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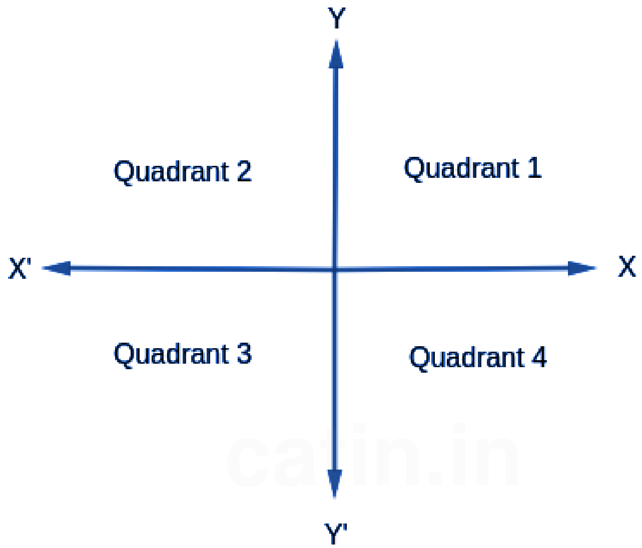
CAT Geometry Formulas

- Geometry is one of the hardest sections to crack without preparation and one of the easiest with preparation.
- With so many formulas to learn and remember, this section is going to take a lot of time to master.
- Remember, read a formula, try to visualize the formula and solve as many questions related to the formula as you can.
- Knowing a formula and knowing when to apply it are two different abilities.
- The first will come through reading the formulae list and theory but the latter can come only through solving many different problems.
- So in this document we are going to provide an exhaustive list of formulas and tips for making the geometry section a lot easier.
- Try to remember all of them and don't forget to share.

Quadrants

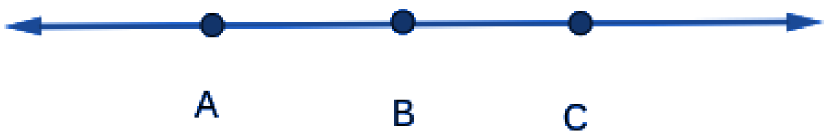


Quadrant I	X is Positive	Y is Positive
Quadrant II	X is Negative	Y is Positive
Quadrant III	X is Negative	Y is Negative
Quadrant IV	X is Positive	Y is Negative

Lines and Angles

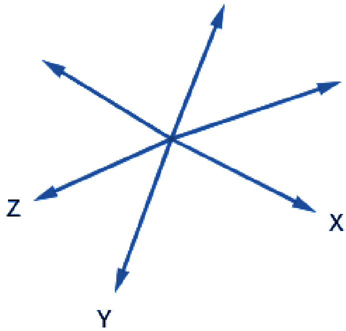
Collinear points:

Three or more points lying on the single straight line.
In this diagram the three points A,B and C are collinear



Concurrent lines:

If three or more lines lying in the same plane intersect at a single point then those lines are called concurrent lines.
The three lines X, Y and Z are concurrent lines here.



- The distance between two points with coordinates (X_1, Y_1), (X_2,Y_2) is given by D = $\sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2}$
- Slope, m=$\frac{y_2 - y_1}{x_2 - x_1}$(If $x_2 = x_1$ then the lines are perpendicular to each other)
- Mid point between two points A(x_1,y_1) and B (x_2, y_2) is $\left(\frac{x_1 + x_2}{2}, \frac{y_1 + y_2}{2}\right)$
- When two lines are parallel, their slopes are equal i.e. $m_1 = m_2$
- When two lines are perpendicular, product of their slopes = -1 i.e, $m_1 * m_2 = -1$

- If two intersecting lines have slopes m1 and m2 then the angle between two lines will be

  $\tan\theta = \frac{m_1 - m_2}{1 + m_1 m_2}$ (where θ is the angle between the lines)

