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CAT QUANT Formulas

Maruti Konduri
5 Time CAT 100%iler

Sayali Kale
2 Time CAT 99.97%iler

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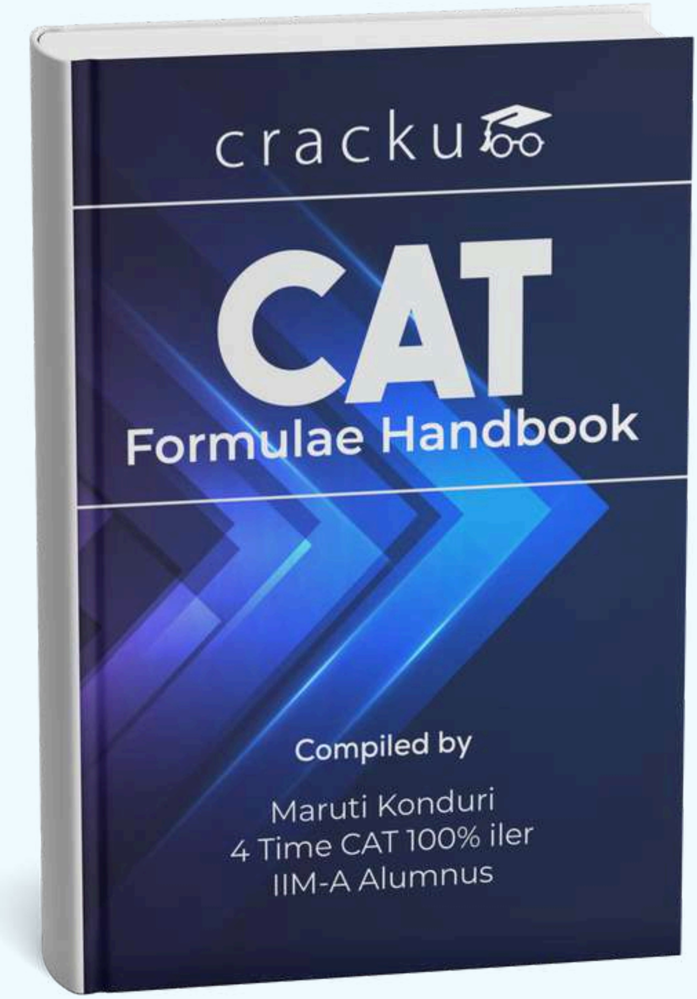

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Our Results

45 Students scored 99.9+ Percentile in CAT 2024

270 Students scored 99.50+ Percentile in CAT 2024

540 Students scored 99+ Percentile in CAT 2024

Our Faculty

Maruti Konduri

5 Time CAT 100%iler

IIM Ahmedabad Alumnus

Sayali Kale

CAT 99.97 %iler

IIM Ahmedabad Alumna

CAT Ratio & Proportion Formulas

- Ratio and Proportions is one of the easiest concepts in CAT. Questions from this concept are mostly asked in conjunction with other concepts like similar triangles, mixtures and alligations.
- Hence fundamentals of this concept are important not just from a stand-alone perspective, but also to answer questions from other concepts
- A ratio can be represented as fraction a/b or using the notation a:b. In each of these representations 'a' is called the antecedent and 'b' is called the consequent.
- For a ratio to be defined, the quantities of the items should be of the same nature. We can not compare the length of the rod to the area of a square.

- However if these quantities are represented in numbers, i.e., length of a rod is ‘a’ cm and area of a square is ‘b’ sq.km, we can still define the ratio of these numbers as a:b
- The Ratio of the number a to the number b ($b \neq 0$) is also expressed as $\frac{a}{b}$
- Example: As mentioned, a Ratio can be expressed or represented in a variety of ways. For instance, the ratio of 2 to 3 can be expressed as 2:3 or $\frac{2}{3}$
- The order in which the terms of a ratio are written is important. For example, The ratio of the number of months having precisely 30 days to the number of months with exactly 31 days, is $\frac{4}{7}$, not $\frac{7}{4}$

Properties of Ratios:

- It is not necessary for a ratio to be positive. When dealing with quantities of objects, however, the ratios will be positive. Only positive ratios will be considered in this notion.

- A ratio remains the same if both antecedent and consequent are multiplied or divided by the same non-zero number, i.e.,

$$\frac{a}{b}=\frac{pa}{pb}=\frac{qa}{qb}, \text{ p,q} \neq 0$$

$$\frac{a}{b}=\frac{a/p}{b/p}=\frac{a/q}{b/q}, \text{ p,q} \neq 0$$

- Two ratios in fraction notation can be compared in the same way that actual numbers can.

$$\frac{a}{b}=\frac{p}{q} \Leftrightarrow aq = bp$$

$$\frac{a}{b} > \frac{p}{q} \Leftrightarrow aq > bp$$

$$\frac{a}{b} < \frac{p}{q} \Leftrightarrow aq < bp$$

  - If antecedent > consequent, the ratio is said to be the ratio of greater inequality.

- If antecedent < consequent, the ratio is said to be the ratio of lesser inequality.
- If the antecedent = consequent, the ratio is said to be the ratio of equality.

If a, b, x are positive, then

If a > b, then $\frac{a+x}{b+x} < \frac{a}{b}$

If a < b, then $\frac{a+x}{b+x} > \frac{a}{b}$

If a > b, then $\frac{a-x}{b-x} > \frac{a}{b}$

If a < b, then $\frac{a-x}{b-x} < \frac{a}{b}$

If $\frac{a}{p} = \frac{b}{q} = \frac{c}{r} = \frac{d}{s} = \ldots$,

then a:b:c:d:... = p:q:r:s:...

If two ratios $\frac{a}{b}$ and $\frac{c}{d}$ are equal

1. **Invertendo:** $\frac{a}{b} = \frac{c}{d} \Longrightarrow \frac{b}{a} = \frac{d}{c}$

2. **Alternendo:** $\frac{a}{b} = \frac{c}{d} \Longrightarrow \frac{a}{c} = \frac{b}{d}$

3. **Componendo:** $\frac{a}{b} = \frac{c}{d} \Longrightarrow \frac{a+b}{b} = \frac{c+d}{d}$

4. **Dividendo:** $\frac{a}{b} = \frac{c}{d} \Longrightarrow \frac{a-b}{b} = \frac{c-d}{d}$

5. **Componendo-Dividendo:** $\frac{a}{b} = \frac{c}{d} \Longrightarrow \frac{a+b}{a-b} = \frac{c+d}{c-d}$

6. $\frac{a}{b} = \frac{c}{d} \Longrightarrow \frac{pa+qb}{ra+sb} = \frac{pc+qd}{rc+sd}$,

   for all real p, q, r, s such that $pa+qb \neq 0$ and $rc+sd \neq 0$

Other Properties:

- If a, b, c, d, e, f, p, q, r are constants and are not equal to zero and $\frac{a}{b} = \frac{c}{d} = \frac{e}{f} = \ldots$ then each of these ratios is equal to $\frac{a+c+e\ldots}{b+d+f\ldots}$
- If a, b, c, d, e, f, p, q, r are constants and are not equal to zero and $\frac{a}{b} = \frac{c}{d} = \frac{e}{f} = \ldots$ then each of these ratios is equal to $\frac{pa+qc+re\ldots}{pb+qd+rf\ldots}$
- If a, b, c, d, e, f, p, q, r are constants and are not equal to zero and $\frac{a}{b} = \frac{c}{d} = \frac{e}{f} = \ldots$ then each of these ratios is equal to $\left(\frac{pa^n+qc^n+re^n+\ldots}{pb^n+qd^n+rf^n+\ldots}\right)^{1/n}$

➔ Duplicate Ratio of a : b is $a^2 : b^2$

➔ Sub-duplicate ratio of a : b is $\sqrt{a} : \sqrt{b}$

➔ Triplicate Ratio of a : b is $a^3 : b^3$

➔ Sub-triplicate ratio of a : b is $\sqrt[3]{a} : \sqrt[3]{b}$

Proportions :

- A proportion is defined as an equalisation of ratios.
- As a result, if a:b = c:d is a ratio, the first and last terms are referred to as extremes, whereas the middle two phrases are referred to as means.
- When four terms a, b, c, and d are considered to be proportionate, a:b = c:d is the result. When three terms a, b, and c are considered to be proportionate, a:b = b:c is the result.
- A proportion is a statement that two ratios are equal; for example $\frac{2}{3} = \frac{8}{12}$ is a proportion.

- One way to solve a proportion involving an unknown is to cross multiply, obtaining a new equality.
- For example, to solve for n in the proportion $\frac{2}{3}=\frac{n}{12}$, cross multiply, obtaining 24=3n, then divide both sides by 3, to get n=8

Properties of proportions :

- If a:b = c:d is a proportion, then Product of extremes = product of means i.e., ad = bc
- Denominator addition/subtraction: a:a+b = c:c+d and a:a-b = c:c-d
- a, b, c, d,.... are in continued proportion means, a:b = b:c = c:d = ...
- a:b = b:c then b is called mean proportional and b^2= ac

- The third proportional of two numbers, a and b, is c, such that, a:b = b:c.
- ‘d’ is fourth proportional to numbers a, b, c if a:b = c:d

Variations :

- If x varies directly to y, then x is said to be in directly proportional with y and is written as $x \propto y$

➔ x = ky (where k is direct proportionality constant)

➔ x = ky + C (If x depends upon some other fixed constant C)

- If x varies inversely to y, then x is said to be in inversely proportional with y and is written as

$$x \propto \frac{1}{y}$$

➔ $x = k\frac{1}{y}$

(where k is indirect proportionality constant)

➔ $x = k\frac{1}{y} + C$

(If x depends upon some other fixed constant C)

- If $x \propto y$ and $y \propto z$ then $x \propto z$
- If $x \propto y$ and $x \propto z$ then $x \propto (y \pm z)$
- If $a \propto b$ and $x \propto y$ then $ax \propto by$

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CAT Mixtures And Alligations Formulas

- Mixtures and alligations are a common type of quantitative problem that may appear on the CAT.
- These problems involve mixing two or more substances to form a new mixture, and then finding the ratio or quantity of each substance in the mixture.
- Alligation is a specific method for solving mixture problems that involves representing the ingredients and the mixture as points on a line, and using the distance between these points to find the ratio of the ingredients in the mixture.
- There are many variations of mixture and alligation problems that may appear on the CAT, but they all involve some variation of this basic concept.

- To prepare for these types of problems, it is important to practise solving a variety of mixture and alligation problems, and to become familiar with the basic formulas and methods for solving them.

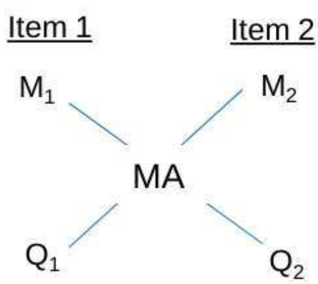
Types of mixtures:

- **Simple mixture:** A simple mixture is formed by the mixture of two or more different substances.

Example: Water and Wine mixture.

- **Compound mixture:** A Compound mixture is formed by the mixture of two or more simple mixtures.

Example: one part of 'water and wine' mixture mixed with two parts of 'water and milk' mixture.



- If M_1 and M_2 are the values and Q_1 and Q_2 are the quantities of item 1 and item 2 respectively, and M_A is the weighted average of the two items, then

$$\frac{Q_1}{Q_2} = \frac{M_2 - M_A}{M_A - M_1}$$

- Weighted average M_A can be calculated by

$$M_A = \frac{Q_1 M_1 + Q_2 M_A}{Q_1 + Q_2}$$

- The alligation rule can also be applied when cheaper substance is mixed with expensive substance

$$\frac{Quantity\ of\ cheaper}{Quantity\ of\ dearer} = \frac{Price\ of\ cheaper - Mean\ price}{Mean\ Price - Price\ of\ cheaper}$$

- If two mixtures M_1 and M_2, having substances S_1 and S_2 in the ratio a:b and p:q respectively are mixed, then in the final mixture,

$$\frac{Quantity\ of\ S_1}{Quantity\ of\ S_2} = \frac{M_1\left[\frac{a}{a+b}\right] + M_2\left[\frac{p}{p+q}\right]}{M_1\left[\frac{b}{a+b}\right] + M_2\left[\frac{q}{p+q}\right]}$$

- If there is a container with ‘a’ litres of liquid A and if ‘b’ litres are withdrawn and an equal amount of the mixture is replaced with another liquid B and if this operation is repeated ‘n’ times, then
After the *nth* operation,
- Liquid A in the container

$$= \left[\frac{a-b}{a}\right]^n \times Initial\ quantity\ of\ A\ in\ the\ container$$

- $$\frac{Liquid\ A\ after\ nth\ operation}{Liquid\ B\ after\ nth\ operation} = \frac{\left[\frac{a-b}{a}\right]^n}{1-\left[\frac{a-b}{a}\right]^n}$$

CAT Profit And Loss, Discount Formulas

- Profit, Loss and Discount is a very important topic for CAT and a significant number of questions are asked from this topic every year.
- The number of concepts in these topics is limited and most of the problems can be solved by applying the formulae directly.
- This document covers various formulas, tips and shortcuts of Profit, Loss and Discount topics.

