

## EXERCISE 16.1

**Define the following terms:**

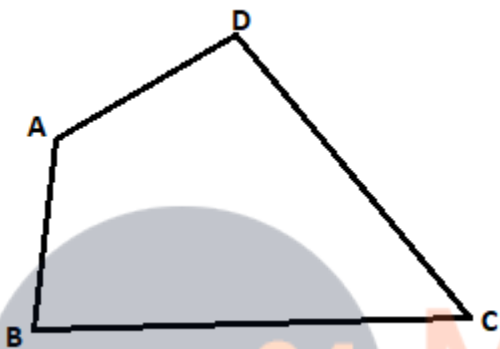
**(i) Quadrilateral**

**(ii) Convex Quadrilateral**

**Solution:**

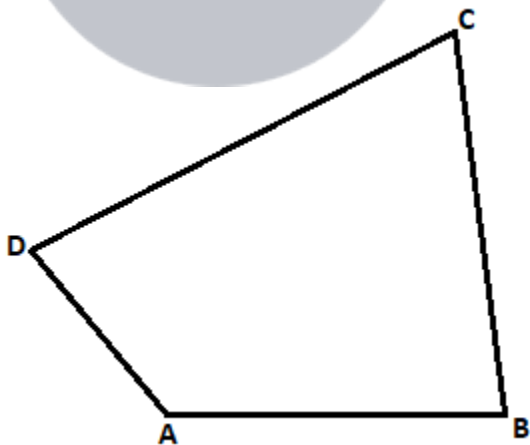
(i) Quadrilateral

Definition: Let A, B, C and D be four points in a plane such that: (a) no three of them are collinear. (b) The line segments AB, BC, CD and DA do not intersect except at their end points. Then an Enclosed figure with four sides is termed as Quadrilateral.



(ii) Convex Quadrilateral

Definition: If the line containing any side of the quadrilateral has the remaining vertices on the same side of it is termed as Convex Quadrilateral.



Vertices A, B lie on the same side of line CD, vertices B, C lie on the same side of line DA, vertices C, D lie on the same side of line AB, vertices D, A lie on the same side of line BC.

**2. In a quadrilateral, define each of the following:**

**(i) Sides**

**(ii) Vertices**

**(iii) Angles**

**(iv) Diagonals**

**(v) Adjacent angles**

**(vi) Adjacent sides**

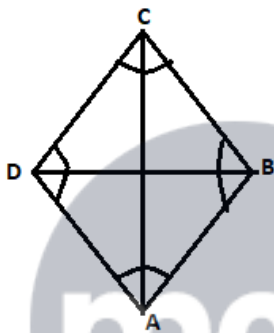
**(vii) Opposite sides**

**(viii) Opposite angles**

**(ix) Interior**

**(x) Exterior**

**Solution:**



**(i) Sides:** In a quadrilateral. All the sides may have same or different length. The four line segments AB, BC, CD and DA are called its sides.

**(ii) Vertices**

Vertices are the angular points where two sides or edges meet.

A, B, C and D are the four vertices in a quadrilateral.

**(iii) Angles**

Angle is the inclination between two sides of a quadrilateral. i.e. meeting point of two sides is an angle.  $\angle ABC$ ,  $\angle BCA$ ,  $\angle CDA$  and  $\angle DAB$  are the four angles in a quadrilateral.

**(iv) Diagonals**

The lines joining two opposite vertices is called the diagonals in a quadrilateral.

BD and AC are the two diagonals.

**(v) Adjacent angles**

Angles having one common arm onto the sides is called the adjacent angles.

$\angle ABC$ ,  $\angle BCD$  are adjacent angles in a quadrilateral.

**(vi) Adjacent sides**

When two sides have common endpoint is termed as adjacent sides.

AB BC, BC CA, CD DA, DA AB are pairs of adjacent sides in a quadrilateral.

**(vii) Opposite sides:** Opposite sides when they don't meet at any point is termed as opposite sides.

AB CD, BC DA are the pairs of opposite sides in a quadrilateral.

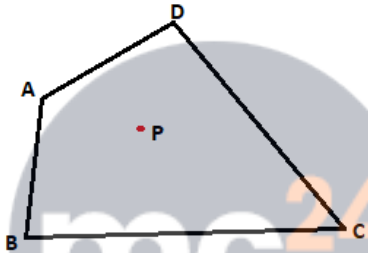
**(viii) Opposite angles**

Two angles, which are not adjacent angles are termed as opposite angles.

