half of it.**

We can also verify the converse of the above stated result.

Draw any  $\Delta PQR$ . Find the mid point of side  $RQ$ , and mark it as  $L$ . From  $L$ , draw a line  $LX \parallel PQ$ , which intersects,  $PR$  at  $M$ .

Measure  $PM$  and  $MR$ . Are they equal? Yes, they are equal.

You may repeat with different triangles and by naming each of them as  $PQR$  and taking each time  $L$  as the mid-point of  $RQ$  and drawing a line  $LM \parallel PQ$ , you will find in each case that  $RM = MP$ . Thus, we conclude that

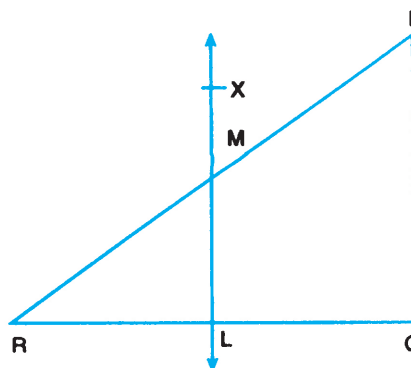


Fig 13.24

**“The line drawn through the mid point of one side of a triangle parallel to the another side bisects the third side.”**

**Example 13.7:** In Fig. 13.25,  $D$  is the mid-point of the side  $AB$  of  $\Delta ABC$  and  $DE \parallel BC$ . If  $AC = 8$  cm, find  $AE$ .

**Solution:** In  $\Delta ABC$ ,  $DE \parallel BC$  and  $D$  is the mid point of  $AB$

$\therefore E$  is also the mid point of  $AC$

$$\begin{aligned} \text{i.e. } AE &= \frac{1}{2} AC \\ &= \left(\frac{1}{2} \times 8\right) \text{ cm} \quad [ \because AC = 8 \text{ cm} ] \\ &= 4 \text{ cm} \end{aligned}$$

Hence,  $AE = 4$  cm

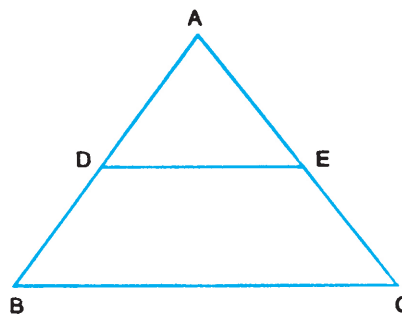


Fig 13.25

**Example 13.8:** In Fig. 13.26,  $ABCD$  is a trapezium in which  $AD$  and  $BC$  are its non-parallel sides and  $E$  is the mid-point of  $AD$ .  $EF \parallel AB$ . Show that  $F$  is the mid-point of  $BC$ .

**Solution:** Since  $EG \parallel AB$  and  $E$  is the mid-point of  $AD$  (considering  $\Delta ABD$ )

$\therefore G$  is the mid point of  $DB$

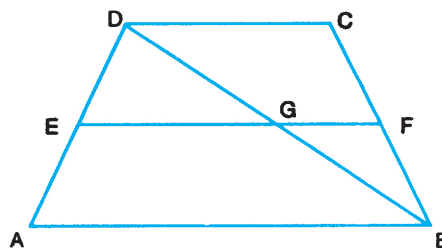


Fig 13.26



Notes

In  $\triangle DBC$ ,  $GF \parallel DC$  and  $G$  is the mid-point of  $DB$ ,  
 $\therefore F$  is the mid-point of  $BC$ .

**Example 13.9:**  $ABC$  is a triangle, in which  $P, Q$  and  $R$  are mid-points of the sides  $AB, BC$  and  $CA$  respectively. If  $AB = 8$  cm,  $BC = 7$  cm and  $CA = 6$  cm, find the sides of the triangle  $PQR$ .

**Solution:**  $P$  is the mid-point of  $AB$  and  $R$  the mid-point of  $AC$ .

$$\begin{aligned} \therefore PR \parallel BC \text{ and } PR &= \frac{1}{2} BC \\ &= \frac{1}{2} \times 7 \text{ cm} \quad [\because BC = 7 \text{ cm}] \\ &= 3.5 \text{ cm} \end{aligned}$$

Similarly,

$$\begin{aligned} PQ &= \frac{1}{2} AC \\ &= \frac{1}{2} \times 6 \text{ cm} \quad [\because AC = 6 \text{ cm}] \\ &= 3 \text{ cm} \end{aligned}$$

and

$$\begin{aligned} QR &= \frac{1}{2} AB \\ &= \frac{1}{2} \times 8 \text{ cm} \quad [\because AB = 8 \text{ cm}] \\ &= 4 \text{ cm} \end{aligned}$$

Hence, the sides of  $\triangle PQR$  are  $PQ = 3$  cm,  $QR = 4$  cm and  $PR = 3.5$  cm.