- The length of the perpendicular from a point (X_1, Y_1) on the line AX+BY+C = 0 is

$$P = \frac{AX_1 + BY_1 + C}{\sqrt{A^2 + B^2}}$$

- The distance between two parallel lines $Ax + By + C_1 = 0$ and $Ax + By + C_2 = 0$ is

$$D = \left| \frac{C_1 - C_2}{\sqrt{A^2 + B^2}} \right|$$

- Coordinates of a point P that divides the line joining A (x_1, y_1) and B (x_2, y_2) internally in the ratio

$$l:m : \left(\frac{lx_2 + mx_1}{l+m}, \frac{ly_2 + my_1}{l+m}\right)$$

- Coordinates of a point P that divides the line joining A (x_1, y_1) and B (x_2, y_2) externally in the ratio

$$l:m : \left(\frac{lx_2 - mx_1}{l-m}, \frac{ly_2 - my_1}{l-m}\right)$$

- For a triangle ABC, A (x_1, y_1) and B (x_2, y_2), C (x_3, y_3):

Centroid = $\left(\frac{(x_1 + x_2 + x_3)}{3}, \frac{(y_1 + y_2 + y_3)}{3}\right)$

- Incentre = $\left(\frac{(ax_1 + bx_2 + cx_3)}{3}, \frac{(ay_1 + by_2 + cy_3)}{3}\right)$;

where a, b and c are the lengths of the BC, AC and AB respectively.

Equations of a lines

General equation of a line	$Ax + By = C$
Slope intercept form	$y = mx + c$ (c is y intercept)
Point-slope form	$y - y_1 = m(x - x_1)$
Intercept form	$\frac{x}{a} + \frac{y}{b} = 1$
Two point form	$\frac{y - y_1}{y_2 - y_1} = \frac{x - x_1}{x_2 - x_1}$

General Equation Of a Circle

The general equation of a circle is
$x^2 + y^2 + 2gx + 2fy + c = 0$

- Centre of the circle is (-g,-f)
- Radius of the circle = $\sqrt{g^2 + f^2 - c}$
- If the origin is the center of the circle then equation of the circle is $x^2 + y^2 = r^2$

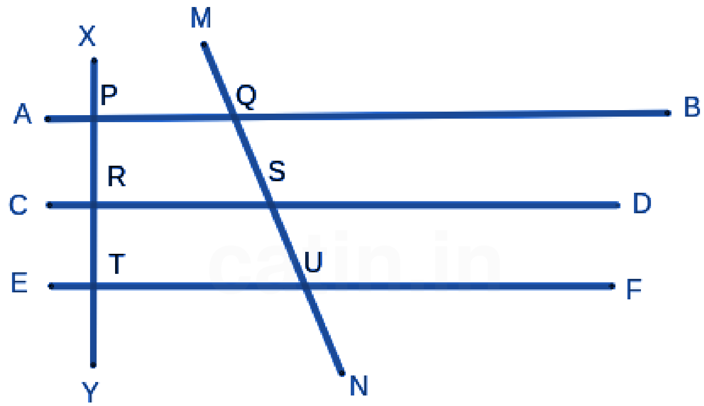
➢ When two angles A and B are complementary, sum of A and B is 90°

➢ When two angles A and B are supplementary, sum of A and B is 180°

➢ When two lines intersect, opposite angles are equal. Adjacent angles are supplementary

➢ When any number of lines intersect at a point, the sum of all the angles formed = 360°

➢ Consider parallel lines AB, CD and EF as shown in the figure.



➢ XY and MN are known as transversals

➢ ∠XPQ = ∠PRS = ∠RTU as corresponding angles are equal

➢ Interior angles on the side of the transversal are supplementary. i.e. ∠PQS + ∠QSR = 180°

➢ Exterior angles on the same side of the transversal are supplementary. i.e.

$$\angle MQB + \angle DSU = 180°$$

➢ Two transversals are cut by three parallel lines in the same ratio i.e. $\frac{PR}{RT} = \frac{QS}{SU}$

Equations of a lines

General equation of a line	$Ax + By = C$
Slope intercept form	$y = mx + c$ $(c\ is\ y\ intercept)$
Point-slope form	$y - y_1 = m(x - x_1)$
Intercept form	$\frac{x}{a} + \frac{y}{b} = 1$
Two point form	$\frac{y - y_1}{y - y} = \frac{x - x_1}{x - x}$

Triangles

⇒ Sum of all angles in a triangle is 180°

⇒An angle less than 90° is called an acute angle.