Profit and Loss

Cost Price: The amount paid to purchase an article or the cost of manufacturing an article is called Cost Price (C.P)

Selling Price: The price at which a product is sold is called Selling price (S.P)

Marked Price:

➔ The price at which an article is marked is called Marked price (M.P)

➔ If S.P>C.P, then Profit or Gain, P = S.P – S.P

➔ If C.P>S.P, then Loss, L = C.P – S.P

➔ % Profit or Gain percentage or Profit

$$\text{Percentage} = \frac{Profit}{C.P} \times 100$$

$$\%\text{Loss} = \frac{Loss}{C.P} \times 100$$

➔ Discount = M.P – S.P (If no discount is given, then M.P = S.P)

➔ $\%\text{Discount} = \frac{Discount}{M.P} \times 100$

➔ Total increase in price due to two subsequent increases of X% and Y% is $\left(X + Y + \frac{XY}{100}\right)\%$

➔ If two items are sold at same price, each at Rs. x, one at a profit of P% and other at a loss of P% then there will be overall loss of $\frac{P^2}{100}$ %

➔ The absolute value of loss = $\frac{2P^2x}{100^2 - P^2}$

➔ If C.P of two items is the same, and by selling each item he earned p% profit on one article and p% loss on another, then there will be no loss or gain.

➔ If a trader professes to sell at C.P but uses false weight, then Gain% = $\frac{Difference}{True\ Weight} \times 100\%$

Difference represents the difference in claimed weight and true weight ; claimed weight > true weight

➔ S.P = $\left(\frac{100 + Profit\%}{100}\right)$C.P (if S.P > C.P)

➔ S.P = $\left(\frac{100 + Loss\%}{100}\right)$C.P (if S.P < C.P)

- ➔ C.P = $\left(\frac{100 \times S.P}{100 + Profit\%}\right)$C.P (if S.P > C.P)
- ➔ C.P = $\left(\frac{100 \times S.P}{100 + Profit\%}\right)$C.P (if S.P > C.P)
- ➔ Buy x get y free, then the %discount = $\frac{y}{x+y} \times 100$

  (here x+y articles are sold at C.P of x articles.)
- ➔ When there are two successive discounts of a% and b% are given then the,

  Resultant discount = $\left(a + b - \frac{a \times b}{100}\right)$
- ➔ If C.P of x article is equal to the selling price of y articles then the,

  Resultant profit % or loss % = $\frac{y-x}{y} \times 100$

CAT Simple Interest & Compound Interest Formulas

- Simple Interest (S.I) and Compound Interest (C.I) is one of the easiest topics in the CAT quant section.
- Every year, a significant number of questions appear from each of these sections and students should aim to get most questions right from these topics.
- The number of concepts that are tested from these topics is limited and most of the problems can be solved by applying the formulae directly.
- Many students commit silly mistakes in this topic due to complacency, which should be avoided.
- In Simple Interest, the principal and the interest calculated for a specific year or time interval remains constant.

- In Compound Interest, the interest earned over the period is added over to the existing principal after every compounding period and thus, the principal and the interest change after every compounding period.
- For the same principal, positive rate of interest and time period (>1 year), the compound interest on the loan is always greater than the simple interest.

Simple Interest

- The sum of principal and the interest is called Amount.

  Amount (A) = Principal (P) + Interest (I)
- The Simple Interest (I) occurred over a time period (T) for R% (rate of interest per annum),

$$I = \frac{PTR}{100}$$

Compound Interest:

- The amount to be paid, if money is borrowed at Compound Interest for N number of years,

$$A = P\left(1 + \frac{R}{100}\right)^{N}$$

- The Interest occurred, I = A – P

$$I = P\left(1 + \frac{R}{100}\right)^{N} - P$$

If R is rate of interest per year, N is number of years,

P is the principal

- If the interest is compounded half yearly, then

  Amount, $A = P\left(1 + \frac{R/2}{100}\right)^{2N}$

- If the interest is compounded quarterly, then

  Amount, $A = P\left(1 + \frac{R/4}{100}\right)^{4N}$

- If interest Rate is R_1% for first year, R_2% for second year and R_3% for 3^{rd} year, then the Amount,

$$A = P\left(1 + \frac{R_1}{100}\right)\left(1 + \frac{R_2}{100}\right)\left(1 + \frac{R_3}{100}\right)$$

- If a difference between C.I and S.I for certain sum at same rate of interest is given, the

$Principal\ (P) = (difference\ between\ CI\ and\ SI) * (100/R)^2$

- When interest is compounded annually but time is in fraction, let $a\frac{b}{c}$ then the Amount,

$$A = P\left(1 + \frac{R}{100}\right)^a\left(1 + \frac{R^{\frac{b}{c}}}{100}\right)$$

Installments and Present Worth:

- If R is the rate of interest per annum, then the present worth of Rs. 'K' due N years hence is represented as Present worth $= \frac{K}{\left(1+\frac{R}{100}\right)^N}$

- If an amount of ‘P’ is borrowed for ‘n’ years at ‘r’% per annum, and ‘x’ is the installment that is paid at the end of each year starting from the first year, the

$$x = \frac{P\left(\frac{r}{100}\right)\left(1+\frac{r}{100}\right)^{n}}{\left(1+\frac{r}{100}\right)^{n}-1}$$

CAT Time, Speed, Distance & Work Formulas

- Time, Distance and Work is the most important topic for CAT Quant Section & all competitive exams.
- The questions from this topic vary from easy to difficult.
- This formula sheet covers the most importance tips that helps you to answer the questions in a easy, fast and accurate way

$$Distance = Speed \times Time$$

$$Speed = \frac{Distance}{Time} \quad \Big| \quad Time = \frac{Distance}{Speed}$$

- While converting the speed in m/s to km/hr, multiply it by $\left(\frac{18}{5}\right) \Rightarrow$ 1 m/s = 3.6 km/h

- While converting km/hr into m/sec, we multiply by $\left(\frac{5}{18}\right)$
- If the ratio of the speeds of A and B is a : b, then

➔ The ratio of the times taken to cover the same distance is 1/a : 1/b or b : a.

➔ The ratio of distance travelled in equal time intervals is a : b ,

Average Speed = $\frac{Total\ Distance\ Travelled}{Total\ Time\ Taken}$

➔ If a part of a journey is travelled at speed $S_1\ km/hr$ in T_1 hours and remaining part at speed $S_2\ km/hr$ in T_2 hours then,

Total distance travelled = $S_1T_1 + S_2T_2\ km$

Average Speed $= \frac{S_1T_1+S_2T_2}{T_1+T_2}$**km/hr**

- If $D_1\ km$ is travelled at speed $S_1\ km/hr$, and $D_2\ km$ is travelled at speed $S_2\ km/hr$ then,

  Average Speed = $\frac{D_1+D_2}{\frac{D_1}{S_1}+\frac{D_2}{S_2}}km/hr$

- In a journey travelled with different speeds, if the distance covered in each stage is constant, the average speed is the harmonic mean of the different speeds.
- Suppose a man covers a certain distance at x km/hr and an equal distance at y km/hr. Then the average speed during the whole journey is $\frac{2xy}{x+y}km/hr$
- In a journey travelled with different speeds, if the time travelled in each stage is constant, the average speed is the arithmetic mean of the different speeds.
- If a man travelled for a certain distance at x km/hr and for equal amount of time at the speed of y km/hr

then the average speed during the whole journey is $\frac{x+y}{2}$**km/hr**

Constant Distance

Let the distance travelled in each part of the journey be d_1, d_2 & d_3 and so on till d_n and the speeds in each part be s_1, s_2, s_3 and so on till s_n

If $d_1 = d_2 = d_3 =$......... $= d_n = d$, then the average speed is the harmonic mean of the speeds s_1, s_2, s_3 and so on till s_n.

Constant Time

Let the distance travelled in each part of the journey be d_1, d_2 *and* d_3 and so on till d_n and the time taken for each part be t_1, t_2, t_3 and so on till t_n.

If $t_1 = t_2 = t_3 =\dots\dots\dots = t_n = t$, then the average speed is the arithmetic mean of the speeds s_1, s_2, s_3 and so on till s_n.

Clocks

➔ Calculating the angle/position of the hands

- Speed of hour hand = 0.5^0 per minute
- Speed of minute hand = 6^0 per minute
- Relative speed of two hands = 5.5^0 per minute
- The angle (in degrees) between hour hand and minute hand at time H: M can be represented as: $\theta = \left|\frac{11}{2}M - 30H\right|^0$

→ In a 12-hour period:

- The hour hand and the minute hand meet 11 times
- A 180^0 angle is formed between the two hands 11 times
- A 90^0 angle is formed between the two hands 22 times

→ In a well-functioning clock, both hands meet after every $\frac{720}{11}$ Mins.

→ It is because the relative speed of the minute hand with respect to the hour hand $= \frac{11}{2}$ degrees per minute.

Erroneous Clocks

➔ An erroneous clock is a clock which loses or gains time at a constant rate.

➔ In case of an erroneous clock losing/gaining 'x' sec per minute,

- It will lose/gain 'x' minutes per hour.
- It will show the correct time after every '720/x' hours.
- The clock will show the same time again after 'y' hours where:

  y = $\frac{720}{60+x}$ if the clock gains time.

  y = $\frac{720}{60-x}$ if the clock loses time.

- If the clock is set right at 'Q' AM/PM. Then the time 'T' shown by the clock after 'h' hours pass on a correct clock would be:

T = $Q + (h \times x)$ if the clock gains time.

T = $Q - (h \times x)$ if the clock loses time.'

- If the clock is set right at 'Q' AM/PM. If 'h' hours pass on the erroneous clock, then the actual time 'T' shown by a correct clock would be:

T=Q+y ; y(in hours)

$= \frac{60h}{60+x}$ if the clock gains time

$= \frac{60h}{60-x}$ if the clock loses time.

Circular Tracks

If two people are running on a circular track with speeds in ratio a:b where a and b are co-prime, then

➔ They will meet at $a + b$ distinct points if they are running in opposite directions.

➔ They will meet at $|a - b|$ distinct points if they are running in same direction

- If two people are running on a circular track having perimeter ‘l’, with speeds ‘m’ and ‘n’,

The time for their first meeting = $\frac{I}{(m+n)}$

(when they are running in opposite directions)

The time for their first meeting = $\frac{I}{|(m-n)|}$

(when they are running in the same direction)

- If a person P starts from A and heads towards B and another person Q starts from B and heads towards A and they meet after a time 't' then,

$$t = \sqrt{(x \times y)}$$

where x = time taken (after meeting) by P to reach B and y = time taken (after meeting) by Q to reach A.

- A and B started at a time towards each other. After crossing each other, they took $T_1 hrs,\ T_2 hrs$ respectively to reach their destinations. If they travel at constant speed S_1 and S_2 respectively all over the journey, then $\frac{S_1}{S_2} = \sqrt{\frac{T_2}{T_1}}$

Trains

Two trains of length L_1 and L_2 travelling at speeds S_1 and S_2 cross each other in a time

$=\frac{L_1 + L_2}{S_1 + S_2}$ (If they are going in opposite directions)

$=\frac{L_1 + L_2}{\left|S_1 - S_2\right|}$ (If they are going in the same directions)

Time & Work

⇒ If X can do a work in ‘n’ days, the fraction of work X does in a day is $\frac{1}{n}$

⇒ If X can do work in ‘x’ days, and Y can do work in ‘y’ days, then the number of days taken by both of them together is $\frac{x \times y}{x + y}$

⇒ If M_1 men work for H_1 *hours* per day and worked for D_1 days and completed W_1 work, and if M_2 men work for H_2 hours per day and worked for D_2 days and completed W_2 work, then $\frac{M_1 H_1 D_1}{W_1} = \frac{M_2 H_2 D_2}{W_2}$

Boats & Streams

⇒ If the speed of water is 'W' and speed of a boat in still water is ‘B’

⇒ Speed of the boat (downstream) is B+W

$\Rightarrow$ Speed of the boat (upstream) is B-W

The direction along the stream is called **downstream.** And, the direction against the stream is called **upstream.**

$\Rightarrow$ If the speed of the boat downstream is x km/hr and the speed of the boat upstream is y km/hr, then

$\Rightarrow$ Speed of the boat in still water = $\frac{x+y}{2}$km/hr

$\Rightarrow$ Rate of stream = $\frac{x-y}{2}$km/hr

$\Rightarrow$ While converting the speed in m/s to km/hr, multiply it by $\left(\frac{18}{5}\right)$ $\Rightarrow$ 1 m/s = 3.6 km/h

$\Rightarrow$ While converting km/hr into m/sec, we multiply by $\left(\frac{5}{18}\right)$

Pipes & Cisterns

$\Rightarrow$ Inlet Pipe : A pipe which is used to fill the tank is known as Inlet Pipe.

