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EK DHIKENA P RVE•A

The Sutra (formula) Ek dhikena P rvena means: "By one more than the previous one".

i) Squares of numbers ending in 5 :

Now we relate the sutra to the 'squaring of numbers ending in 5'. Consider the example 25^2 .

Here the number is 25. We have to find out the square of the number. For the number 25, the last digit is 5 and the 'previous' digit is 2. Hence, 'one more than the previous one', that is, $2+1=3$. The Sutra, in this context, gives the procedure 'to multiply the previous digit 2 by one more than itself, that is, by 3'. It becomes the L.H.S (left hand side) of the result, that is, $2 \times 3 = 6$. The R.H.S (right hand side) of the result is 5^2 , that is, 25.

Thus $25^2 = 2 \times 3 / 25 = 625$.

In the same way,

$$35^2 = 3 \times (3+1) / 25 = 3 \times 4 / 25 = 1225;$$

$$65^2 = 6 \times 7 / 25 = 4225;$$

$$105^2 = 10 \times 11 / 25 = 11025;$$

$$135^2 = 13 \times 14 / 25 = 18225;$$

Apply the formula to find the squares of the numbers 15, 45, 85, 125, 175 and verify the answers.

Algebraic proof:

a) Consider $(ax + b)^2 \equiv a^2 \cdot x^2 + 2abx + b^2$.

This identity for $x = 10$ and $b = 5$ becomes

$$\begin{aligned}(10a + 5)^2 &= a^2 \cdot 10^2 + 2 \cdot 10a \cdot 5 + 5^2 \\ &= a^2 \cdot 10^2 + a \cdot 10^2 + 5^2 \\ &= (a^2 + a) \cdot 10^2 + 5^2 \\ &= a(a + 1) \cdot 10^2 + 25.\end{aligned}$$

Clearly $10a + 5$ represents two-digit numbers 15, 25, 35, -----, 95 for the values $a = 1, 2, 3, \dots, 9$ respectively. In such a case the number $(10a + 5)^2$ is of the form whose L.H.S is **$a(a + 1)$** and R.H.S is 25, that is, **$a(a + 1) / 25$** .

Thus any such two digit number gives the result in the same fashion.

Example: $45 = (40 + 5)^2$, It is of the form $(ax+b)^2$ for $a = 4$, $x=10$ and $b = 5$. giving the answer $a(a+1) / 25$ that is, $4(4+1) / 25 + 4 \times 5 / 25 = 2025$.

b) Any three digit number is of the form ax^2+bx+c for $x = 10$, $a \neq 0$, $a, b, c \in \mathbb{W}$.

$$\begin{aligned}\text{Now } (ax^2+bx+c)^2 &= a^2 x^4 + b^2 x^2 + c^2 + 2abx^3 + 2bcx + 2cax^2 \\ &= a^2 x^4 + 2ab \cdot x^3 + (b^2 + 2ca)x^2 + 2bc \cdot x + c^2.\end{aligned}$$

This identity for $x = 10$, $c = 5$ becomes $(a \cdot 10^2 + b \cdot 10 + 5)^2$

$$\begin{aligned}&= a^2 \cdot 10^4 + 2 \cdot a \cdot b \cdot 10^3 + (b^2 + 2 \cdot 5 \cdot a)10^2 + 2 \cdot b \cdot 5 \cdot 10 + 5^2 \\ &= a^2 \cdot 10^4 + 2 \cdot a \cdot b \cdot 10^3 + (b^2 + 10a)10^2 + b \cdot 10^2 + 5^2 \\ &= a^2 \cdot 10^4 + 2ab \cdot 10^3 + b^2 \cdot 10^2 + a \cdot 10^3 + b \cdot 10^2 + 5^2 \\ &= a^2 \cdot 10^4 + (2ab + a) \cdot 10^3 + (b^2 + b)10^2 + 5^2\end{aligned}$$

$$\begin{aligned}
&= [a^2 \cdot 10^2 + 2ab \cdot 10 + a \cdot 10 + b^2 + b] 10^2 + 5^2 \\
&= (10a + b) (10a+b+1) \cdot 10^2 + 25 \\
&= P (P+1) 10^2 + 25, \text{ where } P = 10a+b.
\end{aligned}$$

Hence any three digit number whose last digit is 5 gives the same result as in **(a)** for $P=10a + b$, the 'previous' of 5.

Example : $165^2 = (1 \cdot 10^2 + 6 \cdot 10 + 5)^2$.

It is of the form $(ax^2 + bx + c)^2$ for $a = 1$, $b = 6$, $c = 5$ and $x = 10$. It gives the answer $P(P+1) / 25$, where $P = 10a + b = 10 \times 1 + 6 = 16$, the 'previous'. The answer is $16 (16+1) / 25 = 16 \times 17 / 25 = 27225$.

Apply *Ekadhikena purvena* to find the squares of the numbers 95, 225, 375, 635, 745, 915, 1105, 2545.

ii) Vulgar fractions whose denominators are numbers ending in NINE :

We now take examples of $1 / a9$, where $a = 1, 2, \dots, 9$. In the conversion of such vulgar fractions into recurring decimals, Ekadhika process can be effectively used both in division and multiplication.

a) Division Method : Value of $1 / 19$.

The numbers of decimal places before repetition is the difference of numerator and denominator, i.e., $19 - 1 = 18$ places.

For the denominator 19, the *purva* (previous) is 1.

Hence *Ekadhikena purva* (one more than the previous) is $1 + 1 = 2$.

The sutra is applied in a different context. Now the method of division is as follows:

Step. 1 : Divide numerator 1 by 20.

$$\text{i.e.,, } 1 / 20 = 0.1 / 2 = .1_0 \text{ (0 times, 1 remainder)}$$

Step. 2 : Divide 10 by 2

$$\text{i.e.,, } 0.0_5 \text{ (5 times, 0 remainder)}$$

Step. 3 : Divide 5 by 2

$$\text{i.e.,, } 0.05_1 \text{ (2 times, 1 remainder)}$$

Step. 4 : Divide $_1 2$ i.e., 12 by 2

$$\text{i.e.,, } 0.052_6 \text{ (6 times, No remainder)}$$

Step. 5 : Divide 6 by 2

$$\text{i.e.,, } 0.0526_3 \text{ (3 times, No remainder)}$$

Step. 6 : Divide 3 by 2

$$\text{i.e.,, } 0.05263_1 \text{ (1 time, 1 remainder)}$$

Step. 7 : Divide $_1 1$ i.e., 11 by 2

$$\text{i.e.,, } 0.052631_5 \text{ (5 times, 1 remainder)}$$

Step. 8 : Divide $_1 5$ i.e., 15 by 2

$$\text{i.e.,, } 0.0526315_7 \text{ (7 times, 1 remainder)}$$

Step. 9 : Divide $_1 7$ i.e., 17 by 2

$$\text{i.e.,, } 0.05263157_8 \text{ (8 times, 1 remainder)}$$

Step. 10 : Divide 18 i.e., 18 by 2

i.e., 0.0526315789 (9 times, No remainder)

Step. 11 : Divide 9 by 2

i.e., 0.0526315789 14 (4 times, 1 remainder)

Step. 12 : Divide 14 i.e., 14 by 2

i.e., 0.052631578947 (7 times, No remainder)

Step. 13 : Divide 7 by 2

i.e., 0.052631578947 13 (3 times, 1 remainder)

Step. 14 : Divide 13 i.e., 13 by 2

i.e., 0.0526315789473 16 (6 times, 1 remainder)

Step. 15 : Divide 16 i.e., 16 by 2

i.e., 0.052631578947368 (8 times, No remainder)

Step. 16 : Divide 8 by 2

i.e., 0.0526315789473684 (4 times, No remainder)

Step. 17 : Divide 4 by 2

i.e., 0.05263157894736842 (2 times, No remainder)

Step. 18 : Divide 2 by 2

i.e., 0.052631578947368421 (1 time, No remainder)

Now from step 19, i.e., dividing 1 by 2 , Step 2 to Step. 18 repeats thus giving

$$1 / 19 = 0.052631578947368421 \text{ or } 0.052631578947368421$$

Note that we have completed the process of division only by using '2'. Nowhere the division by 19 occurs.

b) Multiplication Method: Value of $1 / 19$

First we recognize the last digit of the denominator of the type $1 / a9$. Here the last digit is 9.

For a fraction of the form in whose denominator 9 is the last digit, we take the case of $1 / 19$ as follows:

For $1 / 19$, 'previous' of 19 is 1. And one more than of it is $1 + 1 = 2$.

Therefore 2 is the multiplier for the conversion. We write the last digit in the numerator as 1 and follow the steps leftwards.

- Step. 1 :** 1
- Step. 2 :** 21 (multiply 1 by 2, put to left)
- Step. 3 :** 421 (multiply 2 by 2, put to left)
- Step. 4 :** 8421 (multiply 4 by 2, put to left)
- Step. 5 :** 168421 (multiply 8 by 2 = 16,
1 carried over, 6 put to left)
- Step. 6 :** 1368421 ($6 \times 2 = 12, +1$ [carry over]
= 13, 1 carried over, 3 put to left)
- Step. 7 :** 7368421 ($3 \times 2, = 6 +1$ [Carryover]
= 7, put to left)
- Step. 8 :** 147368421 (as in the same process)

Step. 9 : 947368421 (Do – continue to step 18)

Step. 10 : ${}_1$ 8947368421

Step. 11 : ${}_1$ 78947368421

Step. 12 : ${}_1$ 578947368421

Step. 13 : ${}_1$ 1578947368421

Step. 14 : 31578947368421

Step. 15 : 631578947368421

Step. 16 : ${}_1$ 2631578947368421

Step. 17 : 52631578947368421

Step. 18 : 1052631578947368421

Now from step 18 onwards the same numbers and order towards left continue.