An angle greater than 90° is called an obtuse angle.

⇒ A triangle with all sides unequal is called a scalene triangle

⇒ A triangle with two sides equal is called an isosceles triangle. The two angles of an isosceles triangle that are not contained between the equal sides are equal.

⇒ A triangle with all sides equal is called an equilateral triangle. All angles of an equilateral triangle equal 60°.

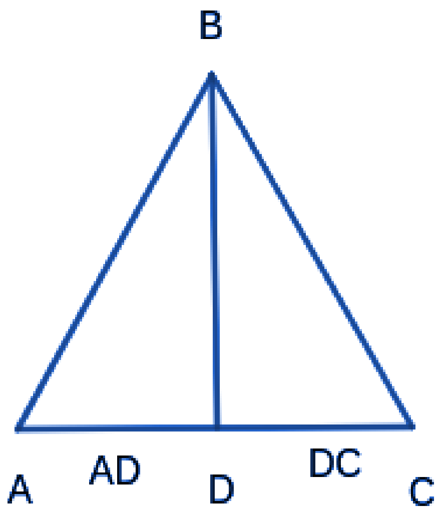
⇒ If in a triangle all of its angles are less than 90° than that triangle is called an acute angled triangle

⇒ A triangle with one of its angles equal to 90° than that triangle is called a Right angled triangle.

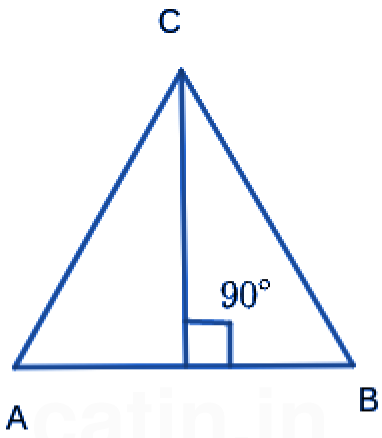
⇒ A triangle with one of its angles greater than 90° than that triangle is called an Obtuse angled triangle.

⇒ If one side of a triangle is produced then that exterior angle formed is equal to the sum of opposite remote interior angles

⇒ A line joining the mid point of a side with the opposite vertex is called a median. (Here D is the midpoint of the AC side or AD = DC). BD is the median of this triangle ABC.



⇒ A perpendicular drawn from a vertex to the opposite side is called the altitude



⇒ A line that bisects and also makes right angle with the same side of the triangle is called perpendicular bisector

⇒ A line that divides the angle at one of the vertices into two parts is called angular bisector

⇒ All points on an angular bisector are equidistant from both arms of the angle.

⇒ All points on a perpendicular bisector of a line are equidistant from both ends of the line.

⇒ In an equilateral triangle, the perpendicular bisector, median, angle bisector and altitude (drawn from a vertex to a side) coincide.

⇒ The point of intersection of the three altitudes is the Orthocentre.

⇒ The point of intersection of the three medians is the centroid.

⇒ The three perpendicular bisectors of a triangle meet at a point called the Circumcentre. A circle drawn from this point with the circumradius would pass through all the vertices of the triangle.

⇒ The three angle bisectors of a triangle meet at a point called the incentre of a triangle. The incentre is equidistant from the three sides and a circle drawn from this point with the inradius would touch all the sides of the triangle.

⇒ Sum of any two sides of a triangle is always greater than its third side.