$\Rightarrow$ Outlet Pipe : A pipe which can empty the tank is known as outlet pipe.

- If a pipe can fill a tank in 'x' hours then the part filled per hour $=\frac{1}{x}$
- If a pipe can empty a tank in 'y' hours, then the part emptied per hour $=\frac{1}{y}$
- If a pipe A can fill a tank in 'x' hours and pipe can empty a tank in 'y' hours, if they are both active at the same time, then

The part filled per hour = $\frac{1}{x} - \frac{1}{y}\ (If\ y > x)$

The part emptied per hour = $\frac{1}{y} - \frac{1}{x}\ (If\ x > y)$

Some Tips and Tricks

- Some of the questions may consume a lot of time. While solving, write down the equations without any errors once you fully understand the given problem. The few extra seconds can help you avoid silly mistakes.
- Check if the units of distance, speed and time match up. If you see yourself adding a unit of distance like m to a unit of speed m/s, you would realise you have possibly missed a term.
- Choose to apply the concept of relative speed wherever possible since it can greatly reduce the complexity of the problem.
- In time and work, while working with equations, ensure that you convert all terms to consistent units like man-hours.

Success Stories

Prasenjit

CAT 2024 - 99.98%ile

Joining Cracku was one of the best decisions I made for my exam preparation. The experienced faculty and structured course material helped me strengthen my concepts and boost my confidence. The regular mock tests simulated the actual exam environment, ensuring I was well-prepared and stress-free on the big day.

Swaraj Pal Kesari

CAT 2024 - 99.95%ile

Sayali Ma'am's explanations helped me a lot. LRDI section again had very challenging sets which prepared me for the worst. And that was the best part of it. Maruti sir's explanations there helped me optimize my time and the problems that I was solving because of concepts. Cracku's mocks prepares you for the worst. And yeah, that's how you be the best, right.

Virajitha Vajha

CAT 2024 - 99.92%ile

I started my CAT preparation with the help of Cracku's cash course. Cracku played a key role in helping me brush up on my quant basics and overcome my fear of RCs. The unlimited resources available in the Cracku study room, along with the regular live sessions, were immensely helpful. Additionally, the high-quality questions in Dashcats prepared me to tackle any challenges CAT could throw my way.

Prasanna Telawane

CAT 2024 - 99.93%ile

Cracku has helped me a lot in my journey to ace CAT 2024. Its comprehensive study material, engaging video lectures, and meticulously designed mock tests provided a one-stop solution for all my preparation needs.Cracku's structured approach helped me develop confidence and a strategic mindset, crucial for tackling the CAT exam.

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CAT Linear Equations Formulas

- Linear equations is one of the foundation topics in the Quant section on the CAT.
- Hence, concepts from this topic are useful in solving questions from a range of different topics.
- A linear equation is an equation which gives a straight line when plotted on a graph.
- Linear equations can be of one variable or two variable or three variable.
- Generally, the number of equations needed to solve the given problem is equal to the number of variables
- Let a, b, c and d are constants and x, y and z are variables. A general form of single variable linear equation is $ax + b = 0$.
- A general form of two variable linear equations is $ax+by = c$.
- A general form of three variable linear equations is $ax+by+cz = d$.

Equations with two variables:

Consider two equations ax+by = c and mx+ny = p.

Each of these equations represent two lines on the x-y coordinate plane. The solution of these equations is the point of intersection.

→ If $\frac{a}{m} = \frac{b}{n} \neq \frac{c}{p}$ then the slope of the two equations is equal and so they are parallel to each other. Hence, no point of intersection occurs. Therefore no solution.

→ If $\frac{a}{m} \neq \frac{b}{n}$ then the slope is different and so they intersect each other at a single point. Hence, it has a single solution.

→ If $\frac{a}{m} = \frac{b}{n} = \frac{c}{p}$ then the two lines are the same and they have infinite points common to each other. So, infinite solutions occur.

General Procedure to solve linear equations:

- ➔ Aggregate the constant terms and variable terms for equations with more than one variable, eliminate variables by substituting equations in their place.
- ➔ Hence, for two equations with two variables x and y, express y in terms of x and substitute this in the other equation.

- ➔ For Example: let x+y = 14 and x+4y = 26 then x = 14-y (from equation 1) substituting this in equation 2, we get 14-y+4y = 26. Hence, y = 4 and x = 10.
- ➔ For equations of the form $ax + by = c$ and $mx + ny = p$, find the LCM of b and n.

  Multiply each equation with a constant to make the y term coefficient equal to the LCM. Then subtract equation 2 from equation 1.

- **Ex:** Let $2x+3y = 13$ and $3x+4y = 18$ are the given equations (1) and (2).

  ⇒ LCM of 3 and 4 is 12.

  ⇒ Multiplying (1) by 4 and (2) by 3, we get $8x+12y = 52$ and $9x+12y = 54$.

  ⇒ (2) - (1) gives $x=2$, $y=3$

- If the system of equations has n variables with n-1 equations then the solution is indeterminate.
- If system of equations has n variables with n-1 equations with some additional conditions (for eg. the variables are integers), then the solution may be determinate.
- If a system of equations has n variables with n-1 equations then some combination of variables may be determinable.

➔ For example, if $ax + by + cz = d$ and $mx + ny + pz = q$, if a, b, c are in Arithmetic progression and m, n and p are in AP then the sum x+y+z is determinable.

Equations with three variables:

➔ Let the equations be $a_1x + b_1y + c_1z = d_1$, $a_2x + b_2y + c_2z = d_2$ and $a_3x + b_3y + c_3z = d_3$.

➔ Here we define the following matrices.

$$D = \begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ a_3 & b_3 & c_3 \end{bmatrix} D_x = \begin{bmatrix} d_1 & b_1 & c_1 \\ d_2 & b_2 & c_2 \\ d_3 & b_3 & c_3 \end{bmatrix}.$$

$$D_y = \begin{bmatrix} a_1 & d_1 & c_1 \\ a_2 & d_2 & c_2 \\ a_3 & d_3 & c_3 \end{bmatrix} D_z = \begin{bmatrix} a_1 & b_1 & d_1 \\ a_2 & b_2 & d_2 \\ a_3 & b_3 & d_3 \end{bmatrix}$$

- ➔ If Determinant of D ≠ 0, then the equations have a unique solution.
- ➔ If Determinant of D = 0, and at least one but not all of the determinants D_x, D_y or D_z is zero, then no solution exists.
- ➔ If Determinant of $D = 0$, and all the three of the determinants D_x, D_y and D_z are zero, then there are infinitely many solutions.
- ➔ Determinant can be calculated by

$$D = a_1(b_2c_3 - c_2b_3) - b_1(a_2c_3 - c_2a_3) + c_1(a_2b_3 - b_2a_3)$$

Our Results

45 Students scored 99.9+ Percentile in CAT 2024

270 Students scored 99.50+ Percentile in CAT 2024

540 Students scored 99+ Percentile in CAT 2024

Our Faculty

Maruti Konduri

5 Time CAT 100%iler

IIM Ahmedabad Alumnus

Sayali Kale

CAT 99.97 %iler

IIM Ahmedabad Alumna

CAT Quadratic Equations Formulas

- Quadratic Equations is also an important topic For CAT Exam.
- The theory involved in this topic is very simple and students should be comfortable with some basic formulas and concepts.
- The techniques like option elimination, value assumption can help to solve questions from this topic quickly.
- This pdf covers all the important formulas and concepts related to Quadratic Equations.
- General Quadratic equation will be in the form of $ax^2 + bx + c = 0$
- The values of ‘x’ satisfying the equation are called roots of the equation.

- The value of roots, p and q = $\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$
- The above formula is known as the Shreedhara Acharya's Formula, after the ancient Indian Mathematician who derived it.
- Sum of the roots = p+q = $\frac{-b}{a}$
- Product of the roots = p × q = $\frac{c}{a}$
- If 'c' and 'a' are equal then the roots are reciprocal to each other.
- If b = 0, then the roots are equal and are opposite in sign.

  Let D denote the discriminant, D = $b^2 - 4ac$.

  Depending on the sign and value of D, nature of the roots would be as follows:
- D < 0 and |D| is not a perfect square:

Roots will be in the form of 'p+iq' and 'p-iq' where p and q are the real and imaginary parts of the complex roots. p is rational and q is irrational.

- D < 0 and |D| is a perfect square:

  Roots will be in the form of p+iq and p-iq where p and q are both rational.

- D = 0 ⇒ Roots are real and equal $\left\{x = \frac{-b}{2a}\right\}$
- D > 0 and D is not a perfect square:

  Roots are conjugate surds of the form $p + \sqrt{q}$ and $p - \sqrt{q}$

- D > 0 and D is a perfect square: Roots are real, rational and unequal

➔ **Signs of the roots:**

Let P be product of roots and S be their sum

- P > 0, S > 0 : Both roots are positive
- P > 0, S < 0 : Both roots are negative

- P < 0, S > 0 : Numerical smaller root is negative and the other root is positive
- P < 0, S < 0 : Numerical larger root is negative and the other root is positive

Minimum and maximum values $ax^2 + bx + c = 0$

- If a > 0: minimum value $= \frac{4ac-b^2}{4a}$ and occurs at $x = \frac{-b}{2a}$
- If a < 0: maximum value = $\frac{4ac-b^2}{4a}$ and occurs at $x = \frac{-b}{2a}$

If $A_nX^n + A_{n-1}X^{n-1} + ... + A_1X + A_0$**, then**

- Sum of the roots = $\frac{(-1)A_{n-1}}{A_n}$
- Sum of roots taken two at a time $= \frac{A_{n-2}}{A_n}$
- Sum of roots taken three at a time $= \frac{(-1)A_{n-3}}{A_n}$

and so on Product of the roots = $\frac{[(-1)^n A_0]}{A_n}$

Finding a Quadratic Equation:

- If roots are given:

  $(x - a)(x - b) = 0 \Rightarrow x^2 - (a + b)x + ab = 0$

- If sum s and product p of roots are given:

$$x^2 - sx + p = 0$$

- If roots are reciprocals of roots of equation $ax^2 + bx + c = 0$, then equation is $cx^2 + bx + a = 0$
- If roots are k more than roots of $ax^2 + bx + c = 0$ then equation is $a(x - k)^2 + b(x - k) + c = 0$
- If roots are k times roots of $ax^2 + bx + c = 0$ then equation is $a(x/k)^2 + b(x/k) + c = 0$

- Descartes Rules: A polynomial equation with n sign changes can have a maximum of n positive roots. To find the maximum possible number of negative roots, find the number of positive roots of f(-x).
- An equation where the highest power is odd must have at least one real root.

CAT Inequalities Formulas

- The topic Inequalities is one of the few sections in the quantitative part which can throw up tricky questions. The questions are often asked in conjunction with other sections like ratio and proportion, progressions etc.

- The theory involved in Inequalities is limited and therefore, students should be comfortable with learning the basics, which involves operations such as addition, multiplication and changing of signs of the inequalities.

- The scope for making an error is high in this section as a minor mistake in calculation (like forgetting the sign) can lead to a completely different answer.