Thus $1 / 19 = 0.052631578947368421$

It is interesting to note that we have

i) not at all used division process

ii) instead of dividing 1 by 19 continuously, just multiplied 1 by 2 and continued to multiply the resultant successively by 2.

Observations :

a) For any fraction of the form $1 / a9$ i.e., in whose denominator 9 is the digit in the units place and a is the set of remaining digits, the value of the fraction is in recurring decimal form and the repeating block's right most digit is 1.

b) Whatever may be a9, and the numerator, it is enough to follow the said

process with $(a+1)$ either in division or in multiplication.

c) Starting from right most digit and counting from the right, we see (in the given example $1 / 19$)

$$\text{Sum of 1}^{\text{st}} \text{ digit} + 10^{\text{th}} \text{ digit} = 1 + 8 = 9$$

$$\text{Sum of 2}^{\text{nd}} \text{ digit} + 11^{\text{th}} \text{ digit} = 2 + 7 = 9$$

$$\text{Sum of 9th digit} + 18^{\text{th}} \text{ digit} = 9 + 0 = 9$$

From the above observations, we conclude that if we find first 9 digits, further digits can be derived as complements of 9.

i) Thus at the step 8 in division process we have 0.0526315_17 and next step. 9 gives 0.052631578

Now the complements of the numbers

0, 5, 2, 6, 3, 1, 5, 7, 8 from 9

9, 4, 7, 3, 6, 8, 4, 2, 1 follow the right order

i.e., 0.052631578947368421

Now taking the multiplication process we have

Step. 8 : ${}_147368421$

Step. 9 : 947368421

Now the complements of 1, 2, 4, 8, 6, 3, 7, 4, 9 from 9

i.e., 8, 7, 5, 1, 3, 6, 2, 5, 0 precede in successive steps,

giving the answer.

$0.052631578947368421.$

d) When we get (Denominator – Numerator) as the product in the multiplicative process, half the work is done. We stop the multiplication there and mechanically

write the remaining half of the answer by merely taking down complements from 9.

e) Either division or multiplication process of giving the answer can be put in a single line form.

Algebraic proof :

Any vulgar fraction of the form $1 / a9$ can be written as

$$1 / a9 = 1 / ((a + 1) x - 1) \text{ where } x = 10$$

$$= \frac{1}{(a + 1) x [1 - 1/(a+1)x]}$$

$$= \frac{1}{(a + 1) x} [1 - 1/(a+1)x]^{-1}$$

$$= \frac{1}{(a + 1) x} [1 + 1/(a+1)x + 1/(a+1)x^2 + \dots]$$

$$= 1/(a+1)x + 1/(a+1)^2x^2 + 1/(a+1)^3x^3 + \dots \text{ ad infinitum}$$

$$= 10^{-1}(1/(a+1)) + 10^{-2}(1/(a+1)^2) + 10^{-3}(1/(a+1)^3) + \dots \text{ ad infinitum}$$

This series explains the process of *ekadhik*.

Now consider the problem of $1 / 19$. From above we get

$$1 / 19 = 10^{-1} (1/(1+1)) + 10^{-2} (1/(1+1)^2) + 10^{-3} (1/(1+1)^3) + \dots$$

(since a=1)

$$= 10^{-1} (1/2) + 10^{-2} (1/2)^2 + 10^{-3} (1/2)^3 + \dots$$

$$\begin{aligned}
&= 10^{-1} (0.5) + 10^{-2} (0.25) + 10^{-3} (0.125) + \text{-----} \\
&= 0.05 + 0.0025 + 0.000125 + 0.00000625 + \text{-----} \\
&= 0.052631 \text{-----}
\end{aligned}$$

Example1 :

1. Find $1 / 49$ by *ekadhikena* process.

Now 'previous' is 4. 'One more than the previous' is $4 + 1 = 5$.

Now by division right ward from the left by '5'.

$$\begin{aligned}
1 / 49 &= .10 \text{-----} \text{---(divide 1 by 50)} \\
&= .02 \text{-----} \text{---(divide 2 by 5, 0 times, 2 remainder)} \\
&= .02_20 \text{-----} \text{---(divide 20 by 5, 4 times)} \\
&= .0204 \text{-----} \text{---(divide 4 by 5, 0 times, 4 remainder)} \\
&= .0204_40 \text{-----} \text{---(divide 40 by 5, 8 times)} \\
&= .020408 \text{-----} \text{---(divide 8 by 5, 1 time, 3 remainder)} \\
&= .020408_31 \text{-----} \text{---(divide 31 by 5, 6 times, 1 remainder)} \\
&= .0204081_6 \text{-----} \text{--- continue} \\
&= .02040816_1332_26_15306_11_12_2_2_4_4_4_8 \text{-----}
\end{aligned}$$

On completing 21 digits, we get 48

i.e., Denominator - Numerator = $49 - 1 = 48$ stands.

i.e, half of the process stops here. The remaining half can be obtained as

complements from 9.

$$\text{Thus } 1 / 49 = 0.020408163265306122448$$

$$979591836734693877551$$

Now finding 1 / 49 by process of multiplication left ward from right by 5, we get

$$\begin{aligned} 1 / 49 &= \text{-----}1 \\ &= \text{-----}51 \\ &= \text{-----}2551 \\ &= \text{-----}27551 \\ &= \text{----} 48_3 9_4 7_2 9_4 59_4 1_1 8_3 3_3 6_1 7_2 3_3 4_4 69_4 3_3 8_3 7_2 7551 \end{aligned}$$

i.e., Denominator – Numerator = 49 – 1 = 48 is obtained as 5X9+3

(Carry over) = 45 + 3 = 48. Hence half of the process is over. The remaining half is automatically obtained as complements of 9.

$$\text{Thus } 1 / 49 = \text{-----}979591836734693877551$$

$$= 0.020408163265306122448$$

$$979591836734693877551$$

Example 2: Find 1 / 39 by Ekadhika process.

Now by multiplication method, Ekadhikena purva is 3 + 1 = 4

$$1 / 39 = \text{-----}1$$

$$= \text{-----}41$$

$$= \text{-----}1641$$

$$= \text{-----}_25641$$

$$= \text{-----}_225641$$

$$= \text{-----}_1025641$$

Here the repeating block happens to be block of 6 digits. Now the rule predicting the completion of half of the computation does not hold. The complete block has to be computed by *ekadhika* process.

Now continue and obtain the result. Find reasons for the non-applicability of the said 'rule'.

Find the recurring decimal form of the fractions $1 / 29$, $1 / 59$, $1 / 69$, $1 / 79$, $1 / 89$ using Ekadhika process if possible. Judge whether the rule of completion of half the computation holds good in such cases.

Note : The Ekadhikena Purvena sutra can also be used for conversion of vulgar fractions ending in 1, 3, 7 such as $1 / 11$, $1 / 21$, $1 / 31$ - - - , $1 / 13$, $1 / 23$, - - - , $1 / 7$, $1 / 17$, - - - - - by writing them in the following way and solving them.

3 4

Vedic Mathematics | **Upa-Sutras anurupyena****NUR PYENA**

The upa-Sutra 'anurupyena' means 'proportionality'. This Sutra is highly useful to find products of two numbers when both of them are near the Common bases i.e powers of base 10 . It is very clear that in such cases the expected 'Simplicity ' in doing problems is absent.

Example 1: 46 X 43

As per the previous methods, if we select 100 as base we get

$$\begin{array}{r} 46 \quad -54 \\ 43 \quad -57 \\ \hline \end{array} \quad \text{This is much more difficult and of no use.}$$

Now by 'anurupyena' we consider a working base In three ways. We can solve the problem.

Method 1: Take the nearest higher multiple of 10. In this case it is 50.

Treat it as $100 / 2 = 50$. Now the steps are as follows:

i) Choose the working base near to the numbers under consideration.
i.e., working base is $100 / 2 = 50$

ii) Write the numbers one below the other

$$\begin{array}{r} \text{i.e.} \quad 4 \quad 6 \\ \quad \quad 4 \quad 3 \\ \hline \end{array}$$

iii) Write the differences of the two numbers respectively from 50 against each number on right side

$$\begin{array}{r} \text{i.e.} \quad 46 \quad -04 \\ \quad \quad 43 \quad -07 \\ \hline \end{array}$$

iv) Write cross-subtraction or cross- addition as the case may be under the line drawn.

$$\begin{array}{r}
 46 \quad -04 \\
 43 \quad -07 \\
 \hline
 (46 - 7) \text{ or} \\
 (43 - 4) \\
 \hline
 = 39
 \end{array}$$

v) Multiply the differences and write the product in the left side of the answer.

$$\begin{array}{r}
 46 \quad -04 \\
 43 \quad -07
 \end{array}$$

$$\overline{39 / -4 \times -7}$$

$$= 28$$

vi) Since base is $100 / 2 = 50$, 39 in the answer represents 39×50 .

Hence divide 39 by 2 because $50 = 100 / 2$

Thus $39 \div 2$ gives $19\frac{1}{2}$ where 19 is quotient and 1 is remainder. This 1 as Remainder gives one 50 making the L.H.S of the answer $28 + 50 = 78$ (or Remainder $\frac{1}{2} \times 100 + 28$)

i.e. R.H.S 19 and L.H.S 78 together give the answer 1978 We represent it as

$$\begin{array}{r}
 46 \quad -04 \\
 43 \quad -07 \\
 \hline
 2) \quad 39 / 28 \\
 \hline
 19\frac{1}{2} / 28 \\
 \\
 = 19 / 78 = 1978
 \end{array}$$

Example 2: 42×48 .