⇒ Difference of any two sides of a triangle is always lesser than it’s third side

Pythagoras theorem:

In a right angled triangle ABC

where $\angle B = 90°$, $AC^2 = AB^2 + BC^2$

Apollonius theorem:

In a triangle ABC, if AD is the median to side BC then by Apollonius theorem,

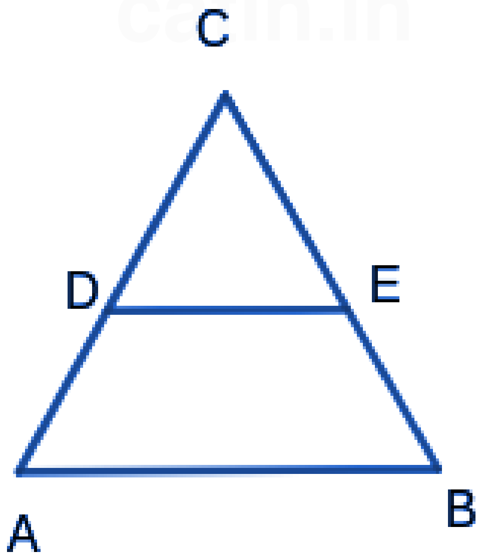
$$2(AD^2 + BD^2) = AC^2 + AB^2$$

Mid Point Theorem :

The line joining the midpoint of any two sides in a triangle is parallel to the third side and is half the length of the third side. If X is the midpoint of CA and Y is the midpoint of CB. Then XY will be parallel to AB and XY = $\frac{1}{2}$* AB

Basic proportionality theorem :

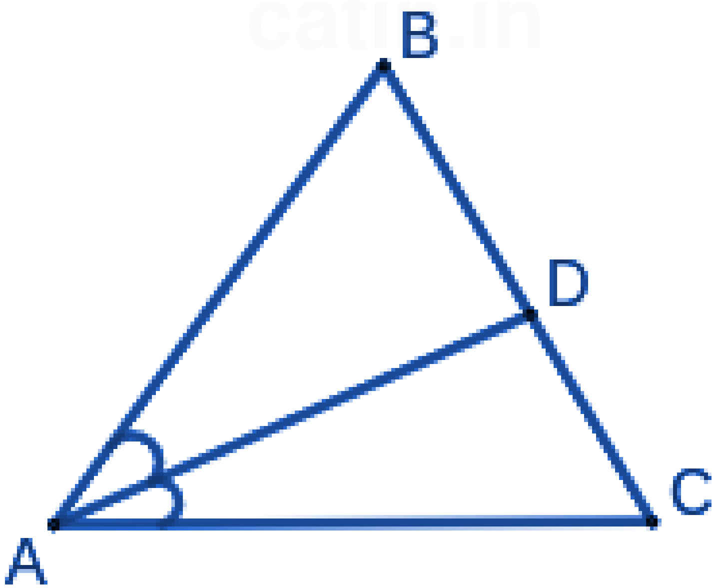
If a line is drawn parallel to one side of a triangle and it intersects the other two sides at two distinct points then it divides the two sides in the ratio of respective sides. If in a triangle ABC, D and E are the points lying on AC and BC respectively and DE is parallel to AB then AD/DC = BE/EC



Interior Angular Bisector theorem :