- The modulus of x, $|x|$ equals the maximum of x and $-x$ is $-|x| \le x \le |x|$

- For any two real numbers 'a' and 'b',

  ➔ $a > b \Rightarrow -a < -b$

  ➔ $|a| + |b| \geq |a + b|$

  ➔ $|a| - |b| \leq |a - b|$

  ➔ $|a \,.\, b| = |a|\,|b|$

  ➔ $|a| > |b| \Rightarrow a > b$ (if both are +ve)

  $\Rightarrow a < b$ (if both are -ve)

- For any three real numbers X, Y and Z;

  if $X > Y$ then $X+Z > Y+Z$

- If $X > Y$ and
  1. Z is positive, then $XZ > YZ$
  2. Z is negative, then $XZ < YZ$
  3. If X and Y are of the same sign, $\frac{1}{X} < \frac{1}{Y}$
  4. If X and Y are of different signs, $\frac{1}{X} > \frac{1}{Y}$

- For any positive real number, $x + \frac{1}{x} \geq 2$
- For any real number x >1,

$$2 < \left[1 + \frac{1}{x}\right]^x < 2.8$$

As x increases, the function tends to an irrational number called 'e' which is approx. equal to 2.718

- If |x| ≤ k then the value of x lies between −k and k, or −k ≤ x ≤ k
- If |x| ≥ k then x ≥ k or x ≤ -k
- If $ax^2 + bx + c < 0$ then (x-m)(x-n) < 0, and if n > m, then m < x < n
- If $ax^2 + bx + c > 0$ then (x-m)(x-n) > 0 and if m < n, then x < m and x > n
- If $ax^2 + bx + c > 0$ but m = n, then the value of x exists for all values, except x is equal to m,

i.e., x < m and x > m but x ≠ m

CAT Progressions & Series Formulas

- Progressions and Series is one of the important topics for CAT and a significant number of questions appear in the examination from this section every year. Some of the questions from this section can be very tough and time consuming while the others can be very easy.
- The trick to ace this section is to quickly figure out whether a question is solvable or not and not waste time on very difficult questions.
- Some of the questions in this section can be answered by ruling out wrong choices among the options available. This method will both save time and improve accuracy.

- There are many shortcuts which will be of vital importance in answering this section.

There are 3 standard types of progressions

➔ Arithmetic Progression

➔ Geometric Progression

➔ Harmonic Progression

Arithmetic progression (A.P):

- If the sum or difference between any two consecutive terms is constant then the terms are said to be in A.P (Example: 2,5,8,11 or a, a+d, a+2d, a+3d...)
- If 'a' is the first term and 'd' is the common difference then the general 'n' term is

$$T_n = a + (n - 1)d$$

- Sum of first 'n' terms in

$$A.P = \frac{n}{2}[2a + (n - 1)d]$$

- Number of terms in $A.P = \frac{Last\ term - First\ term}{Common\ Difference} + 1$

- Sum of all terms of

$$A.P = \frac{n}{2}[First\ term\ +\ Last\ Term]$$

- Arithmetic Mean (AM) of n terms = $\frac{sum\ of\ the\ terms}{number\ of\ terms}$

Properties of A.P:

- If a, b , c, d,.... are in A.P and 'k' is a constant then
- a−k, b−k, c−k,... will also be in A.P
- ak, bk, ck,...will also be in A.P
- $\frac{a}{k}, \frac{b}{k}, \frac{c}{k}$ will also be in A.P

Geometric progression (G.P):

If in a succession of numbers the ratio of any term and the previous term is constant then that number is said to be in Geometric Progression.

- Ex : 1, 3, 9, 27 or a, ar, ar^2, ar^3
- The general expression of an G.P, $T_n = ar^{n-1}$

(where ‘a’ is the first terms and ‘r’ is the common ratio)

- Sum of ‘n’ terms in G.P,

$$Sn = \frac{a(r^n - 1)}{r-1} \text{ (if r>1) or } \frac{a(1-r^n)}{1-r} \text{ (if r<1)}$$

- Sum of term of infinite series in G.P,

$$S_\infty = \frac{a}{1-r} (|r| < 1)$$

- Geometric Mean (GM) of ‘n’ terms =

$$\sqrt[n]{product\ of\ the\ terms}$$

Properties of G.P:

- If a, b , c, d,.... are in G.P and ‘k’ is a constant then
    - ➔ ak, bk, ck,...will also be in G.P
    - ➔ a/k, b/k, c/k will also be in G.P

Harmonic progression (H.P):

- If a, b, c, d,......are unequal numbers then they are said to be in H.P if $\frac{1}{a}, \frac{1}{b}, \frac{1}{c}$,......are in A.P

- The ‘n’ term in H.P is $\frac{1}{(nth\ term\ in\ A.P)}$

Properties of H.P :

If a, b, c, d,...are in H.P, then a+d > b+c and ad > bc

Arithmetic Geometric Series:

- A series will be in arithmetic geometric series if each of its terms is formed by the product of the corresponding terms of an A.P and G.P.
- The general form of A.G.P series is $a, (a + d)r, (a + 2d)r^2$,....
- Sum of ‘n’ terms of A.G.P series

$$s_n = \frac{a-[a+(n-1)d]r^n}{1-r} + \frac{dr(1-r^{n-1})}{(1-r)^2}\ (r \neq 1)$$

$$s_n = \frac{n}{2}[2a + (n - 1)d]$$

- Sum of infinite terms of A.G.P series

$$s_\infty = \frac{a}{1-r} + \frac{dr}{(1-r)^2}\ (|r| < 1)$$

- Relationship between A.M, G.M and H.M for two numbers a and b,

  G. M = $\sqrt{(AM \times HM)}$ | A.M ≥ G.M ≥ H.M

Standard Series:

- The sum of first 'n' natural numbers = $\frac{n(n+1)}{2}$
- The sum of squares of first 'n' natural numbers $= \frac{n(n+1)(2n+1)}{6}$
- The sum of cubes of first 'n' natural numbers = $\left\{\frac{n(n+1)}{2}\right\}^2$
- The sum of first 'n' odd natural numbers = n^2
- The sum of first 'n' even natural numbers = $n(n + 1)$
- In any series, if the sum of first n terms is given by S_n, then the n^{th} term $T_n = S_n - S_{n-1}$

Arithmetic Mean:

- The arithmetic mean = $\frac{Sum\ of\ all\ the\ terms}{Number\ of\ terms}$
- If two number A and B are in A.P then arithmetic mean = $\frac{a+b}{2}$
- Inserting 'n' means between two numbers a and b the total terms will become n+2, a is the first term and b is the last term.
- Then the common difference d = $\frac{b-a}{n+1}$
- The last term b = a+(n+1)d
- The final series is a, a+d, a+2d....

Geometric Mean:

- If a, b, c,... n terms are in G.P then

G.M = $\sqrt[n]{a \times b \times c \times \ldots\ldots.. n\ terms}$

- If two numbers a, b are in G.P then their G.M = $\sqrt{a \times b}$

- Inserting ‘n’ means between two quantities a and b with common ratio ‘r’
- Then the number of terms are n+2 and a,b are the first and last terms

$$r^{n+1} = \frac{b}{a} \text{ (OR) } r = \frac{\sqrt[n+1]{b}}{a}$$

- The final series is $a,\ ar,\ ar^2$

Harmonic Mean:

- If a, b, c, d,.. are the given numbers in H.P then the Harmonic mean of ‘n’ terms = $\frac{Numbers\ of\ terms}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+.......}$
- If two numbers a and b are in H.P then the Harmonic Mean = $\frac{2ab}{a+b}$
- Relationship between AM, GM and HM for two numbers a and b,

- A.M=$\frac{a+b}{2}$
- G.M=$\sqrt{a \times b}$
- H.M= $\frac{2ab}{a+b}$
- G.M=$\sqrt{AM \times HM}$
- A.M $\geq$ G.M $\geq$ H.M

CAT Logarithms, Surds & Indices Formulas

- "Logarithms, Surds and Indices" is one of the easiest topics in the quantitative section of the CAT exam.
- Although the number of formulas is high, the basic concepts are very simple to understand and apply.
- There are no shortcuts to remember and the scope of the questions that can be asked is very limited.
- The accuracy of answering questions from this section is very high and good students tend to score very well here.

- If X,Y > 0 and m,n are rational numbers then

➔ $X^m \times X^n = X^{m+n}$

➔ $X^0 = 1$

→ $\frac{X^m}{X^n} = X^{m-n}$

→ $(X^m)^n = X^{mn}$

→ $X^m \times Y^m = (X \times Y)^m$

→ $\frac{X^m}{Y^m} = \left(\frac{X}{Y}\right)^m$

→ $X^{-m} = \frac{1}{X^m}$

- If X and Y are positive real numbers and a,b are rational numbers

→ $\left(\frac{X}{Y}\right)^{-a} = \left(\frac{Y}{X}\right)^a$

→ $X^{1/a} = \sqrt[a]{X}$

→ $X^{a/b} = \sqrt[b]{X^a}$

→ $\sqrt[a]{X} \times \sqrt[a]{Y} = \sqrt[a]{XY}$

➔ $\frac{\sqrt[a]{X}}{\sqrt[a]{Y}} = \sqrt[a]{\frac{X}{Y}}$

➔ $\frac{1}{\sqrt{N+1}-\sqrt{N}} = \sqrt{N + 1} + \sqrt{N}$

- Surds is an irrational number involving a root.

  Ex: $\sqrt{5}, \sqrt[3]{7}, \sqrt[5]{2}$

- Like surds are two surds having the same number under radical sign.
- Like surds can be added or subtracted.

  $6\sqrt{2} + 3\sqrt{2} = 9\sqrt{2}$

- If $a + \sqrt{b} = c + \sqrt{d}$, then a = c and b = d.
- The conjugate of $a + \sqrt{b}$ is $a - \sqrt{b}$
- $\sqrt{a\sqrt{a\sqrt{a.....\infty}}}$ = a

- $\sqrt{a\sqrt{a\sqrt{a.....x\ times}}} = a^{1-\left[\frac{1}{2^x}\right]}$
- To find $\sqrt{\sqrt{x}+\sqrt{y}}$, $\sqrt{x} + \sqrt{y}$ should be written in the form of $m + n + 2\sqrt{mn}$ where $x = m + n$ and $4mn = y$ and $\sqrt{\sqrt{x}+\sqrt{y}} = \pm\left(\sqrt{m}+\sqrt{n}\right)$
- If N $= a^x$ then, x is defined as the logarithm of N to base or $x = log_a N$ a logarithm of a negative number or zero is not defined
- $log_a 1 = 0$
- $log_a xy = log_a x + log_a y$
- $log_a b^c = c\ log_a b$
- $log_a a = 1$

- $X^{\log_b y} = Y^{\log_b x}$
- $\log_a \sqrt[n]{b} = \frac{\log_a b}{n}$
- $\log_a x = \frac{1}{\log_x a}$
- $b^{\log_b x} = x$
- $\log_a b = \frac{\log_c b}{\log_c a}$
- $\log_a b * \log_b a = 1$
- $\log_a\left(\frac{X}{Y}\right) = \log_a X - \log_a Y$
- If 0 < a < 1, then $\log_a x < \log_a y (if\ x > y)$
- If a > 1 then $\log_a x > \log_a y$ (if x>y)

Success Stories

Prasenjit

CAT 2024 - 99.98%ile

Joining Cracku was one of the best decisions I made for my exam preparation. The experienced faculty and structured course material helped me strengthen my concepts and boost my confidence. The regular mock tests simulated the actual exam environment, ensuring I was well-prepared and stress-free on the big day.

Swaraj Pal Kesari

CAT 2024 - 99.95%ile

Sayali Ma'am's explanations helped me a lot. LRDI section again had very challenging sets which prepared me for the worst. And that was the best part of it. Maruti sir's explanations there helped me optimize my time and the problems that I was solving because of concepts. Cracku's mocks prepares you for the worst. And yeah, that's how you be the best, right.

Virajitha Vajha

CAT 2024 - 99.92%ile

I started my CAT preparation with the help of Cracku's cash course. Cracku played a key role in helping me brush up on my quant basics and overcome my fear of RCs. The unlimited resources available in the Cracku study room, along with the regular live sessions, were immensely helpful. Additionally, the high-quality questions in Dashcats prepared me to tackle any challenges CAT could throw my way.

Prasanna Telawane

CAT 2024 - 99.93%ile

Cracku has helped me a lot in my journey to ace CAT 2024. Its comprehensive study material, engaging video lectures, and meticulously designed mock tests provided a one-stop solution for all my preparation needs.Cracku's structured approach helped me develop confidence and a strategic mindset, crucial for tackling the CAT exam.