A and C, angles B and D are opposite angles in a quadrilateral.

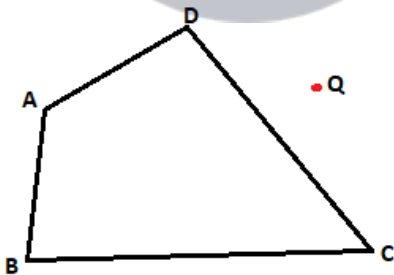
**(ix) Interior**

The part of plane when points are enclosed within the quadrilateral is called as interior.



**(x) Exterior**

The part of plane when points are not enclosed within the quadrilateral is called as exterior.



**3. Complete each of the following, so as to make a true statement:**

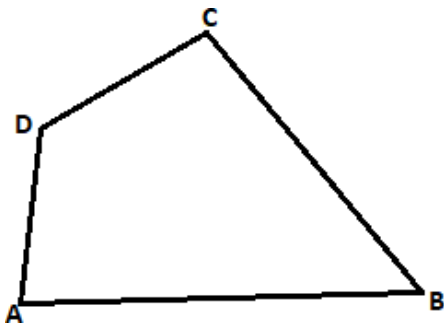
- (i) A quadrilateral has \_\_\_\_\_ sides.
- (ii) A quadrilateral has \_\_\_\_\_ angles.
- (iii) A quadrilateral has \_\_\_\_\_, no three of which are \_\_\_\_\_.
- (iv) A quadrilateral has \_\_\_\_\_ diagonals.
- (v) The number of pairs of adjacent angles of a quadrilateral is \_\_\_\_\_.
- (vi) The number of pairs of opposite angles of a quadrilateral is \_\_\_\_\_.

- (vii) The sum of the angles of a quadrilateral is \_\_\_\_\_.
- (viii) A diagonal of a quadrilateral is a line segment that joins two \_\_\_\_\_ vertices of the quadrilateral.
- (ix) The sum of the angles of a quadrilateral is \_\_\_\_\_ right angles.
- (x) The measure of each angle of a convex quadrilateral is \_\_\_\_\_  $180^\circ$ .
- (xi) In a quadrilateral the point of intersection of the diagonals lies in \_\_\_\_\_ of the quadrilateral.
- (xii) A point is in the interior of a convex quadrilateral, if it is in the \_\_\_\_\_ of its two opposite angles.
- (xiii) A quadrilateral is convex if for each side, the remaining \_\_\_\_\_ lie on the same side of the line containing the side.

**Solution:**

- (i) A quadrilateral has **four** sides.
- (ii) A quadrilateral has **four** angles.
- (iii) A quadrilateral has **four**, no three of which are **collinear**.
- (iv) A quadrilateral has **two** diagonals.
- (v) The number of pairs of adjacent angles of a quadrilateral is **four**.
- (vi) The number of pairs of opposite angles of a quadrilateral is **two**.
- (vii) The sum of the angles of a quadrilateral is  **$360^\circ$** .
- (viii) A diagonal of a quadrilateral is a line segment that joins two **opposite** vertices of the quadrilateral.
- (ix) The sum of the angles of a quadrilateral is **four** right angles.
- (x) The measure of each angle of a convex quadrilateral is **less than**  $180^\circ$ .
- (xi) In a quadrilateral the point of intersection of the diagonals lies in **interior** of the quadrilateral.
- (xii) A point is in the interior of a convex quadrilateral, if it is in the **interiors** of its two opposite angles.
- (xiii) A quadrilateral is convex if for each side, the remaining **vertices** lie on the same side of the line containing the side.

**4. In Fig. 16.19, ABCD is a quadrilateral.**



- (i) Name a pair of adjacent sides.
- (ii) Name a pair of opposite sides.
- (iii) How many pairs of adjacent sides are there?
- (iv) How many pairs of opposite sides are there?
- (v) Name a pair of adjacent angles.
- (vi) Name a pair of opposite angles.
- (vii) How many pairs of adjacent angles are there?
- (viii) How many pairs of opposite angles are there?

**Solution:**

(i) Name a pair of adjacent sides.