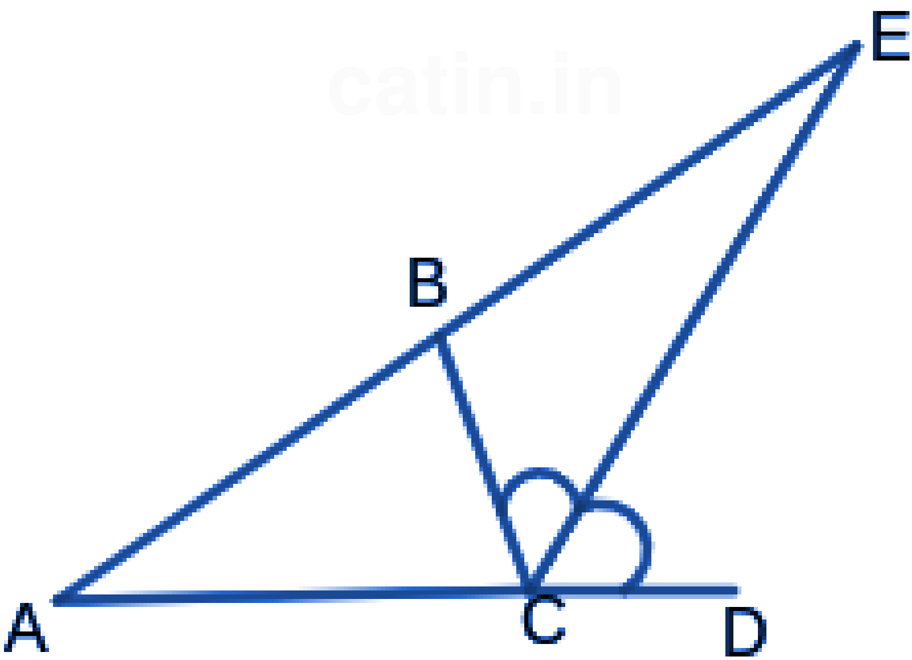
In a triangle the angular bisector of an angle divides the side opposite to the angle, in the ratio of the remaining two sides. In a triangle ABC if AD is the angle bisector of angle A then AD divides the side BC in the same ratio as the other two sides of the triangle.

i.e. BD/ CD= AB/AC.



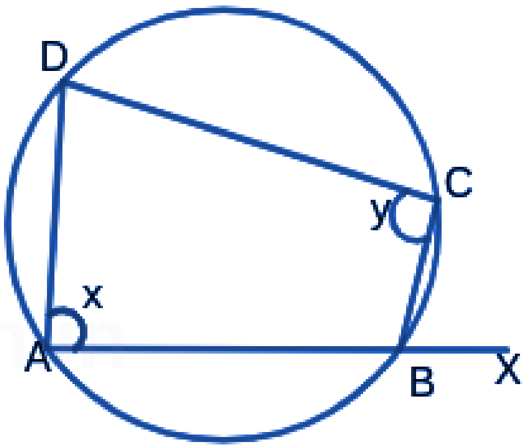
Exterior Angular Bisector theorem :

The angular bisector of the exterior angle of a triangle divides the opposite side externally in the ratio of the sides containing the angle. In a triangle ABC, if CE is the angular bisector of exterior angle BCD of a triangle, then AE/BE = AC/BC



Cyclic Quadrilateral :

If a quadrilateral has all its vertices on the circle and its opposite angles are supplementary (here $x+y = 180^0$) then that quadrilateral is called cyclic quadrilateral.



- In a cyclic quadrilateral the opposite angles are supplementary
- **Area of a cyclic quadrilateral is**

  A = $\sqrt{(s-a)(s-b)(s-c)(s-d)}$

  where s = $\frac{(a+b+c+d)}{2}$
- Exterior angle is equal to its remote interior opposite angle. (here ∠CBX = ∠ADC)

- **If x is the side of an equilateral triangle then the**

  Altitude (h) = $\frac{\sqrt{3}}{2}x$

  Area = $\frac{\sqrt{3}}{4}x^2$

  Inradius = $\frac{1}{3}$ *** h**

  Circumradius = $\frac{2}{3}$*** h**

- **Area of an Isosceles triangle =** $\frac{a}{4}\sqrt{4c^2 - a^2}$

(where a, b and c are the length of the sides of BC, AC and AB respectively and b = c)

Similar triangles :

If two triangles are similar then their corresponding angles are equal and the corresponding sides will be in proportion.

For any two similar triangles :

- Ratio of sides = Ratio of medians = Ratio of heights = Ratio of circumradii = Ratio of Angular bisectors
- Ratio of areas = Ratio of the square of the sides.

Tests of similarity : (AA / SSS / SAS)

Congruent triangles:

If two triangles are congruent then their corresponding angles and their corresponding sides are equal.