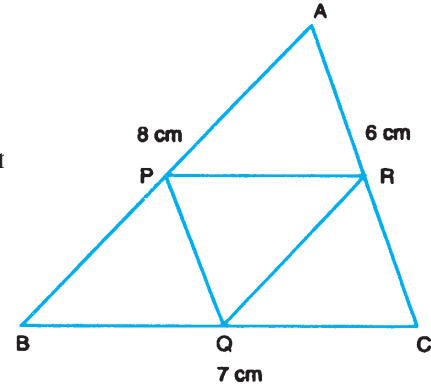


Fig 13.27



CHECK YOUR PROGRESS 13.3

- In Fig. 13.28,  $ABC$  is an equilateral triangle.  $D, E$  and  $F$  are the mid-points of the sides  $AB, BC$  and  $CA$  respectively. Prove that  $DEF$  is also an equilateral triangle.

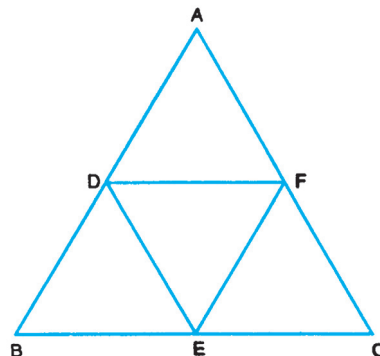


Fig. 13.28



2. In Fig. 13.29, D and E are the mid-points of the sides AB and AC respectively of a  $\triangle ABC$ . If  $BC = 10$  cm; find DE.

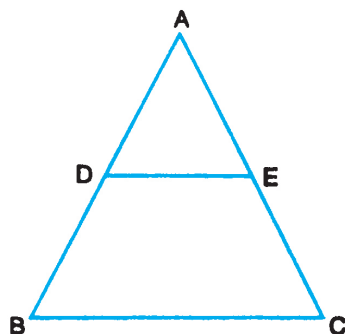


Fig. 13.29

3. In Fig. 13.30, AD is a median of the  $\triangle ABC$  and E is the mid-point of AD, BE is produced to meet AC at F.  $DG \parallel EF$ , meets AC at G. If  $AC = 9$  cm, find AF.

[Hint: First consider  $\triangle ADG$  and next consider  $\triangle CBF$ ]

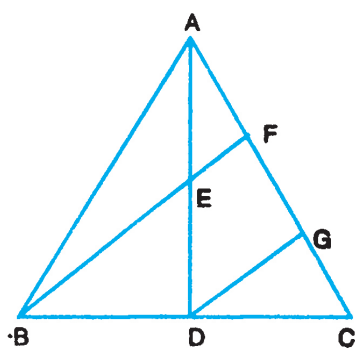


Fig. 13.30

4. In Fig. 13.31, A and C divide the side PQ of  $\triangle PQR$  into three equal parts,  $AB \parallel CD \parallel QR$ . Prove that B and D also divide PR into three equal parts.

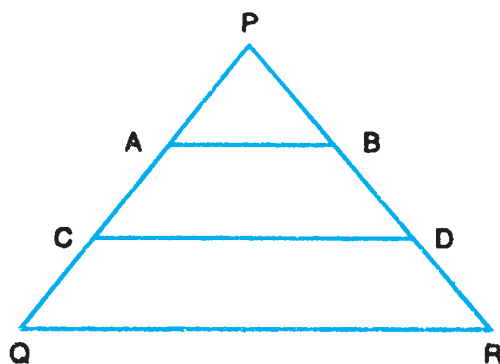


Fig. 13.31



Notes

5. In Fig. 13.32,  $ABC$  is an isosceles triangle in which  $AB = AC$ .  $M$  is the mid-point of  $AB$  and  $MN \parallel BC$ . Show that  $\triangle AMN$  is also an isosceles triangle.

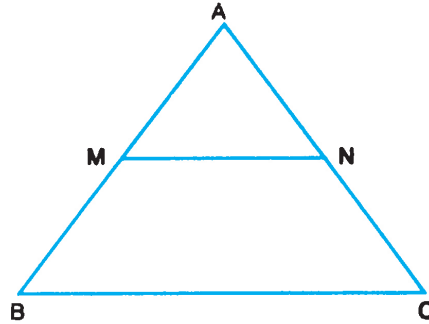


Fig. 13.32

### 13.5 EQUAL INTERCEPT THEOREM

Recall that a line which intersects two or more lines is called a transversal. The line-segment cut off from the transversal by a pair of lines is called an intercept. Thus, in Fig. 13.33,  $XY$  is an intercept made by line  $l$  and  $m$  on transversal  $n$ .