With $100 / 2 = 50$ as working base, the problem is as follows:

$$\begin{array}{r}
 42 \quad -08 \\
 48 \quad -02
 \end{array}$$

$$\begin{array}{r} \text{-----} \\ 2) 40 \ / \ 16 \\ \text{-----} \end{array}$$

$$20 \ / \ 16$$

$$42 \times 48 = 2016$$

Method 2: For the **example 1:** 46X43. We take the same working base 50. We treat it as 50=5X10. i.e. we operate with 10 but not with 100 as in method

now

$$\begin{array}{r} 46 \quad -04 \\ 43 \quad -07 \\ \hline (46 - 7) \text{ or } -4 \times -7 \\ (43 - 4) \quad \quad \quad = 28 \\ = 39 \quad \quad \quad \quad = 28 \\ \hline 39 \times 5 \quad \quad \quad 8 \\ +2 \\ (\text{carried over}) \end{array}$$

$$(195 + 2) / 8 = 1978$$

[Since we operate with 10, the R.H.S portion shall have only unit place .Hence out of the product 28, 2 is carried over to left side. The L.H.S portion of the answer shall be multiplied by 5, since we have taken 50 = 5 X 10.]

Now in the **example 2:** 42 x 48 we can carry as follows by treating 50 = 5 x 10

$$\begin{array}{r} 42 \quad -08 \\ 48 \quad -02 \\ \hline 40 \quad \quad \quad 16 \\ \times 5 \quad \quad \quad \quad \quad \\ \hline 200 \quad \quad \quad 16 \quad = 2016 \end{array}$$

Method 3: We take the nearest lower multiple of 10 since the numbers are 46 and 43 as in the first example, We consider 40 as working base and treat it as 4 X 10.

$$\begin{array}{r}
 46 \quad 06 \\
 43 \quad 03 \\
 \hline
 (46 + 3) \text{ or } 6 \times 3 \\
 (43 + 6) \\
 = 49 \qquad \qquad = 18
 \end{array}$$

Since 10 is in operation 1 is carried out digit in 18.

Since 4×10 is working base we consider 49×4 on L.H.S of answer i.e. 196 and 1 carried over the left side, giving L.H.S. of answer as 1978. Hence the answer is 1978.

We proceed in the same method for 42×48

$$\begin{array}{r}
 42 \quad 02 \\
 48 \quad 08 \\
 \hline
 50 \quad \quad 16 \\
 \times 4 \quad \quad \quad \quad \\
 \hline
 200 \quad \quad 16 \\
 \hline
 \quad \quad \quad = 2016
 \end{array}$$

working base $4 \times 10 = 40$
since 10 is in operation

Let us see the all the three methods for a problem at a glance

Example 3: 24×23

Method - 1: Working base = $100 / 5 = 20$

$$\begin{array}{r}
 24 \quad 04 \\
 23 \quad 03 \\
 \hline
 5) \quad 27 / 12 \\
 \hline
 5 \frac{2}{5} / 12 \quad = \quad 5 / 52 \quad = \quad 552
 \end{array}$$

[Since $2 / 5$ of 100 is $2 / 5 \times 100 = 40$ and $40 + 12 = 52$]

Method - 2: Working base $2 \times 10 = 20$

$$\begin{array}{r}
 24 \quad 04 \\
 23 \quad 03 \\
 \hline
 27 \quad / \quad 12 \\
 \times 2 \quad / \\
 \hline
 54 \quad / \quad 12 = 552
 \end{array}$$

it is more convenient than
method-1 Guss the reason

Now as 20 itself is nearest lower multiple of 10 for the problem under consideration, the case of method – 3 shall not arise.

Let us take another example and try all the three methods.

Example 4: 492 X 404

Method - 1 : working base = 1000 / 2 = 500

$$\begin{array}{r}
 492 \quad -008 \\
 404 \quad -096 \\
 \hline
 \text{2) } 396 \quad / \quad 768 \quad \text{since 1000 is in operation} \\
 \hline
 198 \quad / \quad 768 \quad = 198768
 \end{array}$$

Method 2: working base = 5 x 100 = 500

$$\begin{array}{r}
 492 \quad -008 \\
 404 \quad -096 \\
 \hline
 396 \quad / \quad 768 \\
 \times 5 \quad / \\
 \hline
 1980 \quad / \quad 768 \quad = 198768
 \end{array}$$

Method - 3.

Since 400 can also be taken as working base, treat 400 = 4 X 100 as working base.

Thus

$$\begin{array}{r}
 492 \quad 092 \\
 404 \quad 004 \quad \text{since 100 is in operation} \\
 \hline
 496 \quad 368 \\
 \times 4 \\
 \hline
 1984 \quad 368 \quad = 198768
 \end{array}$$

No need to repeat that practice in these methods finally takes us to work out all these mentally and getting the answers straight away in a single line.

Example 5: 3998 X 4998

$$\text{Working base} = 10000 / 2 = 5000$$

$$\begin{array}{r}
 3998 \quad -1002 \\
 4998 \quad -0002 \\
 \hline
 \end{array}$$

$$2) 3996 / 2004 \quad \text{since 10,000 is in operation}$$

$$1998 / 2004 \quad = 19982004$$

or taking working base = 5 x 1000 = 5,000 and

$$\begin{array}{r}
 3998 \quad -1002 \\
 4998 \quad -0002 \quad \text{since 2 is carried out} \\
 \hline
 3996 \quad 2004 \\
 \times 5 \\
 \hline
 19980 \quad 2004 \quad = 19982004
 \end{array}$$

What happens if we take 4000 i.e. 4 X 1000 as working base?

$$\begin{array}{r}
 3998 \quad 0002 \\
 4998 \quad 0998 \quad \text{Since 1000 is an operation} \\
 \hline
 4996 / 1996
 \end{array}$$

As 1000 is in operation, 1996 has to be written as ${}_1996$ and 4000 as base, the L.H.S portion 5000 has to be multiplied by 4. i. e. the answer is

$$\begin{array}{r|l}
 4996 & \overline{1996} \\
 \times 4 & \\
 \hline
 19982 & 004 \\
 \hline
 & = 19982004
 \end{array}$$

A simpler example for better understanding.

Example 6: 58×48

Working base $50 = 5 \times 10$ gives

$$\begin{array}{r|l}
 50 & +8 \\
 48 & \overline{2} \\
 \hline
 56 & \overline{16} \\
 \times 5 & \\
 \hline
 280 & \overline{16} \\
 \hline
 & = 280 / 4 = 2784
 \end{array}$$

Since 10 is in operation.

Use anurupyena by selecting appropriate working base and method.

Find the following product.

1. 46×46

2. 57×57

3. 54×45

4. 18×18

5. 62×48

6. 229×230

7. 47×96

8. 87965×99996

9. 49×499

10. 389×512

NIKHILAM NAVATAS' CARAMAM DASATAH

The formula simply means : "all from 9 and the last from 10"

The formula can be very effectively applied in multiplication of numbers, which are nearer to bases like 10, 100, 1000 i.e., to the powers of 10 . The procedure of multiplication using the Nikhilam involves minimum number of steps, space, time saving and only mental calculation. The numbers taken can be either less or more than the base considered.

The difference between the number and the base is termed as deviation. Deviation may be positive or negative. Positive deviation is written without the positive sign and the negative deviation, is written using Rekhank (a bar on the number). Now observe the following table.

Number	Base	Number – Base	Deviation
14	10	14 - 10	4
8	10	8 - 10	-2 or $\overline{2}$
97	100	97 - 100	-03 or $\overline{03}$
112	100	112 - 100	12
993	1000	993 - 1000	-007 or $\overline{007}$
1011	1000	1011 - 1000	011

Some rules of the method (near to the base) in Multiplication

a) Since deviation is obtained by Nikhilam sutra we call the method as Nikhilam multiplication.

Eg : 94. Now deviation can be obtained by 'all from 9 and the last from 10' sutra i.

e., the last digit 4 is from 10 and remaining digit 9 from 9 gives 06.

b) The two numbers under consideration are written one below the other. The deviations are written on the right hand side.

Eg : Multiply 7 by 8.

Now the base is 10. Since it is near to both the numbers,

we write the numbers one below the other.