Tests of congruence : (SSS / SAS / AAS / ASA)

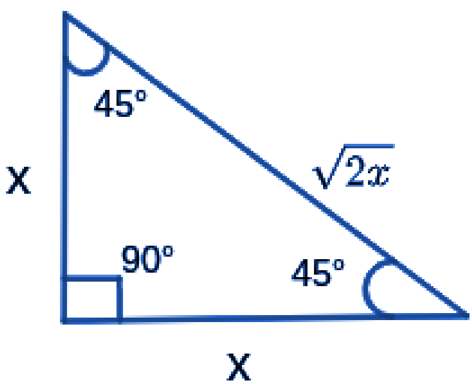
Area of a triangle:

- A = $\sqrt{s(s-a)(s-b)(s-c)}$ where s = $\frac{(a+b+c)}{2}$
- A = $\frac{1}{2} * base * altitude$
- A = $\frac{1}{2} * ab * sinC$
  (C is the angle formed between sides a and b)
- A = $\frac{abc}{4R}$ where R is the circumradius
- A = r * s where r is the inradius and s is the semi perimeter. (where a, b and c are the lengths of the sides BC, AC and AB)

Special triangles :

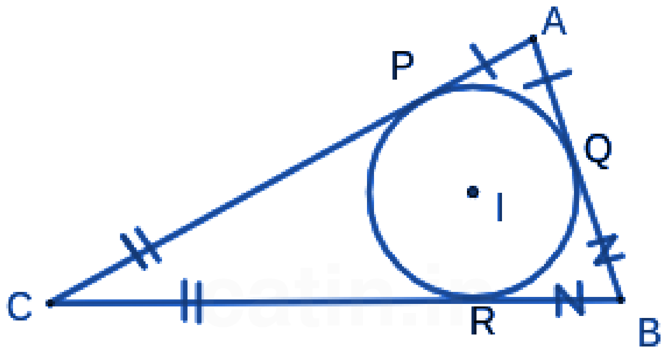
$30^0, \ 60^0, 90^0$

$45^0, \ 45^0, 90^0$



$$\text{Area} = \frac{x^2}{2}$$

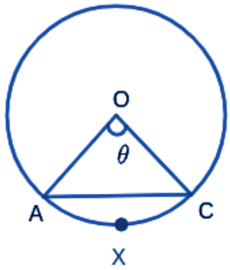
- Consider the triangle ABC with incentre I, and the incircle touching the triangle at P, Q, R as shown in the diagram. As tangents drawn from a point are equal, AP=AQ, CP=CR and BQ=BR.



- In an equilateral triangle, the centroid divides the median in the ratio 2:1. As the median is also the perpendicular bisector, angle bisector, G is also the circumcentre and incentre.
- If a is the side of an equilateral triangle, circumradius $=a/\sqrt{3}$ and inradius $= a/(2\sqrt{3})$

Circles

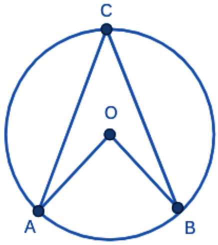
- The angle subtended by a diameter of circle on the circle $= 90^0$
- Angles subtended by an equal chord are equal. Also, angles subtended in the major segment are half the angle formed by the chord at the center
- Equal chords of a circle are equidistant from the center
- The radius from the center to the point where a tangent touches a circle is perpendicular to the tangent
- Tangents drawn from the same point to a circle are equal in length
- A perpendicular drawn from the center to any chord, bisects the chord



Area of sector OAXC = $\frac{\theta}{360} * \pi r^2$

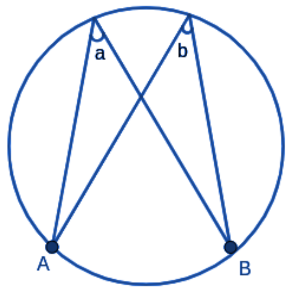
Area of minor segment AXC = $\frac{\theta}{360}\pi r^2 - \frac{1}{2}r^2 Sin\theta$

Inscribed angle Theorem :