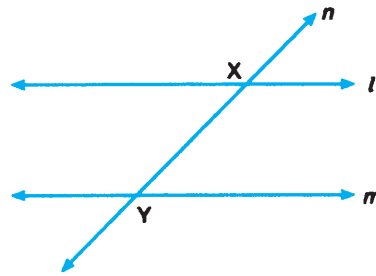


Fig. 13.33

The intercepts made by parallel lines on a transversal have some special properties which we shall study here.

Let  $l$  and  $m$  be two parallel lines and  $XY$  be an intercept made on the transversal “ $n$ ”. If there are three parallel lines and they are intersected by a transversal, there will be two intercepts  $AB$  and  $BC$  as shown in Fig. 13.34 (ii).

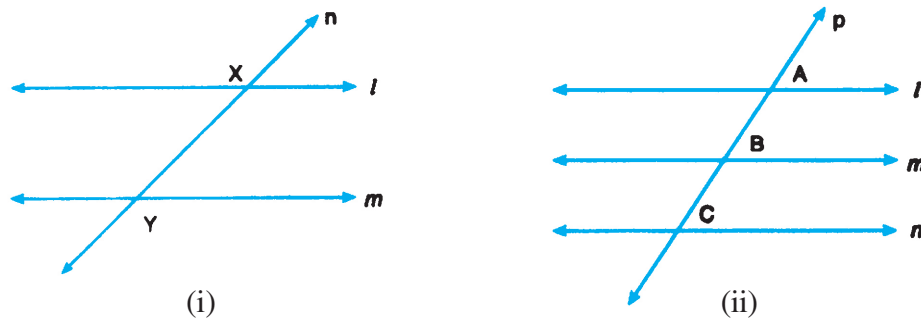


Fig. 13.34



Now let us learn an important property of intercepts made on the transversals by the parallel lines.

On a page of your note-book, draw any two transversals  $l$  and  $m$  intersecting the equidistant parallel lines  $p, q, r$  and  $s$  as shown in Fig. 13.35. These transversals make different intercepts. Measure the intercept  $AB, BC$  and  $CD$ . Are they equal? Yes, they are equal.

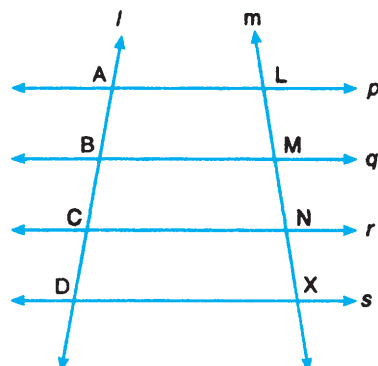


Fig. 13.35

Also, measure  $LM, MN$  and  $NX$ . Do you find that they are also equal? Yes, they are.

Repeat this experiment by taking another set of two or more equidistant parallel lines and measure their intercepts as done earlier. You will find in each case that the intercepts made are equal.

Thus, we conclude the following:

**If there are three or more parallel lines and the intercepts made by them on a transversal are equal, the corresponding intercepts made on any other transversal are also equal.**

Let us illustrate it by some examples: This result is known as Equal Intercept Theorem.

**Example 13.10:** In Fig. 13.36,  $p \parallel q \parallel r$ . The transversal  $l, m$  and  $n$  cut them at  $L, M, N; A, B, C$  and  $X, Y, Z$  respectively such that  $XY = YZ$ . Show that  $AB = BC$  and  $LM = MN$ .

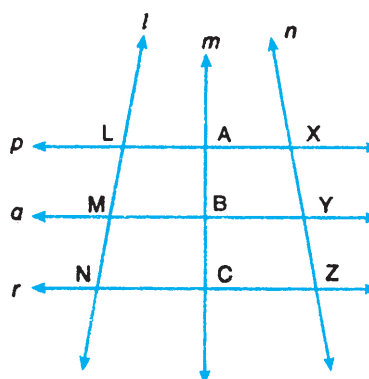


Fig. 13.36

**Solution:** Given that  $XY = YZ$

$\therefore AB = BC$  (Equal Intercept theorem)