Take the deviations of both the numbers from the base and represent

$$\begin{array}{r} 7 \\ 8 \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ \hline 3 \end{array}$$

Rekhank or the minus sign before the deviations

$$\begin{array}{r} 8 \\ \hline \bar{2} \end{array}$$

$$\begin{array}{r} \hline \hline \end{array}$$

or $\begin{array}{r} 7 \\ \hline -3 \end{array}$
 $\begin{array}{r} 8 \\ \hline -2 \end{array}$

$$\begin{array}{r} \hline \hline \end{array}$$

or remainders 3 and 2 implies that the numbers to be multiplied are both less than 10

c) The product or answer will have two parts, one on the left side and the other on the right. A vertical or a slant line i.e., a slash may be drawn for the demarcation of the two parts i.e.,

$$\begin{array}{r} 7 \quad \bar{3} \\ 8 \quad \bar{2} \\ \hline \diagup \\ \hline \end{array}$$

(or)

$$\begin{array}{r} 7 \quad -3 \\ 8 \quad -2 \\ \hline \diagup \\ \hline \end{array}$$

d) The R.H.S. of the answer is the product of the deviations of the numbers. It shall contain the number of digits equal to number of zeroes in the base.

i.e., $\begin{array}{r} 7 \\ \hline \bar{3} \\ \hline \end{array}$

$$\begin{array}{r} 8 \quad 2 \\ \hline / (3 \times 2) = 6 \end{array}$$

Since base is 10, 6 can be taken as it is.

e) L.H.S of the answer is the sum of one number with the deviation of the other. It can be arrived at in any one of the four ways.

i) Cross-subtract deviation 2 on the second row from the original number 7 in the first row i.e., $7 - 2 = 5$.

ii) Cross-subtract deviation 3 on the first row from the original number 8 in the second row (converse way of (i))
i.e., $8 - 3 = 5$

iii) Subtract the base 10 from the sum of the given numbers.
i.e., $(7 + 8) - 10 = 5$

iv) Subtract the sum of the two deviations from the base.
i.e., $10 - (3 + 2) = 5$

Hence 5 is left hand side of the answer.

$$\begin{array}{r} \text{Thus} \quad 7 \quad \bar{3} \\ \quad \quad 8 \quad \bar{2} \\ \quad \quad \text{-----} \\ \quad \quad 5 \quad / \end{array}$$

Now (d) and (e) together give the solution

$$\begin{array}{r} 7 \quad \bar{3} \quad \quad \quad 7 \\ 8 \quad \bar{2} \quad \text{i.e.,} \quad \times \quad 8 \\ \text{-----} \quad \quad \quad \text{-----} \\ 5 \quad / \quad 6 \quad \quad \quad 56 \end{array}$$

f) If R.H.S. contains less number of digits than the number of zeros in the base, the remaining digits are filled up by giving zero or zeroes on the left side of the R. H.S. If the number of digits are more than the number of zeroes in the base, the

excess digit or digits are to be added to L.H.S of the answer.

The general form of the multiplication under Nikhilam can be shown as follows :

Let N_1 and N_2 be two numbers near to a given base in powers of 10, and D_1 and D_2 are their respective deviations from the base. Then $N_1 \times N_2$ can be represented as

$$\begin{array}{r} N_1 \qquad D_1 \\ N_2 \qquad D_2 \\ \hline (N_1 + D_2) \text{ or } D_1 \times D_2 \\ (N_2 + D_1) \end{array}$$

Case (i) : Both the numbers are lower than the base. We have already considered the example 7×8 , with base 10.

Now let us solve some more examples by taking bases 100 and 1000 respectively.

Ex. 1: Find 97×94 . Here base is 100. Now following the rules, the working is as follows:

$$\begin{array}{r} 97 \qquad \overline{03} \\ 94 \qquad \overline{06} \\ \hline (97 - 06) \text{ or } 3 \times 6 \\ (94 - 03) \end{array}$$

Ex. 2: 98×97 Base is 100.

$$\begin{array}{r} 98 \qquad \overline{02} \\ 97 \qquad \overline{03} \\ \hline (98 - 03) \text{ or } 2 \times 3 \\ (97 - 02) \end{array}$$

Ex. 3: 75X95. Base is 100.

$$\begin{array}{r}
 75 \qquad \overline{25} \\
 95 \qquad \overline{05} \\
 \hline
 (75 - 05) \text{ or } 25 \times 5 = 70/125 \text{ (observe rule-f)} \\
 (95 - 25) \qquad \qquad \qquad = (70+1)/25 = 7125
 \end{array}$$

Ex. 4: 986 X 989. Base is 1000.

$$\begin{array}{r}
 986 \qquad \overline{014} \\
 989 \qquad \overline{011} \\
 \hline
 (986 - 14) \text{ or } 14 \times 11 = 975/154 = 975154 \\
 (989 - 14)
 \end{array}$$

Ex. 5: 994X988. Base is 1000.

$$\begin{array}{r}
 994 \qquad \overline{006} \\
 988 \qquad \overline{012} \\
 \hline
 (994 - 12) \text{ or } 6 \times 12 = 982/072 \text{ (rule-f)} \\
 (988 - 06) \qquad \qquad \qquad = 982072
 \end{array}$$

Ex. 6: 750X995.

$$\begin{array}{r}
 750 \qquad \overline{250} \\
 995 \qquad \overline{005} \\
 \hline
 (750 - 005) \text{ or } 250 \times 5 = 745/1250 \text{ (rule-f)} \\
 (995 - 250) \qquad \qquad \qquad = 746250
 \end{array}$$

Case (ii) : Both the numbers are higher than the base.

The method and rules follow as they are. The only difference is the positive deviation. Instead of cross – subtract, we follow cross – add.

Ex. 7: 13X12. Base is 10

$$\begin{array}{r}
 13 \quad 03 \\
 12 \quad 02 \\
 \hline
 (13 + 02) \text{ or } 3 \times 2 = 15/6 = 156 \\
 (12 + 03)
 \end{array}$$

Ex. 8: 18X14. Base is 10.

$$\begin{array}{r}
 18 \quad 08 \\
 14 \quad 04 \\
 \hline
 (18 + 06) \text{ or } 8 \times 4 = 22/32 \\
 (14 + 03) \quad \quad \quad \text{(rule - f, 3 carry over)} \\
 \hline
 = 252
 \end{array}$$

Ex. 9: 104X102. Base is 100.

$$\begin{array}{r}
 104 \quad 04 \\
 102 \quad 02 \\
 \hline
 106 / 4 \times 2 = 10608 \quad (\text{rule - f})
 \end{array}$$

Ex. 10: 1275X1004. Base is 1000.

$$\begin{array}{r}
 1275 \quad 275 \\
 1004 \quad 004 \\
 \hline
 1279 / 275 \times 4 = 1279 / {}_1100 \quad (\text{rule - f}) \\
 \hline
 = 1280100
 \end{array}$$

Case (iii): One number is more and the other is less than the base.

In this situation one deviation is positive and the other is negative. So the product of deviations becomes negative. So the right hand side of the answer obtained will therefore have to be subtracted. To have a clear representation and understanding a vinculum is used. It proceeds into normalization.

Ex.11: 13X7. Base is 10

$$\begin{array}{r}
 13 \qquad 03 \\
 7 \qquad \overline{03} \\
 \hline
 (13 - 03) \text{ or } 3 \times \overline{3} = 10 / \overline{9} = 100 - 9 = 91 \\
 (7 + 03)
 \end{array}$$

Note : Conversion of common number into vinculum number and vice versa.

Eg :

$$9 = 10 - 1 = \overline{11}$$

$$98 = 100 - 2 = 10\overline{2}$$

$$196 = 200 - 4 = 20\overline{4}$$

$$\overline{32} = 30 - 2 = 28$$

$$14\overline{5} = 140 - 5 = 135$$

$$32\overline{2} = 300 - 22 = 278. \text{ etc}$$

The procedure can be explained in detail using Nikhilam Navatascaram Dasatah, Ekadhikena purvena, Ekanyunena purvena in the foregoing pages of this book.]

Ex. 12: 108 X 94. Base is 100.

$$\begin{array}{r}
 108 \qquad 08 \\
 94 \qquad \overline{06} \\
 \hline
 (108 - 06) \text{ or } 8 \times \overline{6} = 102 / \overline{48} = 10152 \\
 (94 + 08) \qquad \qquad \qquad \text{(Since the complement } \\
 \qquad \qquad \qquad \qquad \qquad \text{of 48 is 52 - base 10)}
 \end{array}$$

Ex. 13: 998 X 1025. Base is 1000.

$$\begin{array}{r}
 998 \quad \overline{002} \\
 1025 \quad \overline{025} \\
 \hline
 (998 - 25) \text{ or } \overline{2} \times 25 = 1023 / \overline{050} = 1022950 \\
 (1025 + 2) \quad \hline
 \end{array}$$

(Since the complement of 50 is 950 for the base 1000

Algebraic Proof:

Case (i):

Let the two numbers N_1 and N_2 be less than the selected base say x .

$N_1 = (x-a)$, $N_2 = (x-b)$. Here a and b are the corresponding deviations of the numbers N_1 and N_2 from the base x . Observe that x is a multiple of 10.

$$\text{Now } N_1 \times N_2 = (x-a)(x-b) = x \cdot x - x \cdot b - a \cdot x + ab$$

$$= x(x - a - b) + ab. \text{ [rule - e(iv), d]}$$

$$= x[(x - a) - b] + ab = x(N_1 - b) + ab \text{ [rule - e(i), d]}$$

$$\text{or } = x[(x - b) - a] = x(N_2 - a) + ab. \text{ [rule - e(ii), d]}$$

$x(x - a - b) + ab$ can also be written as

$$x[(x - a) + (x - b) - x] + ab = x[N_1 + N_2 - x] + ab \text{ [rule - e(iii), d]}.$$

A difficult can be faced, if the vertical multiplication of the deficit digits or deviations i.e., $a \cdot b$ yields a product consisting of more than the required digits. Then rule-f will enable us to surmount the difficulty.

Case (ii) :

When both the numbers exceed the selected base, we have $N_1 = x + a$, $N_2 = x + b$, x being the base. Now the identity $(x+a)(x+b) = x(x+a+b) + a \cdot b$ holds good, of course with relevant details mentioned in case (i).

Case (iii) :

When one number is less and another is more than the base, we can use $(x-a)(x+b) = x(x-a+b) - ab$. and the procedure is evident from the examples given.

Find the following products by Nikhilam formula.

1) 7×4

2) 93×85

3) 875×994

4) 1234×1002

5) 1003×997

6) 11112×9998

7) 1234×1002

8) 118×105

Nikhilam in Division

Consider some two digit numbers (dividends) and same divisor 9. Observe the following example.

i) $13 \div 9$ The quotient (Q) is 1, Remainder (R) is 4.

since $9 > 13$ (1

9

—
4

ii) $34 \div 9$, Q is 3, R is 7.

iii) $60 \div 9$, Q is 6, R is 6.

iv) $80 \div 9$, Q is 8, R is 8.