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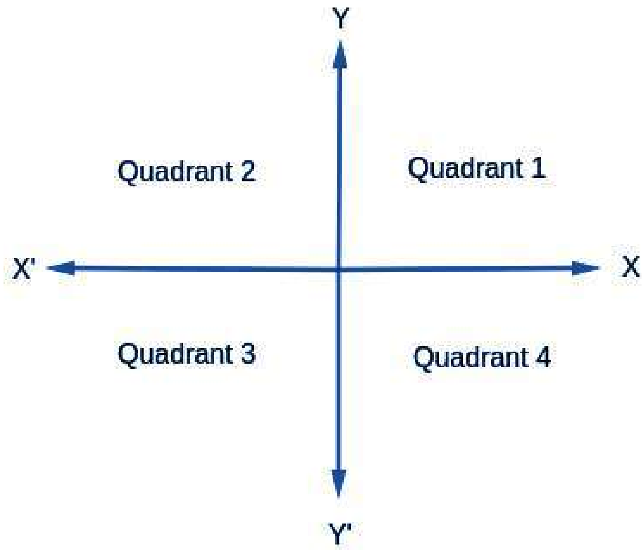
CAT Geometry Formulas

- 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 visualise 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

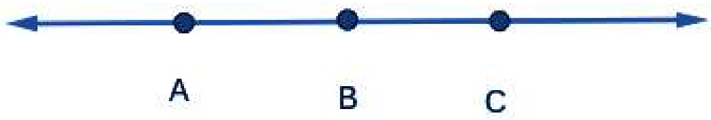


Quadrant I	X is Positive	Y is Positive
Quadrant II	X is Negative	Y is Positive
Quadrant III	X is Negative	Y is Negative
Quadrant IV	X is Positive	Y is Negative

Lines and Angles

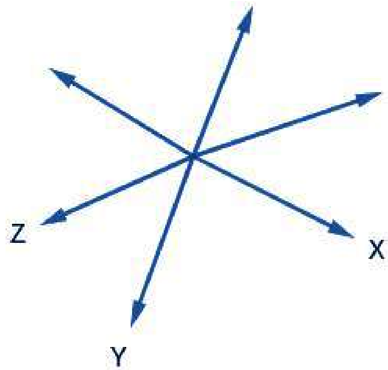
Collinear points:

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 $B\left(x_2, y_2\right)$ 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 $\tan\theta = \frac{m_1-m_2}{1+m_1m_2}$ (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

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

- 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

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

- 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 centre of the circle then equation of the circle is $x^2 + y^2 = r^2$

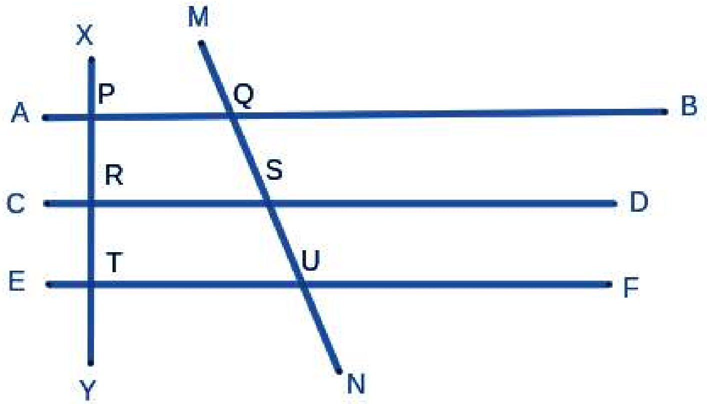
➔ When two angles A and B are complementary, sum of A and B is 90°

➔ 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

➔ $\angle XPQ = \angle PRS = \angle RTU$ as corresponding angles are equal

➔ Interior angles on the side of the transversal are supplementary. i.e. $\angle PQS + \angle QSR = 180°$

➔ 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	$\frac{y-y_1}{y_2-y_1} = \frac{x-x_1}{x_2-x_1}$

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°.

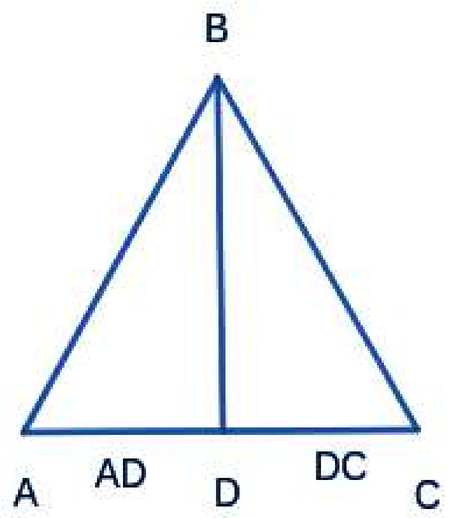
⇒ If in a triangle all of its angles are less than 90° than that triangle is called an acute angled triangle

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

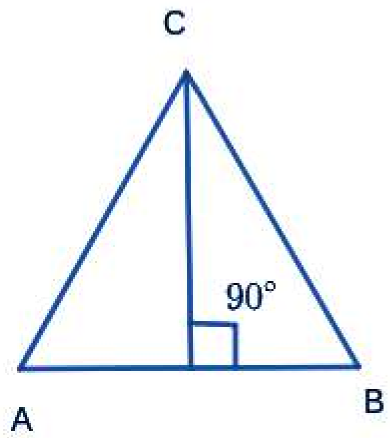
⇒ A triangle with one of its angles greater than 90° than that triangle is called an Obtuse angled triangle.

⇒ 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 ∠B= 90°, $AC^2 = AB^2 + BC^2$

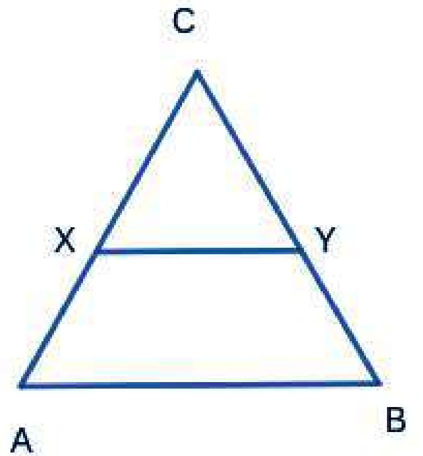
Apollonius theorem:

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

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

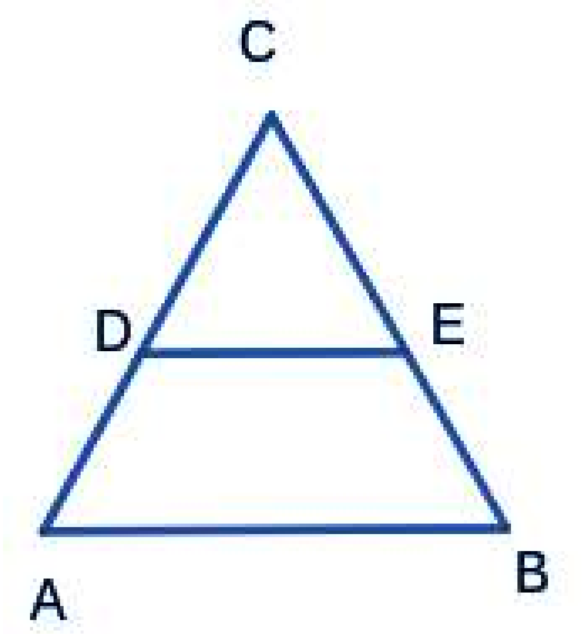
Mid Point Theorem :

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 :

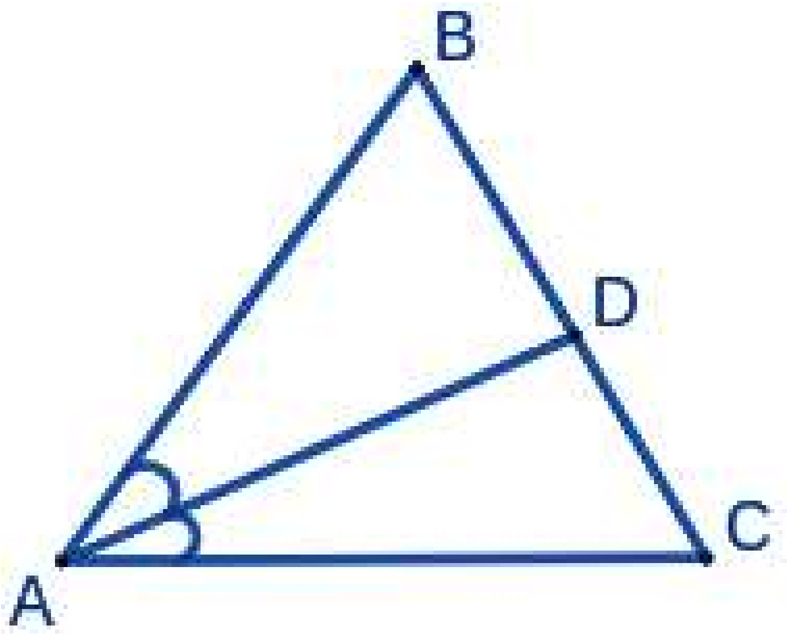
If a line is drawn parallel to one side of a triangle and it intersects the other two sides at two distinct points then it divides the two sides in the ratio of respective sides. If in a triangle ABC, D and E are the points lying on AC and BC respectively and DE is parallel to AB then AD/DC = BE/EC



Interior Angular Bisector theorem :

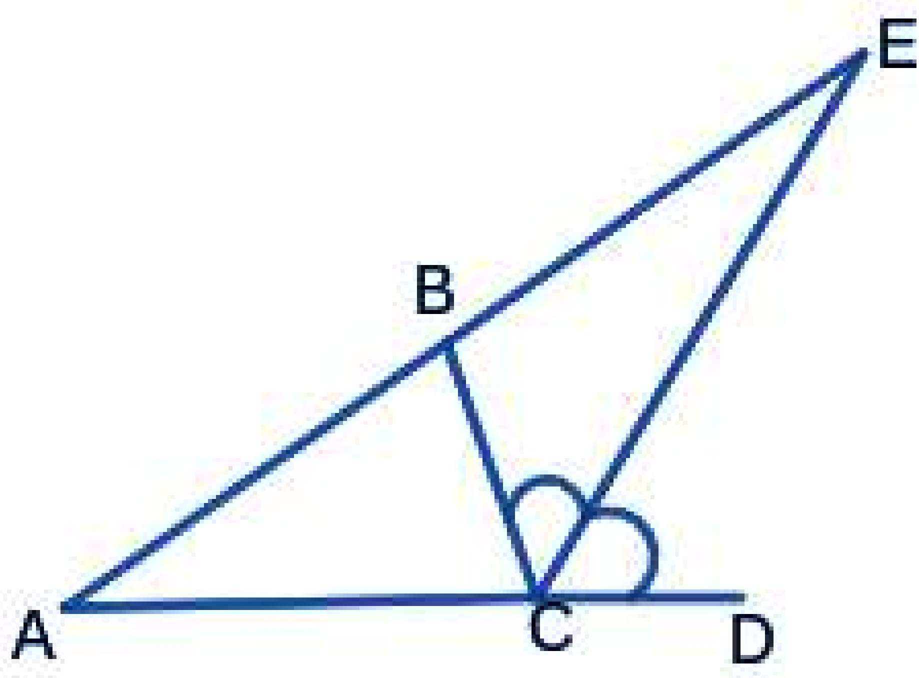
In a triangle the angular bisector of an angle divides the side opposite to the angle, in the ratio of the remaining two sides. In a triangle ABC if AD is the angle bisector of angle A then AD divides the side BC in the same ratio as the other two sides of the triangle.

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



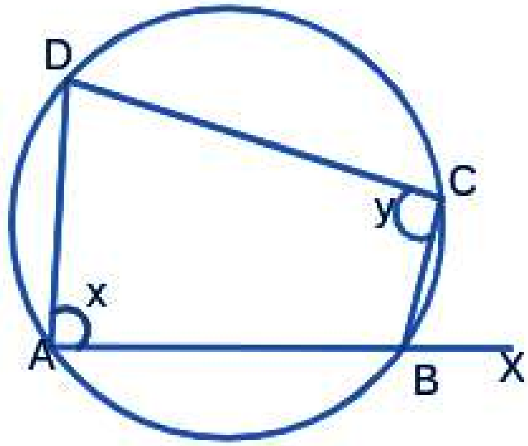
Exterior Angular Bisector theorem :

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 $\angle$CBX = $\angle$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)

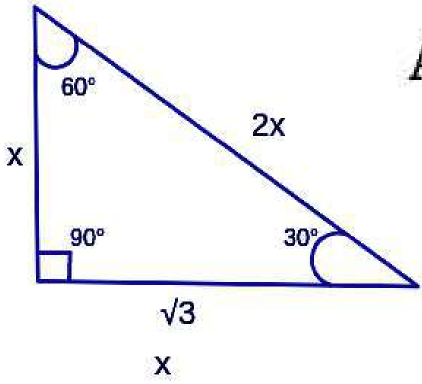
Area of a triangle:

- 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)

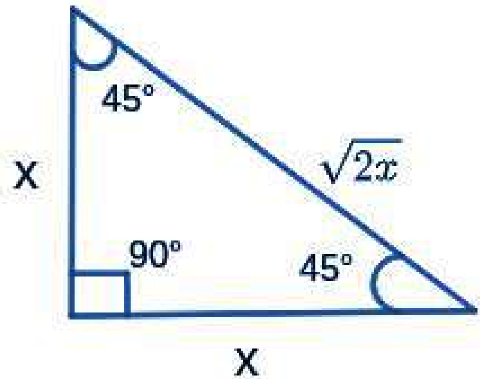
Special triangles :

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



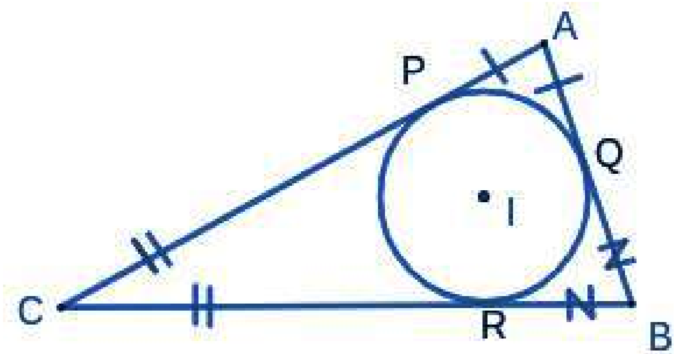
$$\text{Area} = \frac{\sqrt{3}}{2}x^2$$

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



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

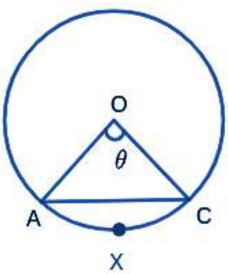
- Consider the triangle ABC with incentre I, and the incircle touching the triangle at P, Q, R as shown in the diagram. As tangents drawn from a point are equal, AP=AQ, CP=CR and BQ=BR.