Adjacent sides are: AB, BC or BC, CD or CD, DA or AD, AB

(ii) Name a pair of opposite sides.

opposite sides are: AB, CD or BC, DA

(iii) How many pairs of adjacent sides are there?

Four pairs of adjacent sides i.e. AB BC, BC CD, CD DA and DA AB

(iv) How many pairs of opposite sides are there?

Two pairs of opposite sides. AB, DC and DA, BC

(v) Name a pair of adjacent angles.

Four pairs of Adjacent angles are:  $\angle DAB$   $\angle ABC$ ,  $\angle ABC$   $\angle BCA$ ,  $\angle BCA$   $\angle CDA$  or  $\angle CDA$   $\angle DAB$

(vi) Name a pair of opposite angles.

Four pair of opposite angles are:  $\angle DAB$   $\angle BCA$  and  $\angle ABC$   $\angle CDA$

(vii) How many pairs of adjacent angles are there?

Four pairs of adjacent angles.  $\angle DAB$   $\angle ABC$ ,  $\angle ABC$   $\angle BCA$ ,  $\angle BCA$   $\angle CDA$  and  $\angle CDA$   $\angle DAB$

(viii) How many pairs of opposite angles are there?

Two pairs of opposite angles.  $\angle DAB$   $\angle BCA$  and  $\angle ABC$   $\angle CDA$

**5. The angles of a quadrilateral are  $110^\circ$ ,  $72^\circ$ ,  $55^\circ$  and  $x^\circ$ . Find the value of  $x$ .**

**Solution:**

We know that Sum of angles of a quadrilateral is =  $360^\circ$

So,

$$110^\circ + 72^\circ + 55^\circ + x^\circ = 360^\circ$$

$$x^\circ = 360^\circ - 237^\circ$$

$$x^\circ = 123^\circ$$

∴ Value of x is  $123^\circ$

**6. The three angles of a quadrilateral are respectively equal to  $110^\circ$ ,  $50^\circ$  and  $40^\circ$ .**

**Find its fourth angle.**

**Solution:**

We know that Sum of angles of a quadrilateral is  $= 360^\circ$

So,

$$110^\circ + 50^\circ + 40^\circ + x^\circ = 360^\circ$$

$$x^\circ = 360^\circ - 200^\circ$$

$$x^\circ = 160^\circ$$

∴ Value of fourth angle is  $160^\circ$

**7. A quadrilateral has three acute angles each measures  $80^\circ$ . What is the measure of the fourth angle?**

**Solution:**

We know that Sum of angles of a quadrilateral is  $= 360^\circ$

So,

$$80^\circ + 80^\circ + 80^\circ + x^\circ = 360^\circ$$

$$x^\circ = 360^\circ - 240^\circ$$

$$x^\circ = 120^\circ$$

∴ Value of fourth angle is  $120^\circ$

**8. A quadrilateral has all its four angles of the same measure. What is the measure of each?**

**Solution:**

We know that Sum of angles of a quadrilateral is  $= 360^\circ$

Let each angle be  $x^\circ$

So,

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

$$x^\circ = 360^\circ/4$$

$$= 90^\circ$$

∴ Value of angle is  $90^\circ$  each.

**9. Two angles of a quadrilateral are of measure  $65^\circ$  and the other two angles are equal. What is the measure of each of these two angles?**

**Solution:**

We know that Sum of angles of a quadrilateral is =  $360^\circ$

Let each angle be  $x^\circ$

So,

$$65^\circ + 65^\circ + x^\circ + x^\circ = 360^\circ$$

$$2x^\circ = 360^\circ - 130^\circ$$

$$x^\circ = 230^\circ/2$$

$$= 115^\circ$$

$\therefore$  Value of two angles is  $115^\circ$  each.

**10. Three angles of a quadrilateral are equal. Fourth angle is of measure  $150^\circ$ . What is the measure of equal angles?**

**Solution:**

We know that Sum of angles of a quadrilateral is =  $360^\circ$

Let each angle be  $x^\circ$

So,

$$150^\circ + x^\circ + x^\circ + x^\circ = 360^\circ$$

$$3x^\circ = 360^\circ - 150^\circ$$

$$x^\circ = 210^\circ/3$$

$$= 70^\circ$$

$\therefore$  Value of equal angles is  $70^\circ$  each.