Now we have another type of representation for the above examples as given hereunder:

i) Split each dividend into a left hand part for the Quotient and right - hand part for the remainder by a slant line or slash.

Eg. 13 as $1 / 3$, 34 as $3 / 4$, 80 as $8 / 0$.

ii) Leave some space below such representation, draw a horizontal line.

Eg. $1 / 3$ $3 / 4$ $8 / 0$

_____ , _____ , _____

iii) Put the first digit of the dividend as it is under the horizontal line. Put the same digit under the right hand part for the remainder, add the two and place the sum i. e., sum of the digits of the numbers as the remainder.

Eg.

$1 / 3$	$3 / 4$	$8 / 0$
1	3	8
-----	-----	-----
$1 / 4$	$3 / 7$	$8 / 8$

Now the problem is over. i.e.,

$$13 \div 9 \text{ gives } Q = 1, R = 4$$

$$34 \div 9 \text{ gives } Q = 3, R = 7$$

$$80 \div 9 \text{ gives } Q = 8, R = 8$$

Proceeding for some more of the two digit number division by 9, we get

a) $21 \div 9$ as

$$\begin{array}{r} 9) 2 / 1 \quad \text{i.e.} \quad Q=2, R=3 \\ \quad 2 \\ \quad \text{-----} \\ \quad 2 / 3 \end{array}$$

b) $43 \div 9$ as

$$\begin{array}{r} 9) 4 / 3 \quad \text{i.e.} \quad Q = 4, R = 7. \\ \quad 4 \\ \quad \text{-----} \\ \quad 4 / 7 \end{array}$$

The examples given so far convey that in the division of two digit numbers by 9, we can mechanically take the first digit down for the quotient – column and that, by adding the quotient to the second digit, we can get the remainder.

Now in the case of 3 digit numbers, let us proceed as follows.

i)

$$\begin{array}{r} 9 \) \ 104 \ (\ 11 \\ \underline{99} \\ 5 \end{array}$$

as

$$\begin{array}{r} 9 \) \ 10 \ / \ 4 \\ \underline{1 \ / \ 1} \\ 11 \ / \ 5 \end{array}$$

ii)

$$\begin{array}{r} 9 \) \ 212 \ (\ 23 \\ \underline{207} \\ 5 \end{array}$$

as

$$\begin{array}{r} 9 \) \ 21 \ / \ 2 \\ \underline{2 \ / \ 3} \\ 23 \ / \ 5 \end{array}$$

iii)

$$\begin{array}{r} 9 \) \ 401 \ (\ 44 \\ \underline{396} \\ 5 \end{array}$$

as

$$\begin{array}{r} 9 \) \ 40 \ / \ 1 \\ \underline{4 \ / \ 4} \\ 44 \ / \ 5 \end{array}$$

Note that the remainder is the sum of the digits of the dividend. The first digit of the dividend from left is added mechanically to the second digit of the dividend to obtain the second digit of the quotient. This digit added to the third digit sets the remainder. The first digit of the dividend remains as the first digit of the quotient.

Consider $511 \div 9$

Add the first digit 5 to second digit 1 getting $5 + 1 = 6$. Hence Quotient is 56. Now second digit of 56 i.e., 6 is added to third digit 1 of dividend to get the remainder i.e., $1 + 6 = 7$

Thus

$$\begin{array}{r} 9 \) \ 51 \ / \ 1 \\ \underline{5 \ / \ 6} \\ 56 \ / \ 7 \end{array}$$

Q is 56, R is 7.

Extending the same principle even to bigger numbers of still more digits, we can get the results.

Eg : $1204 \div 9$

i) Add first digit 1 to the second digit 2. $1 + 2 = 3$

ii) Add the second digit of quotient 13. i.e., 3 to third digit '0' and obtain the Quotient. $3 + 0 = 3$, 133

iii) Add the third digit of Quotient 133 i.e., 3 to last digit '4' of the dividend and write the final Quotient and Remainder. $R = 3 + 4 = 7$, $Q = 133$

In symbolic form

$$\begin{array}{r} 9 \) \ 120 \ / \ 4 \\ \quad 13 \ / \ 3 \\ \hline \quad 133 \ / \ 7 \end{array}$$

Another example.

gives

$$\begin{array}{r} 9 \) \ 13210 \ / \ 1 \\ \quad 1467 \ / \ 7 \\ \hline \quad 14677 \ / \ 8 \end{array} \quad 132101 \div 9$$

$Q = 14677, R = 8$

In all the cases mentioned above, the remainder is less than the divisor. What about the case when the remainder is equal or greater than the divisor?

Eg.

$$\begin{array}{r} 9 \) \ 3 \ / \ 6 \\ \quad 3 \\ \hline 3 \ / \ 9 \text{ (equal)} \end{array} \quad \text{or} \quad \begin{array}{r} 9 \) \ 24 \ / \ 6 \\ \quad 2 \ / \ 6 \\ \hline 26 \ / \ 12 \text{ (greater).} \end{array}$$

We proceed by re-dividing the remainder by 9, carrying over this Quotient to the quotient side and retaining the final remainder in the remainder side.

$$\begin{array}{r} 9 \) \ 3 \ / \ 6 \\ \quad / \ 3 \\ \hline 3 \ / \ 9 \\ \hline 4 \ / \ 0 \end{array} \quad \begin{array}{r} 9 \) \ 24 \ / \ 6 \\ \quad 2 \ / \ 6 \\ \hline 26 \ / \ 12 \\ \hline 27 \ / \ 3 \end{array}$$

$$Q = 4, \quad R = 0 \quad Q = 27, \quad R = 3.$$

When the remainder is greater than divisor, it can also be represented as

$$\begin{array}{r} 9 \) \ 24 \ / \ 6 \\ \quad 2 \ / \ 6 \\ \hline 26 \ / \ 1 \ / \ 2 \\ \quad \quad \ / \ 1 \\ \hline \quad \quad 1 \ / \ 3 \\ \hline \quad \quad 27 \ / \ 3 \end{array}$$

Now consider the divisors of two or more digits whose last digit is 9, when divisor is 89.

We Know $113 = 1 \times 89 + 24, \quad Q = 1, \quad R = 24$

$$10015 = 112 \times 89 + 47, \quad Q = 112, \quad R = 47.$$

Representing in the previous form of procedure, we have

$$\begin{array}{r} 89 \) \ 1 \ / \ 13 \\ \quad \quad \ / \ 11 \\ \hline \quad \quad 1 \ / \ 24 \end{array} \qquad \begin{array}{r} 89 \) \ 100 \ / \ 15 \\ \quad \quad \quad \ / \ 32 \\ \hline \quad \quad \quad 112 \ / \ 47 \end{array}$$

But how to get these? What is the procedure?

Now Nikhilam rule comes to rescue us. The nikhilam states "all from 9 and the last from 10". Now if you want to find $113 \div 89$, $10015 \div 89$, you have to apply nikhilam formula on 89 and get the complement 11. Further while carrying the added numbers to the place below the next digit, we have to multiply by this 11.

$$\begin{array}{r} 89 \) \ 1 \ / \ 13 \\ \quad \quad \ / \ 11 \\ \hline \quad \quad 1 \ / \ 24 \end{array} \qquad \begin{array}{r} 89 \) \ 100 \ / \ 15 \\ \quad \quad \quad \ / \ 32 \\ \hline \quad \quad \quad 11 \quad 11 \ / \\ \quad \quad \quad \quad \quad \ / \ 1 \\ \hline \quad \quad \quad \quad \quad 22 \end{array}$$

first digit 1 x 11
total second is 1x11
total of 3rd digit is 2 x 11

What is $10015 \div 98$? Apply Nikhilam and get $100 - 98 = 02$. Set off the 2 digits from the right as the remainder consists of 2 digits. While carrying the added numbers to the place below the next digit, multiply by 02.

Thus

$$\begin{array}{r} 98 \) \ 100 \ / \ 15 \\ \underline{\quad} \end{array}$$

$$\begin{array}{r} 02 \quad 02 \ / \\ \quad 0 \ / \ 0 \\ \quad \quad / \ 04 \\ \hline \end{array}$$

$$102 \ / \ 19$$

i.e., $10015 \div 98$ gives
 $Q = 102, \quad R = 19$

In the same way

$$\begin{array}{r} 897 \) \ 11 \ / \ 422 \\ \underline{\quad} \end{array}$$

$$\begin{array}{r} 103 \quad 1 \ / \ 03 \\ \quad \quad / \ 206 \\ \hline \end{array}$$

$$12 \ / \ 658$$

gives $11,422 \div 897, \quad Q = 12, R=658$.

In this way we have to multiply the quotient by 2 in the case of 8, by 3 in the case of 7, by 4 in the case of 6 and so on. i.e., multiply the Quotient digit by the divisors complement from 10. In case of more digit numbers we apply Nikhilam and proceed. Any how, this method is highly useful and effective for division when the numbers are near to bases of 10.

*** Guess the logic in the process of division by 9.**

*** Obtain the Quotient and Remainder for the following problems.**

1) $311 \div 9$

2) $120012 \div 9$

3) $1135 \div 97$

4) $2342 \div 98$

5) $113401 \div 997$

6) $11199171 \div 99979$

Observe that by nikhilam process of division, even lengthier divisions involve no division or no subtraction but only a few multiplications of single digits with small numbers and a simple addition. But we know fairly well that only a special type of cases are being dealt and hence many questions about various other types of problems arise. The answer lies in Vedic Methods.