and  $LM = MN$

Thus, the other pairs of equal intercepts are

$$AB = BC \text{ and } LM = MN.$$

**Example 13.11:** In Fig. 13.37,  $l \parallel m \parallel n$  and  $PQ = QR$ . If  $XZ = 20$  cm, find  $YZ$ .



Notes

**Solution:** We have  $PQ = QR$

$\therefore$  By intercept theorem,

$$XY = YZ$$

Also  $XZ = XY + YZ$

$$= YZ + YZ$$

$$\therefore 20 = 2YZ \Rightarrow YZ = 10 \text{ cm}$$

Hence,  $YZ = 10 \text{ cm}$

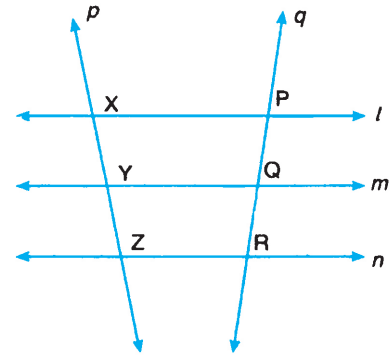


Fig. 13.37



**CHECK YOUR PROGRESS 13.4**

- In Fig. 13.38,  $l, m$  and  $n$  are three equidistant parallel lines.  $AD, PQ$  and  $GH$  are three transversals, If  $BC = 2 \text{ cm}$  and  $LM = 2.5 \text{ cm}$  and  $AD \parallel PQ$ , find  $MS$  and  $MN$ .

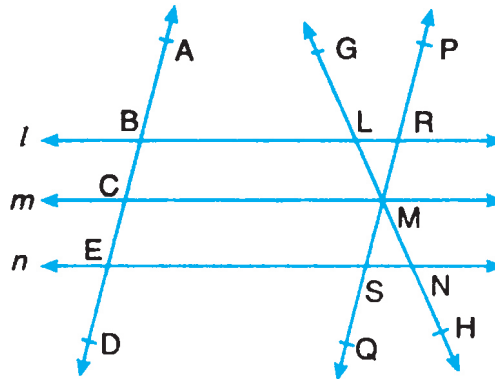


Fig. 13.38

- From Fig. 13.39, when can you say that  $AB = BC$  and  $XY = YZ$ ?

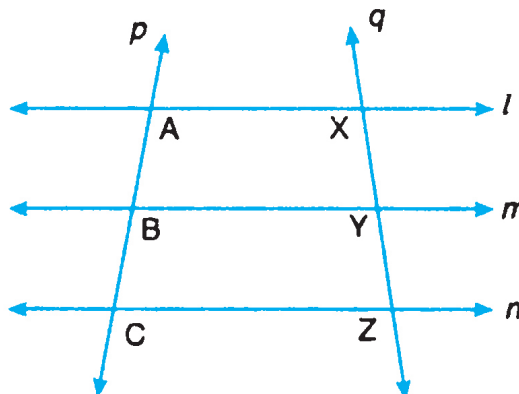


Fig. 13.39



Notes

3. In Fig. 13.40,  $LM = MZ = 3$  cm, find  $XY$ ,  $XP$  and  $BZ$ . Given that  $l \parallel m \parallel n$  and  $PQ = 3.2$  cm,  $AB = 3.5$  cm and  $YZ = 3.4$  cm.

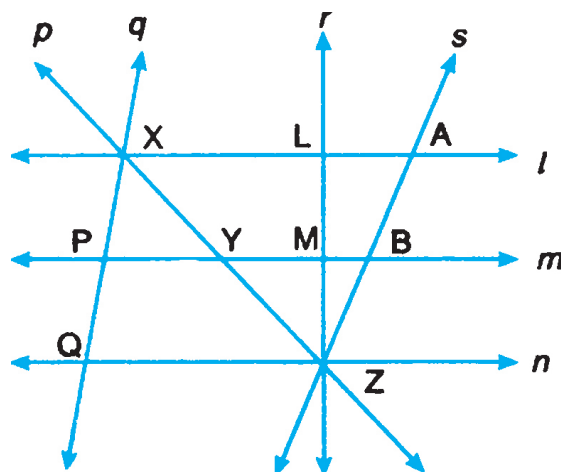


Fig. 13.40

### 13.6 THE DIAGONAL OF A PARALLELOGRAM AND RELATION TO THE AREA

Draw a parallelogram  $ABCD$ . Join its diagonal  $AC$ .  $DP \perp DC$  and  $QC \perp DC$ .

Consider the two triangles  $ADC$  and  $ACB$  in which the parallelogram  $ABCD$  has been divided by the diagonal  $AC$ . Because  $AB \parallel DC$ , therefore  $PD = QC$ .

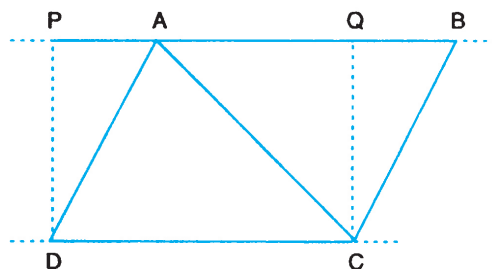


Fig. 13.41

Now, Area of  $\triangle ADC = \frac{1}{2} DC \times PD$  ....(i)

Area of  $\triangle ACB = \frac{1}{2} AB \times QC$  ....(ii)

As  $AB = DC$  and  $PD = QC$

$\therefore$  Area ( $\triangle ADC$ ) = Area ( $\triangle ACB$ )

Thus, we conclude the following:



A diagonal of a parallelogram divides it into two triangles of equal area.