**11. The four angles of a quadrilateral are as 3 : 5 : 7 : 9. Find the angles.**

**Solution:**

We know that Sum of angles of a quadrilateral is =  $360^\circ$

Let each angle be  $x^\circ$

So,

$$3x^\circ + 5x^\circ + 7x^\circ + 9x^\circ = 360^\circ$$

$$24x^\circ = 360^\circ$$

$$x^\circ = 360^\circ/24$$

$$= 15^\circ$$

Value of angles are

$$3x = 3 \times 15 = 45^\circ$$

$$5x = 5 \times 15 = 75^\circ$$

$$7x = 7 \times 15 = 105^\circ$$

$$9x = 9 \times 15 = 135^\circ$$

$\therefore$  Value of angles are  $45^\circ, 75^\circ, 105^\circ, 135^\circ$

**12. If the sum of the two angles of a quadrilateral is  $180^\circ$ . What is the sum of the**

remaining two angles?

**Solution:**

We know that Sum of angles of a quadrilateral is  $= 360^\circ$

Let the sum of two angles be  $180^\circ$

Let angle be  $x^\circ$

So,

$$180^\circ + x^\circ = 360^\circ$$

$$x^\circ = 360^\circ - 180^\circ$$

$$x^\circ = 180^\circ$$

$\therefore$  Sum of remaining two angles is  $180^\circ$

**13. In Figure, find the measure of  $\angle MPN$ .**



**Solution:**

We know that Sum of angles of a quadrilateral is  $= 360^\circ$

In the quadrilateral MPNO

$$\angle NOP = 45^\circ, \angle OMP = \angle PNO = 90^\circ$$

Let angle  $\angle MPN$  is  $x^\circ$

$$\angle NOP + \angle OMP + \angle PNO + \angle MPN = 360^\circ$$

$$45^\circ + 90^\circ + 90^\circ + x^\circ = 360^\circ$$

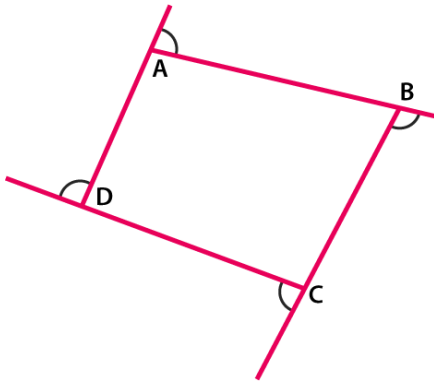
$$x^\circ = 360^\circ - 225^\circ$$

$$x^\circ = 135^\circ$$

$\therefore$  Measure of  $\angle MPN$  is  $135^\circ$

**14. The sides of a quadrilateral are produced in order. What is the sum of the four exterior angles?**

**Solution:**



We know that, exterior angle + interior adjacent angle =  $180^\circ$  [Linear pair]

Applying relation for polygon having  $n$  sides

Sum of all exterior angles + Sum of all interior angles =  $n \times 180^\circ$

Sum of all exterior angles =  $n \times 180^\circ$  - Sum of all interior angles

$$= n \times 180^\circ - (n - 2) \times 180^\circ \text{ [Sum of interior angles is } = (n - 2) \times 180^\circ \text{]}$$

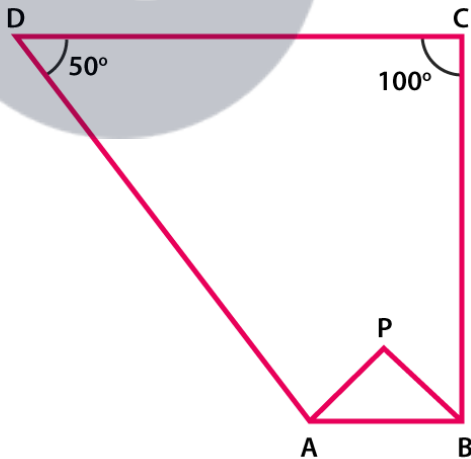
$$= n \times 180^\circ - n \times 180^\circ + 2 \times 180^\circ$$

$$= 180^\circ n - 180^\circ n + 360^\circ$$

$$= 360^\circ$$

$\therefore$  Sum of four exterior angles is  $360^\circ$

15. In Figure, the bisectors of  $\angle A$  and  $\angle B$  meet at a point P. If  $\angle C = 100^\circ$  and  $\angle D = 50^\circ$ , find the measure of  $\angle APB$ .