3 4

I. WHY VEDIC MATHEMATICS?

Many Indian Secondary School students consider Mathematics a very difficult subject. Some students encounter difficulty with basic arithmetical operations. Some students feel it difficult to manipulate symbols and balance equations. In other words, abstract and logical reasoning is their hurdle.

Many such difficulties in learning Mathematics enter into a long list if prepared by an experienced teacher of Mathematics. Volumes have been written on the diagnosis of 'learning difficulties' related to Mathematics and remedial techniques. Learning Mathematics is an unpleasant experience to some students mainly because it involves mental exercise.

Of late, a few teachers and scholars have revived interest in Vedic Mathematics which was developed, as a system derived from Vedic principles, by Swami Bharati Krishna Tirthaji in the early decades of the 20th century.

Dr. Narinder Puri of the Roorke University prepared teaching materials based on Vedic Mathematics during 1986 - 89. A few of his opinions are stated hereunder:

- i) Mathematics, derived from the Veda, provides one line, mental and super- fast methods along with quick cross checking systems.
- ii) Vedic Mathematics converts a tedious subject into a playful and blissful one which students learn with smiles.
- iii) Vedic Mathematics offers a new and entirely different approach to the study of Mathematics based on pattern recognition. It allows for constant expression of a student's creativity, and is found to be easier to learn.
- iv) In this system, for any problem, there is always one general technique applicable to all cases and also a number of special pattern problems. The element of choice and flexibility at each stage keeps the mind lively and alert to develop clarity of thought and intuition, and thereby a holistic development of the human brain automatically takes place.
- v) Vedic Mathematics with its special features has the inbuilt potential to solve the psychological problem of Mathematics - anxiety.

J.T.Glover (London, 1995) says that the experience of teaching Vedic Mathematics' methods to children has shown that a high degree of mathematical ability can be attained from an early stage while the subject is enjoyed for its own merits.

A.P. Nicholas (1984) puts the Vedic Mathematics system as 'one of the most delightful chapters of the 20th century mathematical history'.

Prof. R.C. Gupta (1994) says 'the system has great educational value because the Sutras contain techniques for performing some elementary mathematical operations in simple ways, and results are obtained quickly'.

Prof. J.N. Kapur says 'Vedic Mathematics can be used to remove math-phobia, and can be taught to (school) children as enrichment material along with other high speed methods'.

Dr. Michael Weinless, Chairman of the Department of Mathematics at the M.I.U, Iowa says thus: 'Vedic Mathematics is easier to learn, faster to use and less prone to error than conventional methods. Furthermore, the techniques of Vedic Mathematics not only enable the students to solve specific mathematical problems; they also develop creativity, logical thinking and intuition.'

Keeping the above observations in view, let us enter Vedic Mathematics as given by Sri Bharati Krishna Tirthaji (1884 - 1960), Sankaracharya of Govardhana Math, Puri. Entering into the methods and procedures, one can realize the importance and applicability of the different formulae (Sutras) and methods.

3 4

II. VEDIC MATHEMATICAL FORMULAE

What we call VEDIC MATHEMATICS is a mathematical elaboration of '**Sixteen Simple Mathematical formulae from the Vedas**' as brought out by **Sri Bharati Krishna Tirthaji**. In the text authored by the Swamiji, nowhere has the list of the Mathematical formulae (Sutras) been given. But the Editor of the text has compiled the list of the formulae from stray references in the text. The list so compiled contains Sixteen Sutras and Thirteen Sub - Sutras as stated hereunder.

Sixteen Sutras

- | | |
|---|--|
| 1. एकाधिकेन पूर्वेण
<i>Ekādhikena Pūrveṇa</i> (also
a corollary) | 9. चलनकलनाभ्याम्
<i>Calana-Kalanābhyām</i> |
| 2. निखिलं नवतश्चरमं दशतः
<i>Nikhilam Navataścaramam
Daśataḥ</i> | 10. यावदूनम्
<i>Yāvadūnam</i> |
| 3. ऊर्ध्वतिर्यग्भ्याम्
<i>Ūrdhva-tiryagbhyām</i> | 11. व्यष्टिसमष्टिः
<i>Vyaṣṭisamaṣṭiḥ</i> |
| 4. परावर्त्यं योजयेत्
<i>Parāvartya Yojayet</i> | 12. शेषाण्यङ्केन चरमेण
<i>Śeṣāṅyāṅkena Carameṇa</i> |
| 5. शून्यं साम्यसमुच्चये
<i>Śūnyam Sāmyasamuccaye</i> | 13. सोपान्त्यद्वयमन्त्यम्
<i>Sopāntyadvayamantyaṃ</i> |
| 6. (अनुरूप्ये) शून्यमन्यत्
<i>(Anurūpye) Śūnyamanyat</i> | 14. एकन्यूनेन पूर्वेण
<i>Ekanyūṇena Pūrveṇa</i> |
| 7. संकलनव्यवकलनाभ्याम्
<i>San̄kalana-vyavakalanā-
bhyam</i> (also a corollary) | 15. गुणितसमुच्चयः
<i>Guṇitasamuccayaḥ</i> |
| 8. पूरणापूरणाभ्याम्
<i>Pūraṇāpūraṇābhyām</i> | 16. गुणकसमुच्चयः
<i>Guṇakasamuccayaḥ</i> |

Thirteen Sub – Sutras

- | | |
|---|---|
| 1. आनुरूप्येण
<i>Anurūpyeṇa</i> | 8. अन्त्ययोर्दशकेऽपि
<i>Antyayordaśake'pi</i> |
| 2. शिष्यते शेषसंज्ञः
<i>Śiṣyate Śeṣasamjñah</i> | 9. अन्त्ययोरेव
<i>Antyayoreva</i> |
| 3. आद्यमाद्ये नान्त्यमन्त्येन
<i>Ādyamādyenāntya-mantye-
na</i> | 10. समुच्चयगुणितः
<i>Samuccayaguṇitaḥ</i> |
| 4. केवलैः सप्तकं गुण्यात्
<i>Kevalaiḥ Saptakaṁ Guṇ-
yāt</i> | 11. लोपस्थापनाभ्याम्
<i>Lopanasthāpanābhyām</i> |
| 5. वेष्टनम्
<i>Veṣṭanam</i> | 12. विलोकनम्
<i>Vilokanam</i> |
| 6. यावदूनं तावदूनम्
<i>Yāvadūnaṁ Tāvadūnaṁ</i> | 13. गुणितसमुच्चयः समुच्चयगुणितः
<i>Gunitasamuccayaḥ
Samuccayaguṇitaḥ</i> |
| 7. यावदूनं तावदूनोक्त्य वर्गं च
योजयेत्
<i>Yāvadūnaṁ Tāvadūnikṛtya
Vargaṅca Yojayet</i> | |

In the text, the words Sutra, aphorism, formula are used synonymously. So are also the words Upa-sutra, Sub-sutra, Sub-formula, corollary used.

Now we shall have the literal meaning, contextual meaning, process, different methods of application along with examples for the Sutras. Explanation, methods, further short-cuts, algebraic proof, etc follow. What follows relates to a single formula or a group of formulae related to the methods of Vedic Mathematics.

ANTYAYOR DA•AKE'PI

The Sutra signifies numbers of which the last digits added up give 10. i.e. the Sutra works in multiplication of numbers for example: 25 and 25, 47 and 43, 62 and 68, 116 and 114. Note that in each case the sum of the last digit of first number to the last digit of second number is 10. Further the portion of digits or numbers left wards to the last digits remain the same. At that instant use Ekadhikena on left hand side digits. Multiplication of the last digits gives the right hand part of the answer.

Example 1 : 47 X 43

See the end digits sum $7 + 3 = 10$; then by the sutras antyayor dasakepi and ekadhikena we have the answer.

$$\begin{aligned} 47 \times 43 &= (4 + 1) \times 4 / 7 \times 3 \\ &= 20 / 21 \\ &= 2021. \end{aligned}$$

Example 2: 62 x 68

$2 + 8 = 10$, L.H.S. portion remains the same i.e., 6.

Ekadhikena of 6 gives 7

$$\begin{aligned} 62 \times 68 &= (6 \times 7) / (2 \times 8) \\ &= 42 / 16 \\ &= 4216. \end{aligned}$$

Example 3: 127 x 123

As antyayor dasakepi works, we apply ekadhikena

$$\begin{aligned} 127 \times 123 &= 12 \times 13 / 7 \times 3 \\ &= 156 / 21 \\ &= 15621. \end{aligned}$$

Example 4: 65 x 65

We have already worked on this type. As the present sutra is applicable.

$$\begin{aligned} \text{We have } 65 \times 65 &= 6 \times 7 / 5 \times 5 \\ &= 4225. \end{aligned}$$

Example 5: 395^2

$$\begin{aligned} 395^2 &= 395 \times 395 \\ &= 39 \times 40 / 5 \times 5 \\ &= 1560 / 25 \\ &= 156025. \end{aligned}$$

Use Vedic sutras to find the products

1. 125×125

2. 34×36

3. 98×92

4. 401×409

5. 693×697

6. 1404×1406

It is further interesting to note that the same rule works when the sum of the last 2, last 3, last 4 - - - digits added respectively equal to 100, 1000, 10000 - - - . The simple point to remember is to multiply each product by 10, 100, 1000, - - as the case may be . You can observe that this is more convenient while working with the product of 3 digit numbers.

Eg. 1: 292×208

Here $92 + 08 = 100$, L.H.S portion is same i.e. 2

$$292 \times 208 = (2 \times 3) / 92 \times 8$$

$$\begin{aligned} \longrightarrow 60 / &= 736 \text{ (for 100 raise the L.H.S. product by 0)} \\ &= 60736. \end{aligned}$$

Eg. 2: 848×852

Here $48 + 52 = 100$, L.H.S portion is 8 and its 'ekhadhikena' is 9.