### 13.7 PARALLELOGRAMS AND TRIANGLES BETWEEN THE SAME PARALLELS

Two parallelograms or triangles, having same or equal bases and having their other vertices on a line parallel to their bases, are said to be on the same or equal bases and between the same parallels.

We will prove an important theorem on parallelogram and their area.

**Theorem:** Parallelogram on the same base (or equal bases) and between the same parallels are equal in area.

Let us prove it logically.

**Given:** Parallelograms ABCD and PBCQ stand on the same base BC and between the same parallels BC and AQ.

**To prove:** Area (ABCD) = Area (BCQP)

we have  $AB = DC$  (Opposite sides of a parallelogram)

and  $BP = CQ$  (Opposite sides of a parallelogram)

$$\angle 1 = \angle 2$$

$$\therefore \triangle ABP \cong \triangle DCQ$$

$$\therefore \text{Area} (\triangle ABP) = \text{Area} (\triangle DCQ) \quad \dots(i)$$

$$\text{Now, Area} (\parallel^{\text{gm}} \text{ABCD}) = \text{Area} (\triangle ABP) + \text{Area Trapezium, BCDP} \quad \dots(ii)$$

$$\text{Area} (\parallel^{\text{gm}} \text{BCQP}) = \text{Area} (\triangle DCQ) + \text{Area Trapezium, BCDP} \quad \dots(iii)$$

From (i), (ii) and (iii), we get

$$\text{Area} (\parallel^{\text{gm}} \text{ABCD}) = \text{Area} (\parallel^{\text{gm}} \text{BCQP})$$

**Parallelogram on the same base (or equal bases) and between the same parallels are equal in area.**

**Note:**  $\parallel^{\text{gm}}$  stands for parallelogram.

**Result:** Triangles, on the same base and between the same parallels, are equal in area.

Consider Fig. 13.42. Join the diagonals BQ and AC of the two parallelograms BCQP and ABCD respectively. We know that a diagonal of a  $\parallel^{\text{gm}}$  divides it in two triangles of equal area.

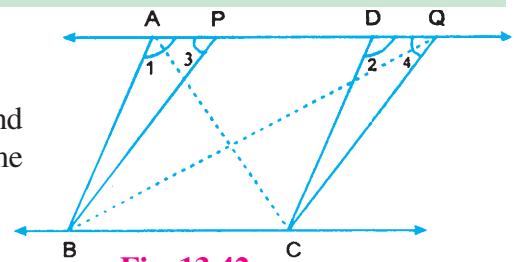


Fig. 13.42





∴ Area ( $\triangle BCQ$ ) = Area ( $\triangle PBQ$ ) [Each half of  $\parallel^{\text{gm}}$  BCQP]  
 and Area ( $\triangle ABC$ ) = Area ( $\triangle CAD$ ) [Each half of  $\parallel^{\text{gm}}$  ABCD]  
 ∴ Area ( $\triangle ABC$ ) = Area ( $\triangle BCQ$ ) [Since area of  $\parallel^{\text{gm}}$  ABCD = Area of  $\parallel^{\text{gm}}$  BCQP]

Thus we conclude the following:

**Triangles on the same base (or equal bases) and between the same parallels are equal in area.**

**13.8 TRIANGLES ON THE SAME OR EQUAL BASES HAVING EQUAL AREAS HAVE THEIR CORRESPONDING ALTITUDES EQUAL**

Recall that the area of triangle =  $\frac{1}{2}$  (Base)  $\times$  Altitude

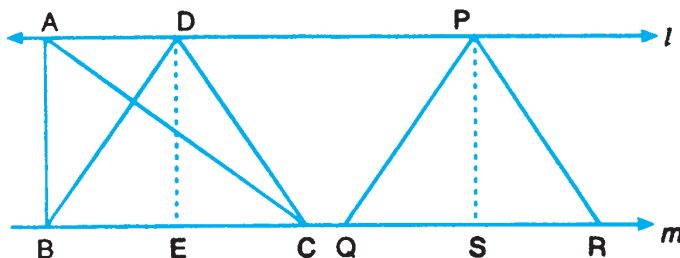


Fig. 13.43

Here  $BC = QR$   
 and Area ( $\triangle ABC$ ) = Area ( $\triangle DBC$ ) = Area ( $\triangle PQR$ ) [Given] ..(i)

Draw perpendiculars DE and PS from D and P to the line m meeting it in E and S respectively.