- 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

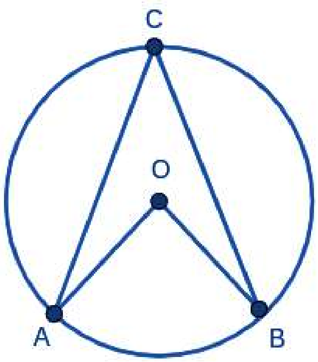
- The angle subtended by a diameter of circle on the circle $= 90^0$
- Angles subtended by an equal chord are equal. Also, angles subtended in the major segment are half the angle formed by the chord at the center
- Equal chords of a circle are equidistant from the center
- The radius from the center 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 centre to any chord, bisects the chord



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

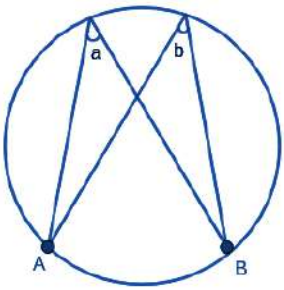
Area of minor segment AXC = $\frac{\theta}{360}\pi r^2 - \frac{1}{2}r^2 Sin\theta$

Inscribed angle Theorem :



$2\angle ACB = \angle AOB$

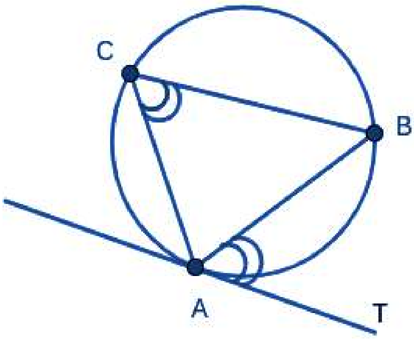
The angle inscribed by the two points lying on the circle, at the centre of the circle, is twice the angle inscribed at any point on the circle by the same points.



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.

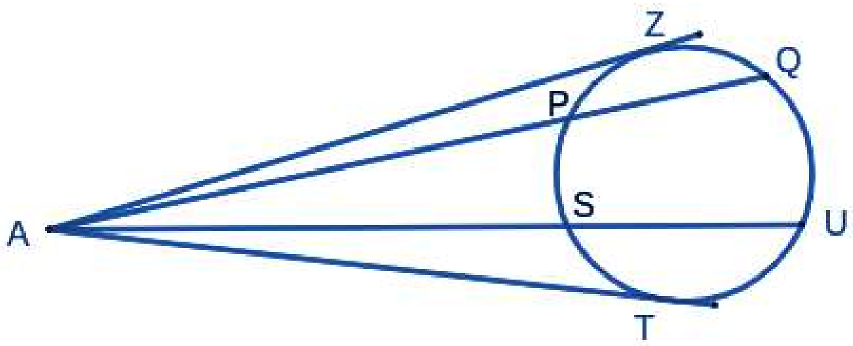
  As shown in the figure, $\angle ACB = \angle BAT$.



Consider a circle as shown in the image. Here,

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

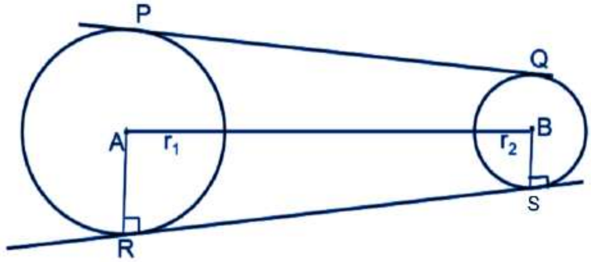
Two tangents drawn to a circle from an external common point will be equal in length. So here AZ = AT



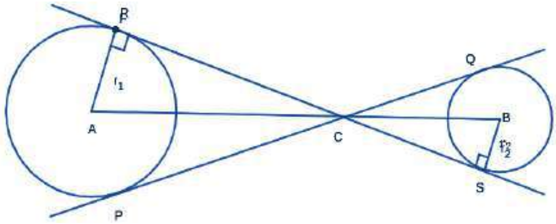
Direct common tangent :

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

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



Transverse common tangent :

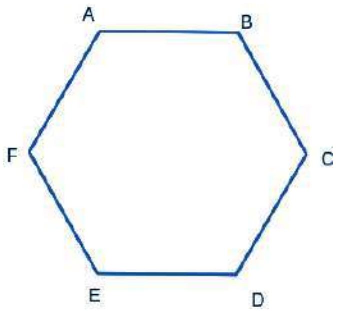


In this figure PQ and RS are the transverse common tangents and let AB (Distance between the two centers) = D, $PQ^2 = RS^2 = D^2 - (r_1 + r_2)^2$

Polygons and Quadrilaterals:

- If all sides and all angles are equal, then the polygon is a regular polygon
- 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	$3\pi r^2$

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.

Our Results

45 Students scored 99.9+ Percentile in CAT 2024

270 Students scored 99.50+ Percentile in CAT 2024

540 Students scored 99+ Percentile in CAT 2024

Our Faculty

Maruti Konduri
5 Time CAT 100%iler
IIM Ahmedabad Alumnus

Sayali Kale
CAT 99.97 %iler
IIM Ahmedabad Alumna

CAT Set Theory And Venn Diagrams Formulas

- It's one of the easiest topics of CAT. Most of the formulae in this section can be deduced logically with little effort.
- The difficult part of the problem is translating the sentences into areas of the Venn diagram. While solving, pay careful attention to phrases like ‘and, or, not, only, in’ as these generally signify the relationship.
- Set is defined as a collection of well-defined objects. Ex. Set of whole numbers.
- Every object is called an element of the set.
- The number of elements in the set is called cardinal number.

Types of Sets

➔ **Null Sets:**

A set with zero or no elements is called a Null set.

It is denoted by { } or Ø. Null set cardinal number is 0.

➔ **Singleton Sets:**

Sets with only one element in them are called singleton sets. Ex. {2}, {a}, {0}

➔ **Finite and Infinite Sets:**

A set having a finite number of elements is called a finite set. A set having infinite or uncountable elements in it is called an infinite set.

➔ **Universal Sets:**

A set which contains all the elements of all the sets and all the other sets in it, is called a universal set.

➔ **Subsets:**

A set is said to be a subset of another set if all the elements contained in it are also part of another set.

Ex. If A = {1,2}, B = {1,2,3,4} then, Set “A” is said to be a subset of set B.

➔ **Equal Sets:**

Two sets are said to be equal sets when they contain the same elements Ex. A = {a,b,c} and B = {a,b,c} then A and B are called equal sets.

➔ **Disjoint Sets:**

When two sets have no elements in common then the two sets are called disjoint sets.

Ex. A = {1,2,3} and B = {6,8,9} then A and B are disjoint sets.

➔ **Power Sets:**

- ➔ A power set is defined as the collection of all the subsets of a set and is denoted by P(A)
- ➔ If A = {a,b} then P(A) = { { }, {a}, {b}, {a,b} }
- ➔ For a set having n elements, the number of subsets are 2^n

➔ **Properties of Sets:**

➔ The null set is a subset of all sets

➔ Every set is subset of itself

➔ $A \cup (B \cup C) = (A \cup B) \cup C$

➔ $A \cap (B \cap C) = (A \cap B) \cap C$

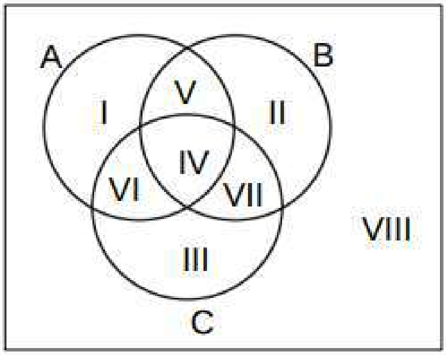
➔ $A \cup (B \cap C) = (A \cup B) \cap (A \cup C)$

➔ $A \cap (B \cup C) = (A \cap B) \cup (A \cap C)$

➔ $A \cup \emptyset = A$

➔ **Venn Diagrams:**

A Venn diagram is a figure to represent various sets and their relationship.



I,II,III are the elements in only A, only B & only C resp.

IV – Elements which are in all of A, B and C.

V - Elements which are in A and B but not in C.

VI – Elements which are in A and C but not in B.

VII – Elements which are in B and C but not in A.

VIII – Elements which are not in either A or B or C.

➔ Union of sets is defined as the collection of elements either in A or B or both. It is represented by the symbol "U". Intersection of set is the collection of elements which are in both A and B.

➔ Let there are two sets A and B then,

$$n(A \cup B) = n(A) + n(B) - n(A \cap B)$$

➔ If there are 3 sets A, B and C then,

$$n(A \cup B \cup C) = n(A) + n(B) + n(C) - n(A \cap B) - n(B \cap C) - n(C \cap A) + n(A \cap B \cap C)$$

- ➔ To maximise overlap,
  - ➔ Union should be as small as possible
  - ➔ Calculate the surplus = $n(A) + n(B) + n(C) - n(A \cup B \cup C)$
  - ➔ This can be attributed to $n(A \cap B \cap C')$, $n(A \cap B' \cap C)$, $n(A' \cap B \cap C)$, $n(A \cap B \cap C)$.
  - ➔ To maximise the overlap, set the other three terms to zero.

- ➔ To minimise overlap:
  - ➔ Union should be as large as possible.
  - ➔ Calculate the surplus =

$$n(A) + n(B) + n(C) - n(A \cup B \cup C).$$

  - ➔ This can be attributed to $n(A \cap B \cap C')$, $n(A \cap B' \cap C)$, $n(A' \cap B \cap C)$, $n(A \cap B \cap C)$.
  - ➔ To minimise the overlap, set the other three terms to maximum possible.

- Some other important properties
  - A’ is called complement of set A, or A’ = U-A
  - $n(A-B) = n(A) - n(A \cap B)$
  - $A-B = A \cap B'$
  - $B-A = A' \cap B$
  - $(A-B) \cup B = A \cup B$

CAT Number System Formulas

- Number Systems is the most important topic in the quantitative section.
- It is a very vast topic and a significant number of questions appear in CAT every year from this section.
- Learning simple tricks like divisibility rules, HCF and LCM, prime number and remainder theorems can help improve the score drastically.
- This PDF covers the best short cuts which makes this topic easy and helps you perform better.

HCF & LCM

- HCF * LCM of two numbers = Product of two numbers

- The greatest number dividing a, b and c leaving remainders of x_1, x_2 and x_3 is the HCF of $(a - x_1)$, $(b - x_2)$ and $(c - x_3)$
- The greatest number dividing a, b and c (a<b<c) leaving the same remainder each time is the HCF of (c-b), (c-a), (b-a).
- If a number, N, is divisible by X and Y and HCF(X,Y) = 1. Then, N is divisible by X × Y

Prime and Composite Numbers:

- Prime numbers are numbers with only two factors, 1 and the number itself.
- Composite numbers are numbers with more than 2 factors. Examples are 4, 6, 8, 9.
- 0 and 1 are neither composite nor prime.
- There are 25 prime numbers less than 100.