Now R.H.S product 48×52 can be obtained by 'anurupyena' mentally.

$$48 \quad \overline{2}$$

$$\begin{array}{r}
 52 \quad 2 \\
 \hline
 2) \quad \overline{50} \quad \overline{4} \quad = \quad 24 / (100 - 4) \\
 \quad \quad \quad \quad = 96 \\
 \quad \quad \quad \quad = 2496
 \end{array}$$

and write $848 \times 852 = 8 \times 9 / 48 \times 52$

$$\begin{aligned}
 \longrightarrow 720 &= 2496 \\
 &= 722496.
 \end{aligned}$$

[Since L.H.S product is to be multiplied by 10 and 2 to be carried over as the base is 100].

Eg. 3: 693×607

$$\begin{aligned}
 693 \times 607 &= 6 \times 7 / 93 \times 7 \\
 &= 420 / 651 \\
 &= 420651.
 \end{aligned}$$

Find the following products using 'antyyordasakepi'

1. 318×312

2. 425×475

3. 796×744

4. 902×998

5. 397×393

6. 551×549

Vedic Mathematics | Ekanyunenapurvena

EKANY • ENA P RVENA

The Sutra Ekanyunena purvena comes as a Sub-sutra to Nikhilam which gives the meaning 'One less than the previous' or 'One less than the one before'.

1) The use of this sutra in case of multiplication by 9,99,999.. is as follows .

Method :

a) The left hand side digit (digits) is (are) obtained by applying the ekanyunena purvena i.e. by deduction 1 from the left side digit (digits) .

e.g. (i) 7×9 ; $7 - 1 = 6$ (L.H.S. digit)

b) The right hand side digit is the complement or difference between the multiplier and the left hand side digit (digits) . i.e. 7×9 R.H.S is $9 - 6 = 3$.

c) The two numbers give the answer; i.e. $7 \times 9 = 63$.

Example 1: 8×9 **Step (a)** gives $8 - 1 = 7$ (L.H.S. Digit)
Step (b) gives $9 - 7 = 2$ (R.H.S. Digit)
Step (c) gives the answer 72

Example 2: 15×99 **Step (a)** : $15 - 1 = 14$
Step (b) : $99 - 14 = 85$ (or $100 - 15$)
Step (c) : $15 \times 99 = 1485$

Example 3: 24×99
 Answer :

$$\begin{array}{r} (24 - 1) \quad / \quad (99 - 23) \\ = 23 \quad \quad \quad = 76 \text{ (or } 100 - 24 \text{)} \end{array} = 2376$$

Example 4: 356×999
 Answer :

$$\begin{array}{r} (356 - 1) \quad / \quad (999 - 335) \\ = 355 \quad \quad \quad = 644 \end{array} = 355644$$

Example 5: 878×9999

Answer :

$$\begin{array}{r} (878 - 1) \quad / \quad (9999 - 877) \\ = 877 \quad \quad \quad = 9122 \quad (10000 - 878) \end{array} = 8779122$$

Note the process : The multiplicand has to be reduced by 1 to obtain the LHS and the rightside is mechanically obtained by the subtraction of the L.H.S from the multiplier which is practically a direct application of Nikhilam Sutra.

Now by Nikhilam

$$\begin{array}{r} 24 - 1 = 23 \quad \text{L.H.S.} \\ \times 99 - 23 = 76 \quad \text{R.H.S.} \quad (100-24) \\ \hline 23 / 76 \quad \quad \quad = 2376 \end{array}$$

Reconsider the **Example 4:**

$$\begin{array}{r} 356 - 1 = 355 \quad \text{L.H.S.} \\ \times 999 - 355 = 644 \quad \text{R.H.S.} \\ \hline 355 / 644 \quad \quad \quad = 355644 \end{array}$$

and in **Example 5:** 878×9999 we write

$$\begin{array}{r} 0878 - 1 = 877 \quad \text{L.H.S.} \\ \times 9999 - 877 = 9122 \quad \text{R.H.S.} \\ \hline 877 / 9122 \quad \quad \quad = 8779122 \end{array}$$

Algebraic proof :

As any two digit number is of the form $(10x + y)$, we proceed

$$\begin{aligned}
& (10x + y) \times 99 \\
&= (10x + y) \times (100 - 1) \\
&= 10x \cdot 10^2 - 10x + 10^2 \cdot y - y \\
&= x \cdot 10^3 + y \cdot 10^2 - (10x + y) \\
&= x \cdot 10^3 + (y - 1) \cdot 10^2 + [10^2 - (10x + y)]
\end{aligned}$$

Thus the answer is a four digit number whose 1000th place is x, 100th place is (y - 1) and the two digit number which makes up the 10th and unit place is the number obtained by subtracting the multiplicand from 100.(or apply nikhilam).

Thus in 37 X 99. The 1000th place is x i.e. 3

100th place is (y - 1) i.e. (7 - 1) = 6

Number in the last two places 100-37=63.

Hence answer is 3663.

Apply Ekanyunena purvena to find out the products

1. 64 x 99

2. 723 x 999

3. 3251 x 9999

4. 43 x 999

5. 256 x 9999

6. 1857 x 99999

We have dealt the cases

- i) When the multiplicand and multiplier both have the same number of digits
- ii) When the multiplier has more number of digits than the multiplicand.

In both the cases the same rule applies. But what happens when the multiplier has lesser digits?

i.e. for problems like 42 X 9, 124 X 9, 26325 X 99 etc.,

For this let us have a re-look in to the process for proper understanding.

Multiplication table of 9.

	a	b	
2 x 9 =	1	8	
3 x 9 =	2	7	

$$\begin{array}{r}
 4 \times 9 = 3 \quad 6 \\
 \text{-----} \\
 8 \times 9 = 7 \quad 2 \\
 9 \times 9 = 8 \quad 1 \\
 10 \times 9 = 9 \quad 0
 \end{array}$$

Observe the left hand side of the answer is always one less than the multiplicand (here multiplier is 9) as read from Column (a) and the right hand side of the answer is the complement of the left hand side digit from 9 as read from Column (b)

Multiplication table when both multiplicand and multiplier are of 2 digits.

a	b
11 x 99 = 10	89 = (11-1) / 99 - (11-1) = 1089
12 x 99 = 11	88 = (12-1) / 99 - (12-1) = 1188
13 x 99 = 12	87 = (13-1) / 99 - (13-1) = 1287
18 x 99 = 17	82 -----
19 x 99 = 18	81
20 x 99 = 19	80 = (20-1) / 99 - (20-1) = 1980

The rule mentioned in the case of above table also holds good here

Further we can state that the rule applies to all cases, where the multiplicand and the multiplier have the same number of digits.

Consider the following **Tables**.

(i)

a	b
11 x 9 = 9	9
12 x 9 = 10	8
13 x 9 = 11	7
18 x 9 = 16	2
19 x 9 = 17	1
20 x 9 = 18	0

(ii)

21 x 9 = 18	9
22 x 9 = 19	8

$$23 \times 9 = 20 \quad 7$$

$$28 \times 9 = 25 \quad 2$$

$$29 \times 9 = 26 \quad 1$$

$$30 \times 9 = 27 \quad 0$$

(iii)

$$35 \times 9 = 31 \quad 5$$

$$46 \times 9 = 41 \quad 4$$

$$53 \times 9 = 47 \quad 7$$

$$67 \times 9 = 60 \quad 3$$

-----so on.

From the above tables the following points can be observed:

- 1) **Table (i)** has the multiplicands with 1 as first digit except the last one. Here L.H.S of products are uniformly 2 less than the multiplicands. So also with 20×9
- 2) **Table (ii)** has the same pattern. Here L.H.S of products are uniformly 3 less than the multiplicands.
- 3) **Table (iii)** is of mixed example and yet the same result i.e. if 3 is first digit of the multiplicand then L.H.S of product is 4 less than the multiplicand; if 4 is first digit of the multiplicand then, L.H.S of the product is 5 less than the multiplicand and so on.
- 4) The right hand side of the product in all the tables and cases is obtained by subtracting the R.H.S. part of the multiplicand by Nikhilam.

Keeping these points in view we solve the problems:

Example1 : 42×9

i) Divide the multiplicand (42) of by a Vertical line or by the Sign : into a right hand portion consisting of as many digits as the multiplier.

i.e. 42 has to be written as **4/2** or **4:2**

ii) Subtract from the multiplicand one more than the whole excess portion on the left. i.e. left portion of multiplicand is 4.

one more than it $4 + 1 = 5$.

We have to subtract this from multiplicand

i.e. write it as

$$\begin{array}{r} 4 : 2 \\ \quad : -5 \\ \hline 3 : 7 \end{array}$$

This gives the L.H.S part of the product.

This step can be interpreted as "take the ekanyunena and sub tract from the previous" i.e. the excess portion on the left.

iii) Subtract the R.H.S. part of the multiplicand by nikhilam process.

i.e. R.H.S of multiplicand is 2

its nikhilam is 8

It gives the R.H.S of the product

i.e. answer is $3 : 7 : 8 = 378$.

Thus 42×9 can be represented as

$$\begin{array}{r} 4 : 2 \\ \quad : -5 : 8 \\ \hline 3 : 7 : 8 = 378. \end{array}$$

Example 2 : 124×9

Here Multiplier has one digit only .