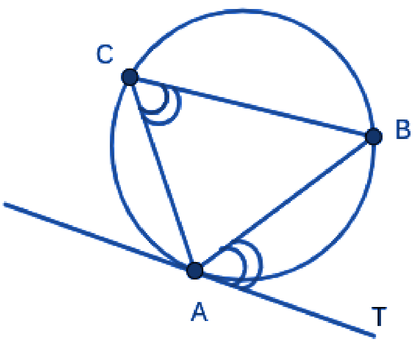
2∠ACB = ∠AOB

The angle inscribed by the two points lying on the circle, at the center of the circle, is twice the angle inscribed at any point on the circle by the same points.



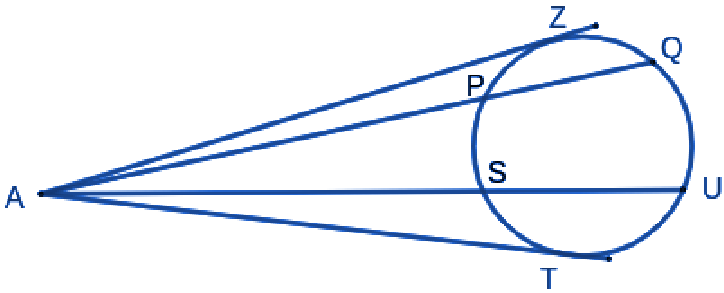
Angles subtended by the same segment on the circle will be equal. So, here angles a and b will be equal.

- The angle made by a chord with a tangent to one of the ends of the chord is equal to the angle subtended by the chord in the other segment. As shown in the figure, ∠ACB = ∠BAT.



Consider a circle as shown in the image. Here,

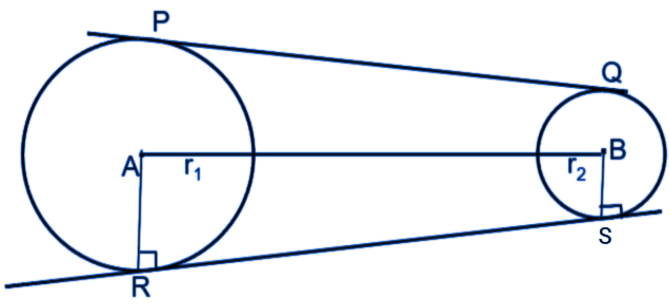
$$AP * AQ = AS * AU = AT^2$$



Two tangents drawn to a circle from an external common point will be equal in length. So here AZ = AT

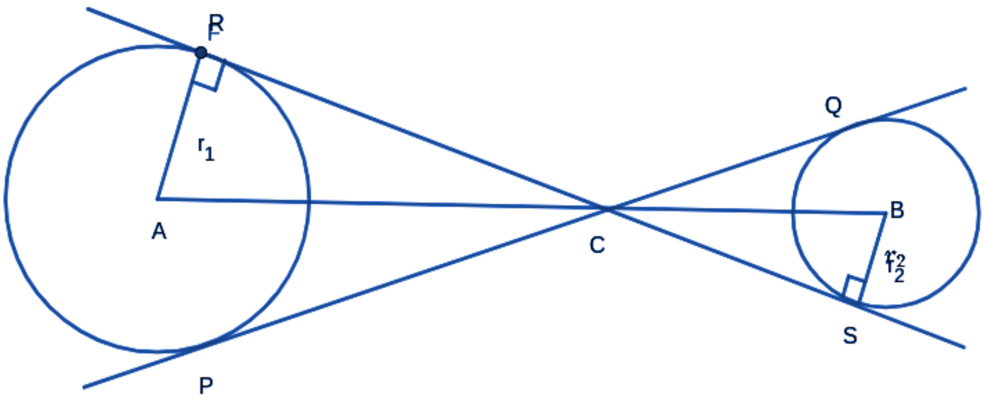
Direct common tangent :

In this figure PQ and RS are the direct common tangents and let AB (Distance between the two centers) = D