**Solution:**

We know that Sum of angles of a quadrilateral is =  $360^\circ$

In the quadrilateral ABCD

Given,  $\angle C = 100^\circ$  and  $\angle D = 50^\circ$

$$\angle A + \angle B + \angle C + \angle D = 360^\circ$$

$$\begin{aligned}\angle A + \angle B + 100^\circ + 50^\circ &= 360^\circ \\ \angle A + \angle B &= 360^\circ - 150^\circ \\ \angle A + \angle B &= 210^\circ \dots\dots\dots \text{(Equation 1)}\end{aligned}$$

Now in  $\Delta APB$

$$\frac{1}{2} \angle A + \frac{1}{2} \angle B + \angle APB = 180^\circ \text{ (since, sum of triangle is } 180^\circ)$$

$$\angle APB = 180^\circ - \frac{1}{2} (\angle A + \angle B) \dots\dots\dots \text{(Equation 2)}$$

On substituting value of  $\angle A + \angle B = 210$  from equation (1) in equation (2)

$$\begin{aligned}\angle APB &= 180^\circ - \frac{1}{2} (210^\circ) \\ &= 180^\circ - 105^\circ \\ &= 75^\circ\end{aligned}$$

$\therefore$  The measure of  $\angle APB$  is  $75^\circ$

**16. In a quadrilateral  $ABCD$ , the angles  $A$ ,  $B$ ,  $C$  and  $D$  are in the ratio  $1 : 2 : 4 : 5$ . Find the measure of each angle of the quadrilateral.**

**Solution:**

We know that Sum of angles of a quadrilateral is  $= 360^\circ$

Let each angle be  $x^\circ$

So,

$$x^\circ + 2x^\circ + 4x^\circ + 5x^\circ = 360^\circ$$

$$12x^\circ = 360^\circ$$

$$x^\circ = 360^\circ / 12$$

$$= 30^\circ$$

Value of angles are

$$x = 30^\circ$$

$$2x = 2 \times 30 = 60^\circ$$

$$4x = 4 \times 30 = 120^\circ$$

$$5x = 5 \times 30 = 150^\circ$$

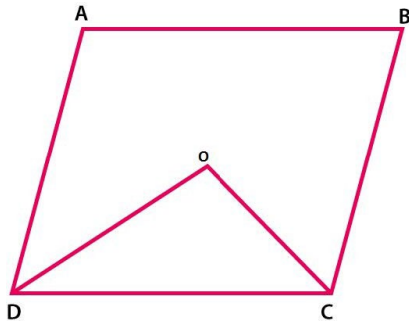
$\therefore$  Value of angles are  $30^\circ, 60^\circ, 120^\circ, 150^\circ$

**17. In a quadrilateral  $ABCD$ ,  $CO$  and  $DO$  are the bisectors of  $\angle C$  and  $\angle D$  respectively. Prove that  $\angle COD = \frac{1}{2} (\angle A + \angle B)$ .**

**Solution:**

We know that sum of angles of a quadrilateral is  $360^\circ$

In the quadrilateral  $ABCD$



$$\angle A + \angle B + \angle C + \angle D = 360^\circ$$

$$\angle A + \angle B = 360^\circ - (\angle C + \angle D)$$

$$\begin{aligned} \frac{1}{2}(\angle A + \angle B) &= \frac{1}{2}[360^\circ - (\angle C + \angle D)] \\ &= 180^\circ - \frac{1}{2}(\angle C + \angle D) \dots\dots\dots \text{(Equation 1)} \end{aligned}$$

Now in  $\triangle DOC$

$$\frac{1}{2} \angle D + \frac{1}{2} \angle C + \angle COD = 180^\circ \text{ (since sum of triangle} = 180^\circ)$$

$$\frac{1}{2}(\angle C + \angle D) + \angle COD = 180^\circ$$

$$\angle COD = 180^\circ - \frac{1}{2}(\angle C + \angle D) \dots\dots\dots \text{(Equation 2)}$$

From above equations (1) and (2) RHS is equal, then LHS will also be equal.

$\therefore \angle COD = \frac{1}{2}(\angle A + \angle B)$  is proved.