Properties of Prime numbers:

- To check if n is a prime number, list all prime factors less than or equal to √n. If none of the prime factors can divide n then n is a prime number.
- For any integer a and prime number p, a^{p-a} is always divisible by p
- All prime numbers greater than 2 and 3 can be written in the form of 6k+1 or 6k-1
- If a and b are coprime then a^{b-1} mod b=1

Theorems on Prime numbers:

Fermat's Theorem:

- Remainder of a^(p-1) when divided by p is 1, where p is a prime.

Wilson's Theorem:

- Remainder when (p-1)! is divided by p is (p-1) where p is a prime

Remainder Theorem:

- If a, b, c are the prime factors of N such that N= $a^p * b^q * c^r$ Then the number of numbers less than N and co-prime to N is

  $\phi(N)= N\,(1 - \frac{1}{a})\,(1 - \frac{1}{b})\,(1 - \frac{1}{c})$.

This function is known as the Euler's totient function.

Euler's theorem

- If M & N are coprime to each other than remainder when $M^{\phi(N)}$ is divided by N is 1.

  (Note: If N is prime, the Euler's Theorem becomes the Fermat's Theorem.)

- Highest power of n in m! is $\left[\frac{m}{n}\right]+\left[\frac{m}{n^2}\right]+\left[\frac{m}{n^3}\right]+$.....

  Ex: Highest power of 7 in 100! = $\left[\frac{100}{7}\right]+\left[\frac{100}{49}\right]$= 16

- To find the number of zeroes in n! find the highest power of 5 in n!
- If all possible permutations of n distinct digits are added together the sum = (n-1)! * (sum of n digits) * (11111... n times)
- If the number can be represented as N = $a^p * b^q * c^r \ldots$ then number of factors the is (p+1) * (q+1) * (r+1)
- Sum of the factors = $\frac{a^{p+1}-1}{a-1} \times \frac{b^{q+1}-1}{b-1} \times \frac{c^{r+1}-1}{c-1}$
- If the number of factors are odd then N is a perfect square.

- If there are n factors, then the number of pairs of factors would be $\frac{n}{2}$. If N is a perfect square then number of pairs (including the square root) is $\frac{(n+1)}{2}$
- If the number can be expressed as N = $2^p * a^q * b^r$ ... where the power of 2 is p and a, b are prime numbers
- Then the number of even factors of

  N = p (1+q) (1+r)......
- The number of odd factors of N = (1+q) (1+r)...
- Number of positive integral solutions of the equation $x^2 - y^2 = k$ is given by
- $\frac{Total\ number\ of\ factors\ of\ k}{2}$ (If k is odd but not a perfect square)
- $\frac{(Total\ number\ of\ factors\ of\ k)-1}{2}$ (If k is odd and a perfect square)

- $\frac{(Total\ number\ of\ factors\ of\ \frac{k}{4}}{2}$ (If k is even and not a perfect square)
- $\frac{\left(Total\ number\ of\ factors\ of\ \frac{k}{4}\right)-1}{2}$(If it is even and a perfect square)
- Number of digits in a^b= [b log_m(a)] + 1 ; where m is the base of the number and [.] denotes greatest integer function.
- Even number which is not a multiple of 4, can never be expressed as a difference of 2 perfect squares.
- Sum of first n odd numbers is n^2
- Sum of first n even numbers is n(n+1)
- The product of the factors of N is given by $N^{a/2}$, where a is the number of factors

- The last two digits of a^2, $(50 - a)^2$, $(50 + a)^2$, $(100 - a)^2$..... are the same.
- If the number is written as 2^{10n}

  When n is odd, the last 2 digits are 24.

  When n is even, the last 2 digits are 76

Divisibility:

- Divisibility by 2: Last digit divisible by 2
- Divisibility by 4: Last two digits divisible by 4
- Divisibility by 8: Last three digits divisible by 8
- Divisibility by 16: Last four digit divisible by 16
- Divisibility by 3: Sum of digits divisible by 3
- Divisibility by 9: Sum of digits divisible by 9
- Divisibility by 27: Sum of blocks of 3 (taken right to left) divisible by 27

- Divisibility by 7: Remove the last digit, double it and subtract it from the truncated original number. Check if number is divisible by 7
- Divisibility by 11: (sum of odd digits) - (sum of even digits) should be 0 or divisible by 11

Divisibility properties:

- For composite divisors, check if the number is divisible by the factors individually. Hence to check if a number is divisible by 6 it must be divisible by 2 and 3.
- The equation $a^n - b^n$ is always divisible by a-b. If n is even it is divisible by a+b. If n is odd it is not divisible by a+b.
- The equation $a^n + b^n$, is divisible by a+b if n is odd. If n is even it is not divisible by a+b.

- Converting from decimal to base b. Let $R_1, R_2 \ldots$ be the remainder left after repeatedly dividing the number with b. Hence, the number in base b is given by ... $R_2 R_1$.
- Converting from base b to decimal - multiply each digit of the number with a power of b starting with the rightmost digit and b^0.
- A decimal number is divisible by b-1 only if the sum of the digits of the number when written in base b are divisible by b-1.

Cyclicity

To find the last digit of a^n find the cyclicity of a.

For Ex. if a=2, we see that

➔ $2^1 = 2$

➔ $2^2 = 4$

➔ $2^3 = 8$

➔ $2^4 = 16$

➔ $2^5 = 32$

Hence, the last digit of 2 repeats after every 4^{th} power.

Hence cyclicity of 2 = 4.

Hence if we have to find the last digit of a^n, The steps are:

1. Find the cyclicity of a, say it is x.
2. Find the remainder when n is divided by x, say remainder r
3. Find a^r if r>0 and a^x when r=0

- $(a + b)(a - b) = \left(a^2 - b^2\right)$
- $(a + b)^2 = \left(a^2 + b^2 + 2ab\right)$
- $(a - b)^2 = \left(a^2 + b^2 - 2ab\right)$
- $(a + b + c)^2 = \left(a^2 + b^2 + 2(ab + bc + ca)\right)$
- $\left(a^3 + b^3\right) = (a + b)\left(a^2 - ab + b^2\right)$

- $\left(a^3 - b^3\right) = (a - b)\left(a^2 + ab + b^2\right)$
- $\left(a^3 + b^3 + c^3 - 3abc\right)$
  $= (a + b + c)\left(a^2 + b^2 + c^2 - ab - bc - ac\right)$
- When a + b + c = 0, then $a^3 + b^3 + c^3 = 3abc$

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CAT Remainder Theorems Formulas

Fermat's little Theorem:

- Fermat's theorem is an important remainder theorem which can be used to find the remainder easily.
- Fermat's theorem states that for any integer 'a' and prime number 'p', $a^p - a$ is always divisible by 'p'.
- Also, if a is not divisible by p, i.e, if a and p are relatively prime, then $a^{(p-1)} \bmod p = 1 \bmod p$. Which means the remainder is 1.
- The second part of the theorem is very useful in solving problems.

- **Example:** when 2^{256} is divided by 17, the remainder would be______:

Here, 7 is a prime number and 2, 17 are relatively prime.

Therefore, 2^{16} mod 17 = 1.

2^{256} can be written as $(2^{16})^{16}$.

Since, 2^{16} mod 17 = 1, $(2^{16})^{16}$ mod 17 = 1.

Thus, the remainder when 2^{256} is divided by 17 is 1.

- **Example:**

Find the remainder when 3^{75} is divided by 37.

Here, 37 is a prime number. Hence, Fermat's theorem can be used. Also, 3 and 37 are relatively prime.

Therefore, 3^{36} mod 37 = 1

3^{72} mod 37 = $(3^{36})^2$ mod 37 = 1

3^{75} mod 37 = 3^{72} . 3^3 mod 37 = 3^3 mod 37

27 mod 37 is equal to 27.

Hence, the remainder when 3^{75} is divided by 37 is 27.

Euler’s Totient:

- Euler's theorem is one of the most important remainder theorems. It is imperative to know about Euler's totient before we can use the theorem.
- Euler's totient is defined as the number of numbers less than ‘n’ that are co-prime to it.
- It is usually denoted as $\phi(n)$.
- The formula to find Euler’s totient is

  $\phi(n) = n * \left(1 - \frac{1}{a}\right) * \left(1 - \frac{1}{b}\right) *$....where a,b are the prime factors of the numbers.

  Eg: Find the number of numbers that are less than 30 and are co-prime to it.

  30 can be written as 2*3*5.

  $\phi(30)=30*\left(\frac{1}{2}\right) * \left(\frac{2}{3}\right) * \left(\frac{4}{5}\right) = 8$

  Therefore, 8 numbers less than 30 are co-prime to it.

➔ Euler's theorem states that $a^{\phi(n)}$ (mod n) = 1 (mod n) if ‘a’ and ‘n’ are co-prime to each other.
So, if the given number ‘a’ and the divisor ‘n’ are co-prime to each other, we can use Euler's theorem.

- **Example 1:**
What is the remainder when 2^{256} is divided by 15?
2 and 15 are co-prime to each other. Hence, Euler’s theorem can be applied.
15 can be written as 5*3.
Euler's totient of 15 = $15*\left(1-\frac{1}{3}\right)*\left(1-\frac{1}{5}\right)$
$= 15*\frac{2}{3}*\frac{4}{5}=8$
Therefore, we have to try to express 256 as 8k + something. 256 can be expressed as 8*32
We know that, $a^{\phi(n)}$ (mod n) = 1 (mod n)
2^{8*32} (mod 15) = 1 (mod 15).
Therefore, 1 is the right answer.

- **Example 2:**

  What are the last 2 digits of 7^{2008}?

  Finding the last 2 digits is similar to finding the remainder when the number is divided by 100.

  100 and 7 are co-prime to each other. Hence, we can use Euler's theorem.

  100 can be written as $2^2 * 5^2$.

  Euler's totient of 100, $\phi(100)$

  $= 100*\left(1-\frac{1}{2}\right)*\left(1-\frac{1}{5}\right)$

  $= 100*\frac{1}{2}*\frac{4}{5}$

  $\phi(100) = 40$

  7^{2008} can be written as $7^{2000} * 7^{8}$

  7^{2000} can be written as 7^{40*25}, Hence, 7^{2000} will yield a remainder of 1 when divided by 100

The problem is reduced to what will be the remainder when 7^8 is divided by 100

We know that $7^4 = 2401$

$7^8 = 7^4 * 7^4 = 2401 * 2401$

As we can clearly see, the last 2 digits will be 01.

Wilson's Theorem:

➔ According to Wilson's theorem for prime number 'p', [(p+1)!+1] is divisible by p.

➔ In other words, (p-1)! Leaves a remainder of (p-1) when divided by p.

Thus, **(p-1)! Mod p = p-1**

For Example:

➔ 4! When divided by 5, we get 4 as remainder.

➔ 6! When divided by 7, we get 6 as remainder.

➔ 10! When divided by 11, we get 10 as a remainder.

➔ If we extend Wilson's theorem further, we get an important corollary (p-2)! Mod p = 1

➔ As from the wilson's theorem we have, (p-1)! Mod p = (p-1)

➔ Thus, [(p-1)(p-2)!] mod p = (p-1)

➔ This will be equal to

[(p-1) mod p]*[(p-2)! Mod p] = (p-1)

➔ For any prime number 'p', we observe that (p-1) mod p = (p-1)

➔ For e.g 6 mod 7 will be 6

Thus, (p-1)*[(p-2)! Mod p] = (p-1)

thus , for RHS to be equal to LHS,

(p-2)! Mod p = 1

Hence, 5! Mod 7 will be 1 and 51! Mod 53 will be 1

- **Examples:**
- Q.1) What will be the remainder when 568! Is it divided by 569?

  Solution: According to Wilson's theorem we have for prime number 'p'. (p-1)! Mod p = (p-1)

  In this case 569 is a prime number.

  Thus, 568! Mod 569 = 568

  Hence, when 568! divided by 569 we get 568 as remainder.

  Answer: 568
- Q.2) What will be the remainder when 225! Is it divided by 227?

  Solution: We know that for the prime number 'p', (p-2)! Mod p = 1.

  In this case, 227 is a prime number.

  Thus, 225! Mod 227 will be equal to 1.

In other words, when 225! divided by 227 we get the remainder as 1.

Answer: 1

- Q.3) What will be the remainder when 15! is divided by 19?

  Solution: 19 is a prime number.

➔ From the corollary of Wilson's theorem, for prime number 'p'.

(p-2)! mod p = 1

Thus, 17! mod 19 = 1

[17*16*15!] mod 19 = 1

[17 mod 19] * [16 mod 19] * [15! mod 19] = 1

[-2] * [-3]*[15! mod 19] = 1

[6 * 15!] mod 19 = 1

➔ Multiplying both sides by 3, we get

[18*15!] mod 19 = 3

[-1*15!] mod 19 = 3

➔ Multiplying both sides by -1, we get

15! mod 19 = -3

➔ Remainder of '-3' when divided by 19 is the same as the remainder of '16' when divided by 19.