Now Area ( $\triangle ABC$ ) =  $\frac{1}{2}$  BC  $\times$  DE

Area ( $\triangle DBC$ ) =  $\frac{1}{2}$  BC  $\times$  DE ... (ii)

and Area ( $\triangle PQR$ ) =  $\frac{1}{2}$  QR  $\times$  PS

Also,  $BC = QR$  (given) ... (iii)

From (i), (ii) and (iii), we get



Notes

$$\frac{1}{2} BC \times DE = \frac{1}{2} QR \times PS$$

or 
$$\frac{1}{2} BC \times DE = \frac{1}{2} BC \times PS$$

$$\therefore DE = PS$$

i.e., Altitudes of  $\triangle ABC$ ,  $\triangle DBC$  and  $\triangle PQR$  are equal in length.

Thus, we conclude the following:

**Triangles on the same or equal bases, having equal areas have their corresponding altitudes equal.**

Let us consider some examples:

**Example 13.12:** In Fig. 13.44, the area of parallelogram ABCD is 40 sq cm. If  $BC = 8$  cm, find the altitude of parallelogram BCEF.

**Solution:** Area of  $\parallel^{\text{gm}}$  BCEF = Area of  $\parallel^{\text{gm}}$  ABCD = 40 sq cm

we know that Area ( $\parallel^{\text{gm}}$  BCEF) = EF  $\times$  Altitude

or  $40 = BC \times \text{Altitude of } \parallel^{\text{gm}} \text{ BCEF}$

or  $40 = BC \times \text{Altitude of } \parallel^{\text{gm}} \text{ BCEF}$

$$\therefore \text{Altitude of } \parallel^{\text{gm}} \text{ BCEF} = \frac{40}{8} \text{ cm or } 5 \text{ cm.}$$

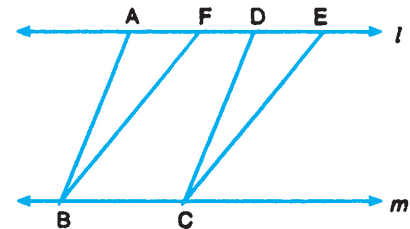


Fig. 13.44

**Example 13.13:** In Fig. 13.45, the area of  $\triangle ABC$  is given to be  $18 \text{ cm}^2$ . If the altitude DL equals 4.5 cm, find the base of the  $\triangle BCD$ .

**Solution:** Area ( $\triangle BCD$ ) = Area ( $\triangle ABC$ ) =  $18 \text{ cm}^2$

Let the base of  $\triangle BCD$  be  $x$  cm

$$\begin{aligned} \therefore \text{Area of } \triangle BCD &= \frac{1}{2} x \times DL \\ &= \left( \frac{1}{2} x \times 4.5 \right) \text{ cm}^2 \end{aligned}$$

or  $18 = \left( \frac{9}{4} x \right)$

$$\therefore x = \left( 18 \times \frac{4}{9} \right) \text{ cm} = 8 \text{ cm.}$$

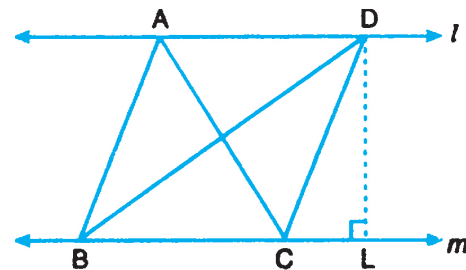


Fig. 13.45



Notes

**Example 13.14:** In Fig. 13.46, ABCD and ACED are two parallelograms. If area of  $\triangle ABC$  equals  $12 \text{ cm}^2$ , and the length of CE and BC are equal, find the area of the trapezium ABED.

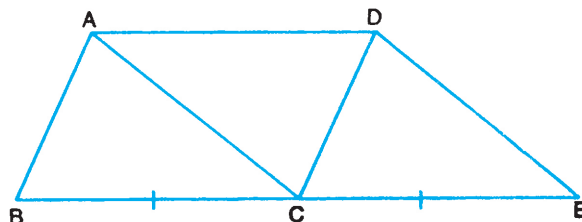


Fig. 13.46

**Solution:** Area ( $\parallel^{\text{gm}} \text{ABCD}$ ) = Area ( $\parallel^{\text{gm}} \text{ACED}$ )

The diagonal AC divides the  $\parallel^{\text{gm}} \text{ABCD}$  into two triangles of equal area.

$$\therefore \text{Area} (\triangle \text{BCD}) = \frac{1}{2} \text{Area} (\parallel^{\text{gm}} \text{ABCD})$$

$$\begin{aligned} \therefore \text{Area} (\parallel^{\text{gm}} \text{ABCD}) &= \text{Area} (\parallel^{\text{gm}} \text{ACED}) = 2 \times 12 \text{ cm}^2 \\ &= 24 \text{ cm}^2 \end{aligned}$$