**18. Find the number of sides of a regular polygon, when each of its angles has a measure of**

- (i)  $160^\circ$
- (ii)  $135^\circ$
- (iii)  $175^\circ$
- (iv)  $162^\circ$
- (v)  $150^\circ$

**Solution:**

The measure of interior angle A of a polygon of n sides is given by  $A = [(n-2) \times 180^\circ]/n$

(i)  $160^\circ$

Angle of quadrilateral is  $160^\circ$

$$160^\circ = [(n-2) \times 180^\circ]/n$$

$$160^\circ n = (n-2) \times 180^\circ$$

$$160^\circ n = 180^\circ n - 360^\circ$$

$$180^\circ n - 160^\circ n = 360^\circ$$

$$20^\circ n = 360^\circ$$

$$n = 360^\circ/20$$

$$= 18$$

∴ Number of sides are 18

**(ii)**  $135^\circ$

Angle of quadrilateral is  $135^\circ$

$$135^\circ = [(n-2) \times 180^\circ]/n$$

$$135^\circ n = (n-2) \times 180^\circ$$

$$135^\circ n = 180^\circ n - 360^\circ$$

$$180^\circ n - 135^\circ n = 360^\circ$$

$$45^\circ n = 360^\circ$$

$$n = 360^\circ/45$$

$$= 8$$

∴ Number of sides are 8

**(iii)**  $175^\circ$

Angle of quadrilateral is  $175^\circ$

$$175^\circ = [(n-2) \times 180^\circ]/n$$

$$175^\circ n = (n-2) \times 180^\circ$$

$$175^\circ n = 180^\circ n - 360^\circ$$

$$180^\circ n - 175^\circ n = 360^\circ$$

$$5^\circ n = 360^\circ$$

$$n = 360^\circ/5$$

$$= 72$$

∴ Number of sides are 72

**(iv)**  $162^\circ$

Angle of quadrilateral is  $162^\circ$

$$162^\circ = [(n-2) \times 180^\circ]/n$$

$$162^\circ n = (n-2) \times 180^\circ$$

$$162^\circ n = 180^\circ n - 360^\circ$$

$$180^\circ n - 162^\circ n = 360^\circ$$

$$18^\circ n = 360^\circ$$

$$n = 360^\circ/18$$

$$= 20$$

∴ Number of sides are 20

**(v)**  $150^\circ$

Angle of quadrilateral is  $160^\circ$

$$150^\circ = [(n-2) \times 180^\circ]/n$$

$$150^\circ n = (n-2) \times 180^\circ$$

$$150^\circ n = 180^\circ n - 360^\circ$$

$$180^\circ n - 150^\circ n = 360^\circ$$

$$30^\circ n = 360^\circ$$

$$n = 360^\circ / 30$$

$$= 12$$

∴ Number of sides are 12

**19. Find the numbers of degrees in each exterior angle of a regular pentagon.**

**Solution:**

We know that the sum of exterior angles of a polygon is  $360^\circ$

Measure of each exterior angle of a polygon is  $= 360^\circ/n$ , where  $n$  is the number of sides

We know that number of sides in a pentagon is 5

Measure of each exterior angle of a pentagon is  $= 360^\circ/5 = 72^\circ$

∴ Measure of each exterior angle of a pentagon is  $72^\circ$

**20. The measure of angles of a hexagon are  $x^\circ$ ,  $(x-5)^\circ$ ,  $(x-5)^\circ$ ,  $(2x-5)^\circ$ ,  $(2x-5)^\circ$ ,  $(2x+20)^\circ$ . Find value of  $x$ .**

**Solution:**

By using the formula,

The sum of interior angles of a polygon  $= (n - 2) \times 180^\circ$ , (where  $n$  = number of sides of polygon.)

We know, a hexagon has 6 sides. So,

The sum of interior angles of a hexagon  $= (6 - 2) \times 180^\circ = 4 \times 180^\circ = 720^\circ$

$$x^\circ + (x-5)^\circ + (x-5)^\circ + (2x-5)^\circ + (2x-5)^\circ + (2x+20)^\circ = 720^\circ$$

$$x^\circ + x^\circ - 5^\circ + x^\circ - 5^\circ + 2x^\circ - 5^\circ + 2x^\circ - 5^\circ + 2x^\circ + 20^\circ = 720^\circ$$

$$9x^\circ = 720^\circ$$

$$x = 720^\circ / 9$$

$$= 80^\circ$$

∴ Value of  $x$  is  $80^\circ$

**21. In a convex hexagon, prove that the sum of all interior angle is equal to twice the sum of its exterior angles formed by producing the sides in the same order.**

**Solution:**

By using the formulas,

The sum of interior angles of a polygon  $= (n - 2) \times 180^\circ$

The sum of interior angles of a hexagon  $= (6 - 2) \times 180^\circ = 4 \times 180^\circ = 720^\circ$

The Sum of exterior angle of a polygon is  $360^\circ$

∴ Sum of interior angles of a hexagon = twice the sum of interior angles.