Thus 15! Mod 19 = 16

Answer: 16

- Q.4) What will be the remainder when $(23!)^2$ is divided by 47?

Solution: 47 is a prime number.

➔ From corollary of Wilson's theorem, for prime number 'p', (p-2) mod p = 1

Thus 45! mod 47 = 1

[45*44*43*.....*25*24*23!] mod 47 = 1

[(-2)*(-3)*(-4)*.....*(-22)*(-23)*23!] mod 47 = 1

➔ We see that there are even numbers of terms from '-2' to '-23'. Thus negative signs cancel off.

➔ We get [23!* 23!] mod 47 = 1

Thus, $(23!)^2$ mod 47 = 1

➔ Hence, when $(23!)^2$ is divided 47, we get 1 as a remainder.

Answer: 1

Chinese Remainder Theorem:

- The Chinese remainder theorem is useful when the divisor of any number is composite.
- Let M be a number which is divided by a divisor N. The theorem states that if N is the divisor which can be expressed as N = a*b where a and b are co-prime
- Then, M mod N = ar_2x+br_1y

  Here r_1 = M mod a

And r_2 = M mod b

Here, ax + by = 1

- **Example 1**
- Find the remainder when 344^{237} is divided by 119

  In the first look it looks difficult but if one knows the chinese remainder theorem then the question can be solved very easily.
- 119 = 17*7, so here a = 17 and b = 7

  344^{237} mod 17 =4^{237} mod 17 = ($4*16^{116}$) mod 17 = 4*1 = 4

  Hence, we get r_1=4

  Now, 344^{237} mod 7 =1^{237} mod 7 = 1, Hence r_2=1

  We know that M mod N = ar_2x +br_1y
- Therefore, 344^{237} mod 119 = 17*1x + 7*4y = 17x + 28y

  We know that 17x + 7y = 1
- We can see that x =5 and y = -12 satisfies the above equation.

Hence, putting the values of x and y in equation 1, we get 344^{237} mod 119 = 117 * 5 - 28 * 12 = 85-336 = -251 Converting this into positive remainder we get 357-251=106

- Hence, the required remainder is 106.

Example 2:

- Let's consider another example to understand is better find the remainder when 495^{2517} is divided by 78.
- In this question also, the divisor is 78 which can be written as 13*6. So, we can use the Chinese remainder theorem in this question as well.

Let's take a = 13 and b = 6

So we can write 495^{2517} mod 78 = $13r_2x+6r_1y$

➔ $r_1=495^{2517}$ mod 13 = 1^{2517} mod 13 = 1

➔ $r_2=495^{2517}$ mod 6 = 3^{2517} mod 6 = (2^{2516} mod 2)*3 =

$1 * 3 = 3$

➔ We also know that $13x + 6y = 1$

$x = 1$ and $y = -2$ satisfies the above equation.

➔ Hence, we can obtain the remainder as
$495^{2517} \bmod 78 = 13r_2x + 6r_1y = 13*3*1 - 6*1-2$
$=39-12 = 27$
Hence, the required answer is 27.

CAT Permutations & Combinations Formulas

- Permutations & Combinations, and Probability are key topics in CAT.
- You don't have to go too deep into these topics, but ensure that you learn the basics well.
- So look through this formula list a few times and understand the formulae.
- The best way to tackle this subject is by solving questions. The more questions you solve, the better you will get at this topic.
- Once you practise a good number of sums, you will start to see that all of them are generally variations of the same few themes that are listed in the formula list.

- In this slide, we will look at the important formulae on P&C, and Probability.
  - ➔ N! = N(N-1)(N-2)(N-3)....1
  - ➔ 0! = 1! = 1
  - ➔ $^nC_r = \frac{n!}{(n-r)!\,r!}$
  - ➔ $^nP_r = \frac{n!}{(n-r)!}$
- **Arrangement:**

  n items can be arranged in n! Ways
- **Permutation:**

  A way of selecting and arranging r objects out of a set of n objects, $^nP_r = \frac{n!}{(n-r)!}$
- **Combination:**
  - ➔ A way of selecting r objects out of n (arrangement does not matter) $^nC_r = \frac{n!}{(n-r)!\,r!}$

➔ Selecting r objects out of n is same as selecting (n-r) objects out of n, ${}^{n}C_{r} = {}^{n}C_{n-r}$

➔ Total selections that can be made from 'n' distinct items is given $\sum_{k=0}^{n} {}^{n}C_{k} = 2^{n}$

- **Partitioning:**

➔ Number of ways to partition n identical things in r distinct slots is given by ${}^{n+r-1}C_{r-1}$

➔ Number of ways to partition n identical things in r distinct slots so that each slot gets at least 1 is given by ${}^{n-1}C_{r-1}$

➔ Number of ways to partition n distinct things in r distinct slots is given by r^{n}

- Number of ways to partition n distinct things in r distinct slots where arrangement matters $=\frac{(n+r-1)!}{(r-1)!}$

- **Arrangement with repetitions :**
  - If x items out of n items are repeated, then the number of ways of arranging these n items is $\frac{n!}{x!}$ ways. If a items, b items and c items are repeated within n items, they can be arranged in $\frac{n!}{a!b!c!}$ ways.
- **Rank of a word :**

- To get the rank of a word in the alphabetical list of all permutations of the word, start with alphabetically arranging the n letters. If there are x letters higher than the first letter of the word, then there are at least x*(n-1)! Words above our word.
- After removing the first affixed letter from the set if there are y letters above the second letter then there are y*(n-2)! words before your word and so on. So rank of word = x*(n-1)! + y*(n-2)! + .. +1

- **Integral Solutions:**
  - ➔ Number of positive integral solutions to $x_1 + x_2 + x_3 + \ldots\ldots + x_n = s$ where $s \geq 0$ is ${}^{s-1}C_{n-1}$
  - ➔ Number of non-negative integral solutions to $x_1 + x_2 + x_3 + \ldots\ldots + x_n = s$ where $s \geq 0$ is ${}^{n+s-1}C_{n-1}$
- **Circular arrangement :**

➔ Number of ways of arranging n items around a circle are 1 for n = 1,2 and (n-1)! for n ≥ 3. If its a necklace or bracelet that can be flipped over, the possibilities are $\frac{(n-1)!}{2}$

- **Derangements :**
  - ➔ If n distinct items are arranged, the number of ways they can be arranged so that they do not occupy their intended spot is

$$D = n!\left(\frac{1}{0!} - \frac{1}{1!} + \frac{1}{2!} - \frac{1}{3!} + \ldots\ldots + \frac{(-1)^n}{n!}\right)$$

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Bayes Theorem (Conditional Probability) for CAT

- ➔ Probability is a key topic in the CAT.
- ➔ Bayes Theorem (conditional probability) is not a very important topic.
- ➔ You don't have to go too deep into this topic, but ensure that you learn the basics well.
- ➔ So look through this formula list a few times and understand the formulae.
- ➔ **Bayes Theorem (Conditional Probability) for CAT:**
- ➔ Conditional probability is used in case of events which are not independent. In the discussion of probabilities all events can be classified into 2 categories: Dependent and Independent.
- ➔ Independent events are those where the happening of one event does not affect the happening of the

other. For example, if an unbiased coin is thrown 'n' times then the probability of heads turning up in any of the attempts will be ½ . It will not be dependent on the results of the previous outcomes.

- Dependent events, on the other hand, are the events in which the outcome of the second event is dependent on the second event is dependent on the outcome of the first event.
- For example, if you have to draw two cards from a desk one after the other, then the probability of the second card being of a particular suit will depend on which card was drawn in the first attempt.
- Let us first discuss the definition of conditional probability.
- Let 'A' & 'B' be two events which are not independent then the probability of occurrence of B given that A has already occurred is given by P(B|A)=$\frac{P(A \cap B)}{P\,(A)}$

- Here, $P(A \cap B)$ is nothing but the probability of occurrence of both A & B. We often use Bayes theorem to solve problems on conditional probability.
- P(B|A)=$\frac{P(A|B)*P(B)}{P\ (A)}$
- Here P(A|B) is the probability of occurrence of A given that B has already occurred.
- P(A) is the probability of occurrence of A
- P(B) is the probability of occurrence of B
- **Example 1:**
- Let us try to understand the application of the conditional probability and Bayes theorem with the help of a few examples.
- Ravi draws two cards from a deck of 52 cards one after another. If it is known that the first card was

king then what is the probability of the second card being 'spades'?

➔ Let us use the conditional probability concept which we discussed above.

Let 'A' be the event of getting a king.

Then P(A) = $\frac{4}{52} = \frac{1}{13}$

Let 'B' be the event of getting a spade.

Then P(B) = $\frac{13}{52} = \frac{1}{4}$

Now we know that one of the spade cards is also a king, Hence, the event P (A ∩ B) contains 1 element.

Thus, P (A ∩ B) = $\frac{1}{52}$

Hence, by using the formula for conditional probability, we get P (B|A) = $\frac{P\,(A \cap B)}{P\,(A)} = \frac{\frac{1}{52}}{\frac{1}{13}} = \frac{1}{4}$

➔ **Example 2:**

➔ Let us consider another problem to get a better understanding of conditional probability.

➔ Ram plays a game of Russian roulette. He loads 2 bullets in the adjacent slots of a six slot revolver. He revolves the cylinder and then pulls the trigger. Luckily, it is an empty slot. Ram has an option either to pull the trigger again or to spin the cylinder first and then pull the trigger. What must Ram choose to maximise his chances of survival?

➔ Let us number the slots as 1,2, 3,4, 5 and 6. Let us assume that slots 1 and 2 contain the bullets. The various combinations when the trigger is pressed continuously are (1,2), (2,3), (3,4), (4,5), (5,6) and (6,1).

- ➔ We know that P (B|A) = $\frac{P(A \cap B)}{P\ (A)}$
- ➔ Here, P(A ∩ B) represents the probability in which both A and B are empty slots and p(A) represents the probability that A is an empty slot. Among the 6 combinations mentioned above, 3 combinations ((3,4), (4,5) and (5,6)) have both the slots empty.

  Therefore, n(A ∩ B) = 3 and p(A ∩ B) =$\frac{3}{6}$.
- ➔ P(A) represents the probability of the first slot being empty. The empty slot can be one among 3, 4, 5 or 6.

  Therefore, n(A) =4 and p(A ∩ B) = $\frac{4}{6}$.
- ➔ If Ram prefers to spin the cylinder, he has P(A) chances of survival (Choosing an empty slot among the given slots).

- ➔ P(A) = $\frac{4}{6}$= 66.66%. Hence, Ram must prefer to press the trigger immediately without revolving the cylinder as chances of survival will be more.
- ➔ **Example 3:**
- ➔ Let us now have a look at a very famous problem on conditional probability. This is known as the Monty Hall problem.
- ➔ There is a game show in which there are three doors. There is a car behind one door and there is nothing behind the other two doors.
- ➔ After you pick a door, the host opens one of the other two doors and shows you that it is empty. Now, he gives you two options — either stick with your initial selection or switch to the other door. What is the optimal strategy that should be followed? Will you switch or remain with the same door?
  (The host knows which door has a car behind it)

- To find the optimal strategy let's compute the probability of winning in both events.

  Without the loss of generality, let's assume that the contestant has picked the door one.

  Let W1, W2, W3 be = events that the car is behind door 1, 2, 3 respectively. Hence, $p(W1) = p(W2) = p(W3) = \frac{1}{3}$

  Let A,B and C be the events that the host opens doors 1, 2 and 3 respectively. Now, The probability that the host opens the third door provided the car is in the second door. $p(C|W2) = 1$
- The probability that the host opens the third door provided the car is in the third door is $p(C|W3) = 0$
- The probability that the host opens the third door provided the car is in the first door.
- $P(c|W1) = \frac{1}{2}$
- Now let's use Bayes theorem, chances of winning by not switching

$$P\left(W1|C\right) = \frac{P\left(C|W1\right) * P\left(W1\right)}{P\left(C\right)} = \frac{\left(\frac{1}{2}\right)*\left(\frac{1}{3}\right)}{\left(\frac{1}{2}\right)} = \frac{1}{3}$$

➔ Chances of winning by switching

$$P\left(W2|C\right) = \frac{P\left(C|W2\right) * P\left(W2\right)}{P\left(C\right)} = \frac{1 * \left(\frac{1}{3}\right)}{\left(\frac{1}{2}\right)} = \frac{2}{3}$$

➔ Therefore, it is always optimal to switch.