$\therefore$  Area of Trapezium ABED

$$\begin{aligned} &= \text{Area} (\triangle \text{ABC}) + \text{Area} (\parallel^{\text{gm}} \text{ACED}) \\ &= (12 + 24) \text{ cm}^2 \\ &= 36 \text{ cm}^2 \end{aligned}$$



### CHECK YOUR PROGRESS 13.5

1. When do two parallelograms on the same base (or equal bases) have equal areas?
2. The area of the triangle ABC formed by joining the diagonal AC of a  $\parallel^{\text{gm}} \text{ABCD}$  is  $16 \text{ cm}^2$ . Find the area of the  $\parallel^{\text{gm}} \text{ABCD}$ .
3. The area of  $\triangle \text{ACD}$  in Fig. 13.47 is  $8 \text{ cm}^2$ . If  $\text{EF} = 4 \text{ cm}$ , find the altitude of  $\parallel^{\text{gm}} \text{BCFE}$ .

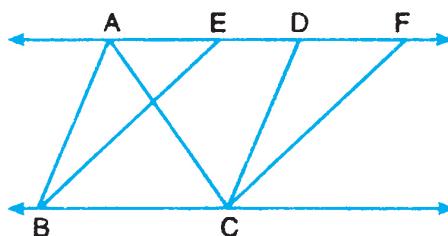


Fig. 13.47



Notes



LET US SUM UP

- A quadrilateral is a four sided closed figure, enclosing some region of the plane.
- The sum of the interior or exterior angles of a quadrilateral is equal to  $360^\circ$  each.
- A quadrilateral is a trapezium if its only one pair of opposite sides is parallel.
- A quadrilateral is a parallelogram if both pairs of sides are parallel.
- In a parallelogram:
  - (i) opposite sides and angles are equal.
  - (ii) diagonals bisect each other.
- A parallelogram is a rhombus if its adjacent sides are equal.
- The diagonals of a rhombus bisect each other at right angle.
- A parallelogram is a rectangle if its one angle is  $90^\circ$ .
- The diagonals of a rectangle are equal.
- A rectangle is a square if its adjacent sides are equal.
- The diagonals of a square intersect at right angles.
- The diagonal of a parallelogram divides it into two triangles of equal area.
- Parallelogram on the same base (or equal bases) and between the same parallels are equal in area.
- The triangles on the same base (or equal bases) and between the same parallels are equal in area.
- Triangles on same base (or equal bases) having equal areas have their corresponding altitudes equal.



TERMINAL EXERCISE

1. Which of the following are trapeziums?

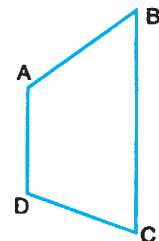
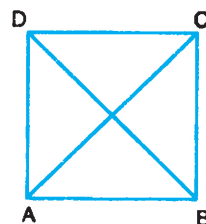
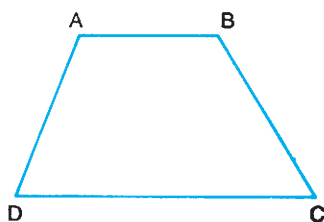


Fig. 13.48



2. In Fig. 13.49,  $PQ \parallel FG \parallel DE \parallel BC$ . Name all the trapeziums in the figure.

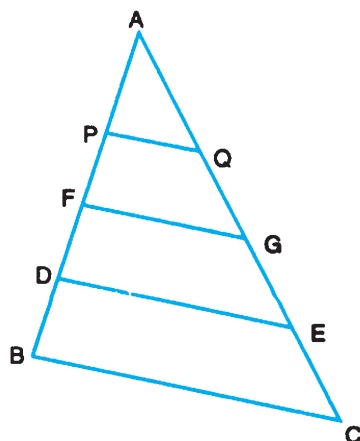


Fig. 13.49

3. In Fig. 13.50, ABCD is a parallelogram with an area of  $48 \text{ cm}^2$ . Find the area of (i) shaded region (ii) unshaded region.