Hence proved.

**22. The sum of the interior angles of a polygon is three times the sum of its exterior angles. Determine the number of sides of the polygon.**

**Solution:**

By using the formulas,

The sum of interior angles of a polygon =  $(n - 2) \times 180^\circ$  .....(i)

The Sum of exterior angle of a polygon is  $360^\circ$

So,

Sum of interior angles =  $3 \times$  sum of exterior angles  
 $= 3 \times 360^\circ = 1080^\circ$  .....(ii)

Now by equating (i) and (ii) we get,

$$(n - 2) \times 180^\circ = 1080^\circ$$

$$n - 2 = 1080^\circ / 180^\circ$$

$$n - 2 = 6$$

$$n = 6 + 2$$

$$= 8$$

$\therefore$  Number of sides of a polygon is 8

**23. Determine the number of sides of a polygon whose exterior and interior angles are in the ratio 1 : 5.**

**Solution:**

By using the formulas,

The sum of interior angles of a polygon =  $(n - 2) \times 180^\circ$  .....(i)

The Sum of exterior angle of a polygon is  $360^\circ$

We know that Sum of exterior angles/Sum of interior angles =  $1/5$ ..... (ii)

So, equating (i) and (ii) we get

$$360^\circ / (n - 2) \times 180^\circ = 1/5$$

On cross multiplication,

$$(n - 2) \times 180^\circ = 360^\circ \times 5$$

$$(n - 2) \times 180^\circ = 1800^\circ$$

$$(n - 2) = 1800^\circ / 180^\circ$$

$$(n - 2) = 10$$

$$n = 10 + 2$$

$$= 12$$

$\therefore$  Numbers of sides of a polygon is 12

**24. PQRSTU is a regular hexagon, determine each angle of  $\Delta$ PQT.**

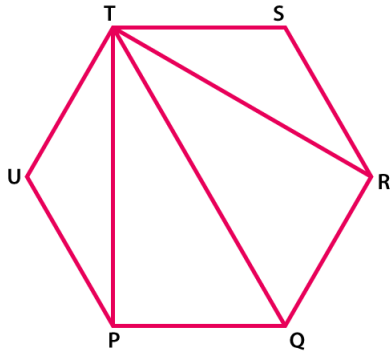
**Solution:**

We know that the sum of interior angles of a polygon =  $(n - 2) \times 180^\circ$

The sum of interior angles of a hexagon =  $(6 - 2) \times 180^\circ = 4 \times 180^\circ = 720^\circ$

Measure of each angle of hexagon =  $720^\circ/6 = 120^\circ$

$\angle PUT = 120^\circ$  Proved.



In  $\Delta PUT$

$\angle PUT + \angle UTP + \angle TPU = 180^\circ$  (sum of triangles)

$120^\circ + 2\angle UTP = 180^\circ$  (since  $\Delta PUT$  is an isosceles triangle)

$2\angle UTP = 180^\circ - 120^\circ$

$2\angle UTP = 60^\circ$

$\angle UTP = 60^\circ/2$

$= 30^\circ$

$\angle UTP = \angle TPU = 30^\circ$  similarly  $\angle RTS = 30^\circ$

$\therefore \angle PTR = \angle UTS - \angle UTP - \angle RTS$

$= 120^\circ - 30^\circ - 30^\circ$

$= 60^\circ$

$\angle TPQ = \angle UPQ - \angle UPT$

$= 120^\circ - 30^\circ$

$= 90^\circ$

$\angle TQP = 180^\circ - 150^\circ$

$= 30^\circ$  (by using angle sum property of triangle in  $\Delta PQT$ )

$\therefore \angle P = 90^\circ, \angle Q = 60^\circ, \angle T = 30^\circ$



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