2 2 2 2

Transverse common tangent :



In this figure PQ and RS are the transverse common tangents and let AB (Distance between the two centers) = D

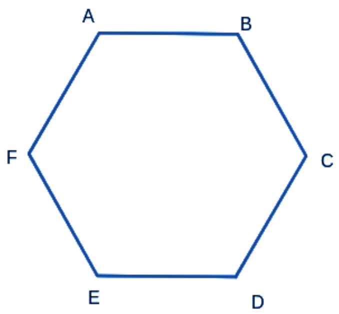
$$PQ^2 = RS^2 = D^2 - (r_1 + r_2)^2$$

Polygons and Quadrilaterals:

- If all sides and all angles are equal, then the polygon is

- A regular polygon of n sides has $\frac{n(n-3)}{2}$ diagonals
- In a regular polygon of n sides, each exterior angle is $\frac{360}{n}$ degrees.
- Sum of measure of all the interior angles of a regular polygon is 180 (n-2) degrees (where n is the number of sides of the polygon)
- Sum of measure of all the exterior angles of regular polygon is 360 degrees

⇒ ABCDEF is a regular hexagon with each side equal to ‘x’ then



- Each interior angle = 120^0
- Each exterior angle = 60^0
- Sum of all the exterior angles = 360^0
- Sum of all the interior angles = 720^0
- Area = $\frac{3\sqrt{3}}{2}a^2$

Areas of different Geometrical Figures:

Triangles	$\frac{1}{2} \times base \times height$
Rectangle	$length \times width$
Trapezoid	$\frac{1}{2} \times sum\ of\ bases \times height$
Parallelogram	$base \times height$
Circle	$\pi \times radius^2$
Rhombus	$\frac{1}{2} \times product\ of\ diagonals$
Square	$side^2\ or\ \frac{1}{2}diagonal^2$
Kite	$\frac{1}{2} \times product\ of\ the\ diagonals$

Solids: Volume of different solids

Cube	$Side^3$
Cuboid	$length \times base \times height$
Prism	$Area\ of\ base \times height$
Cylinder	$\pi r^2 h;$ *where r is the base radius*
Pyramid	$\frac{1}{3} \times Area\ of\ base \times height$
Cone	$\frac{1}{3} \times \pi r^2 \times h$
Cone Frustum	$\frac{1}{3} \times \pi h(R^2 + Rr + r^2)$ (If R is the base radius, r is the upper surface radius and h is the height of the frustum)
Sphere	$\frac{4}{3}\pi r^3$
Hemi-sphere	$\frac{2}{3}\pi r^3$

Solids: Total Surface area of different solids:

Prism	$(2 \times base\ area) + (base\ perimeter \times height)$
Cube	$6 \times side^2$
Cuboid	$2(lh + bh + lb)$
Cylinder	$2\pi rh + 2\pi r^2$
Pyramid	$\frac{1}{2} \times Perimeter\ of\ base \times slant\ height + Area\ of\ base$
Cone	$\pi r (l + r)$ (l is the slant height)
Cone Frustum	$\pi(R^2 + r^2 + Rl + rl)$ (R & r are the radii of the base faces and l is the slant height)
Sphere	$4\pi r^2$
Hemi-sphere	2

Lateral/Curved surface area:

Prism	$base\ perimeter \times height$
Cube	$4 \times length^2$
Cuboid	$2\ (length \times breadth) \times height$
Cylinder	$2\pi rh$
Pyramid	$\frac{1}{2} \times Perimeter\ of\ base \times slant\ height$
Cone	πrl (l is the slant height)
Cone Frustum	$\pi(R + r)L$ (R and r are the radii of the base faces, l is the slant height)

- The angle subtended by a diameter of circle on the circle = 90 degrees
- Angles subtended by equal chords are equal. Also, angles subtended in the major segment are half the angle formed by the chord at the center
- The radius from the center to the point where a tangent touches a circle is perpendicular to the tangent.
- Tangents drawn from the same point to a circle are equal in length.