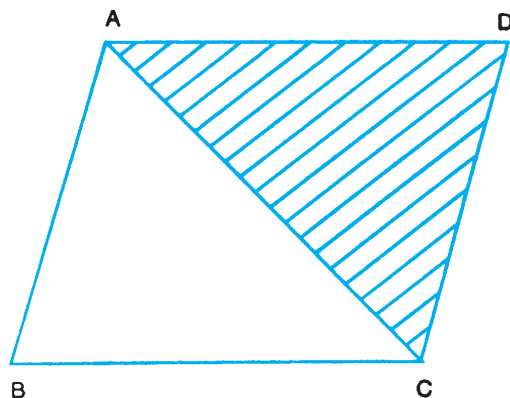


Fig. 13.49

4. Fill in the blanks in each of the following to make them true statements:
- A quadrilateral is a trapezium if ....
  - A quadrilateral is a parallelogram if ....
  - A rectangle is a square if ...
  - the diagonals of a quadrilateral bisect each other at right angle. If none of the angles of the quadrilateral is a right angle, it is a ...
  - The sum of the exterior angles of a quadrilateral is ...
5. If the angles of a quadrilateral are  $(x - 20)^\circ$ ,  $(x + 20)^\circ$ ,  $(x - 15)^\circ$  and  $(x + 15)^\circ$ , find  $x$  and the angles of the quadrilateral.
6. The sum of the opposite angles of a parallelogram is  $180^\circ$ . What type of a parallelogram is it?



Notes

7. The area of a  $\triangle ABD$  in Fig. 13.51 is  $24 \text{ cm}^2$ . If  $DE = 6 \text{ cm}$ , and  $AB \parallel CD$ ,  $BD \parallel CE$ ,  $AE \parallel BC$ , find

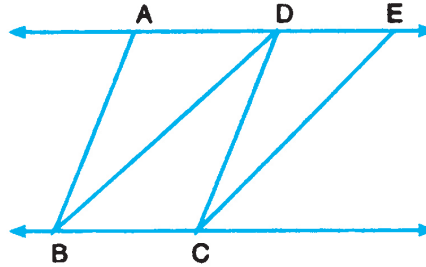


Fig. 13.51

- (i) Altitude of the parallelogram BCED.  
 (ii) Area of the parallelogram BCED.
8. In Fig. 13.52, the area of parallelogram ABCD is  $40 \text{ cm}^2$ . If  $EF = 8 \text{ cm}$ , find the altitude of  $\triangle DCE$ .

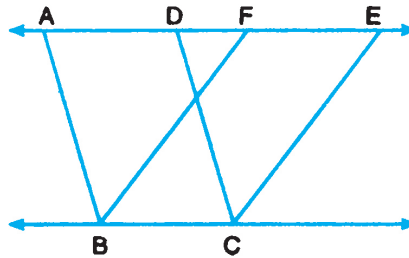


Fig. 13.52



ANSWERS TO CHECK YOUR PROGRESS

13.1

- |  |                |                 |                    |
|--|----------------|-----------------|--------------------|
| 1. (i) Rectangle   | (ii) Trapezium | (iii) Rectangle | (iv) Parallelogram |
| (v) Rhombus  | (vi) Square    |                 |                    |
| 2. (i) True  | (ii) False     | (iii) True      | (iv) True          |
| (v) True   | (vi) True      | (vii) False     | (viii) False       |
| (ix) False   | (x) False      |                 |                    |
| 3. $90^\circ$  |                |                 |                    |
| 4. $60^\circ, 84^\circ, 84^\circ$ and $132^\circ$            |                |                 |                    |
| 5. Other pair of opposite angles will also be supplementary. |                |                 |                    |

13.2

- $\angle B = 118^\circ, \angle C = 62^\circ$  and  $\angle D = 118^\circ$
- $\angle A = 105^\circ, \angle B = 75^\circ, \angle C = 105^\circ$  and  $\angle D = 75^\circ$



3. 30
4.  $\angle CDB = 55^\circ$  and  $\angle ADB = 55^\circ$
5.  $\angle ACD = 61^\circ$
6.  $\angle OPS = 70^\circ$       7.  $\angle CAB = 45^\circ$

**13.3**

2. 5 cm
3. 3 cm

**13.4**

1.  $MS = 2$  cm and  $MN = 2.5$  cm
2. 1, m and n are three equidistant parallel lines
3.  $XY = 3.4$  cm,  $XP = 3.2$  cm and  $BZ = 3.5$  cm

**13.5**

1. When they are lying between the same parallel lines
2.  $32 \text{ cm}^2$
3. 4 cm



**ANSWERS TO TERMINAL EXERCISE**

1. (i) and (iii)
2. PFGQ, FDEG, DBCE, PDEQ, FBCG and PBCQ
3. (i)  $24 \text{ cm}^2$     (ii)  $24 \text{ cm}^2$
4. (i) any one pair of opposite sides are parallel.  
 (ii) both pairs of opposite sides are parallel  
 (iii) pair of adjacent sides are equal  
 (iv) rhombus  
 (v)  $360^\circ$
5.  $x = 90^\circ$ , angles are  $70^\circ$ ,  $110^\circ$ ,  $75^\circ$  and  $105^\circ$  respectively.
6. Rectangle.
7. (i) 8 cm                      (ii)  $48 \text{ cm}^2$
8. 5 cm