We write $12 : 4$

Now step (ii), $12 + 1 = 13$

$$\begin{array}{r} \text{i.e. } 12 : 4 \\ \quad -1 : 3 \\ \hline \end{array}$$

Step (iii) R.H.S. of multiplicand is 4. Its Nikhilam is 6

$$\begin{array}{r} 124 \times 9 \text{ is } 12 : 4 \\ \quad \quad \quad -1 : 3 : 6 \\ \hline \end{array}$$

$$11 : 1 : 6 = 1116$$

The process can also be represented as

$$124 \times 9 = [124 - (12 + 1)] : (10 - 4) = (124 - 13) : 6 = 1116$$

Example 3: 15639×99

Since the multiplier has 2 digits, the answer is

$$[15639 - (156 + 1)] : (100 - 39) = (15639 - 157) : 61 = 1548261$$

Find the products in the following cases.

1. 58×9

2. 62×9

3. 427×99

4. 832×9

5. 24821×999

6. 111011×99

Ekanyunena Sutra is also useful in Recurring Decimals. We can take up this under a separate treatment.

Thus we have a glimpse of majority of the Sutras. At some places some Sutras are mentioned as Sub-Sutras. Any how we now proceed into the use of Sub-Sutras. As already mentioned the book on Vedic Mathematics enlisted 13 Upa-Sutras.

But some approaches in the Vedic Mathematics book prompted some serious research workers in this field to mention some other Upa-Sutras. We can observe those approaches and developments also.

3 4

NUR PYE • NYAMANYAT

The Sutra Anurupye Sunyamanyat says : 'If one is in ratio, the other one is zero'.

We use this Sutra in solving a special type of simultaneous simple equations in which the coefficients of 'one' variable are in the same ratio to each other as the independent terms are to each other. In such a context the Sutra says the 'other' variable is zero from which we get two simple equations in the first variable (already considered) and of course give the same value for the variable.

Example 1:

$$\begin{aligned} 3x + 7y &= 2 \\ 4x + 21y &= 6 \end{aligned}$$

Observe that the y-coefficients are in the ratio 7 : 21 i.e., 1 : 3, which is same as the ratio of independent terms i.e., 2 : 6 i.e., 1 : 3. Hence the other variable $x = 0$ and $7y = 2$ or $21y = 6$ gives $y = 2 / 7$

Example 2:

$$\begin{aligned} 323x + 147y &= 1615 \\ 969x + 321y &= 4845 \end{aligned}$$

The very appearance of the problem is frightening. But just an observation and anurupye sunyamanyat give the solution $x = 5$, because coefficient of x ratio is $323 : 969 = 1 : 3$ and constant terms ratio is $1615 : 4845 = 1 : 3$.
 $y = 0$ and $323 x = 1615$ or $969 x = 4845$ gives $x = 5$.

Solve the following by anurupye sunyamanyat.

$$\begin{aligned} 1. \quad 12x + 78y &= 12 \\ 16x + 96y &= 16 \end{aligned}$$

$$\begin{aligned} 2. \quad 3x + 7y &= 24 \\ 12x + 5y &= 96 \end{aligned}$$

$$\begin{aligned} 3. \quad 4x - 6y &= 24 \\ 7x - 9y &= 36 \end{aligned}$$

$$\begin{aligned} 4. \quad ax + by &= bm \\ cx + dy &= dm \end{aligned}$$

In solving simultaneous quadratic equations, also we can take the help of the 'sutra' in the following way:

Example 3 :

Solve for x and y

$$x + 4y = 10$$

$$x^2 + 5xy + 4y^2 + 4x - 2y = 20$$

$x^2 + 5xy + 4y^2 + 4x - 2y = 20$ can be written as

$$(x + y)(x + 4y) + 4x - 2y = 20$$

$$10(x + y) + 4x - 2y = 20 \quad (\text{Since } x + 4y = 10)$$

$$10x + 10y + 4x - 2y = 20$$

$$14x + 8y = 20$$

$$\text{Now } x + 4y = 10$$

$$14x + 8y = 20 \text{ and } 4 : 8 :: 10 : 20$$

from the Sutra, $x = 0$ and $4y = 10$, i.e., $8y = 20$ $y = 10/4 = 2\frac{1}{2}$

Thus $x = 0$ and $y = 2\frac{1}{2}$ is the solution.

34

RDHVA TIRYAGBHY M

Urdhva – tiryagbhyam is the general formula applicable to all cases of multiplication and also in the division of a large number by another large number. It means “Vertically and cross wise.”

(a) Multiplication of two 2 digit numbers.

Ex.1: Find the product 14×12

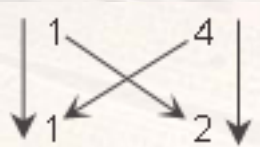
i) The right hand most digit of the multiplicand, the first number (14) i.e., 4 is multiplied by the right hand most digit of the multiplier, the second number (12) i.e., 2. The product $4 \times 2 = 8$ forms the right hand most part of the answer.

ii) Now, diagonally multiply the first digit of the multiplicand (14) i.e., 4 and second digit of the multiplier (12) i.e., 1 (answer $4 \times 1 = 4$); then multiply the second digit of the multiplicand i.e., 1 and first digit of the multiplier i.e., 2 (answer $1 \times 2 = 2$); add these two i.e., $4 + 2 = 6$. It gives the next, i.e., second digit of the answer. Hence second digit of the answer is 6.

iii) Now, multiply the second digit of the multiplicand i.e., 1 and second digit of the multiplier i.e., 1 vertically, i.e., $1 \times 1 = 1$. It gives the left hand most part of the answer.

Thus the answer is 168.

Symbolically we can represent the process as follows :



The symbols are operated from right to left .

Step i) :

$$\begin{array}{r}
 1 \quad 4 \\
 1 \quad 2 \\
 \hline
 : 4 \times 2
 \end{array}$$

Step ii) :

$$\begin{array}{r}
 1 \quad 4 \\
 1 \quad 2 \\
 \hline
 2 + 4 : 8
 \end{array}$$

Step iii) :

$$\begin{array}{r}
 1 \quad 4 \\
 1 \quad 2 \\
 \hline
 1 \times 1 : 6 : 8 \\
 \text{which gives } 168
 \end{array}$$

Now in the same process, answer can be written as

$$\begin{array}{r}
 23 \\
 13 \\
 \hline
 2 : 6 + 3 : 9 = 299 \quad (\text{Recall the 3 steps})
 \end{array}$$

Ex.3

$$\begin{array}{r}
 41 \\
 X 41 \\
 \hline
 16 : 4 + 4 : 1 = 1681.
 \end{array}$$

What happens when one of the results i.e., either in the last digit or in the middle digit of the result, contains more than 1 digit ? Answer is simple. The right – hand – most digit there of is to be put down there and the preceding, i.e., left –hand – side digit or digits should be carried over to the left and placed under the previous digit or digits of the upper row. The digits carried over may be written as in Ex. 4.

Ex.4: 32×24

Step (i) : $2 \times 4 = 8$

Step (ii) : $3 \times 4 = 12$; $2 \times 2 = 4$; $12 + 4 = 16$.

Here 6 is to be retained. 1 is to be carried out to left side.

Step (iii) : $3 \times 2 = 6$. Now the carried over digit 1 of 16 is to be added.
i.e., $6 + 1 = 7$.

Thus $32 \times 24 = 768$

We can write it as follows

$$\begin{array}{r} 32 \\ 24 \\ \hline 668 \\ 1 \\ \hline 768. \end{array}$$

Note that the carried over digit from the result $(3 \times 4) + (2 \times 2) = 12 + 4 = 16$ i.e., 1 is placed under the previous digit $3 \times 2 = 6$ and added.

After sufficient practice, you feel no necessity of writing in this way and simply operate or perform mentally.

Ex.5 28×35 .

Step (i) : $8 \times 5 = 40$. 0 is retained as the first digit of the answer and 4 is carried over.

Step (ii) : $2 \times 5 = 10$; $8 \times 3 = 24$; $10 + 24 = 34$; add the carried over 4 to 34. Now the result is $34 + 4 = 38$. Now 8 is retained as the second digit of the answer and 3 is carried over.

Step (iii) : $2 \times 3 = 6$; add the carried over 3 to 6. The result $6 + 3 = 9$ is the third or final digit from right to left of the answer.

Thus $28 \times 35 = 980$.

Ex.6

$$\begin{array}{r}
 48 \\
 47 \\
 \hline
 1606 \\
 65 \\
 \hline
 2256
 \end{array}$$

Step (i): $8 \times 7 = 56$; 5, the carried over digit is placed below the second digit.

Step (ii): $(4 \times 7) + (8 \times 4) = 28 + 32 = 60$; 6, the carried over digit is placed below the third digit.

Step (iii): Respective digits are added.

Algebraic proof :

a) Let the two 2 digit numbers be $(ax+b)$ and $(cx+d)$. Note that $x = 10$. Now consider the product

$$\begin{aligned}
 (ax + b) (cx + d) &= ac.x^2 + adx + bcx + b.d \\
 &= ac.x^2 + (ad + bc)x + b.d
 \end{aligned}$$

Observe that

i) The first term i.e., the coefficient of x^2 (i.e., 100, hence the digit in the 100th place) is obtained by vertical multiplication of a and c i.e., the digits in 10th place (coefficient of x) of both the numbers;

ii) The middle term, i.e., the coefficient of x (i.e., digit in the 10th place) is obtained by cross wise multiplication of a and d; and of b and c; and the addition of the two products;

iii) The last (independent of x) term is obtained by vertical multiplication of the independent terms b and d.

b) Consider the multiplication of two 3 digit numbers.

Let the two numbers be $(ax^2 + bx + c)$ and $(dx^2 + ex + f)$. Note that $x=10$

Now the product is

$$ax^2 + bx + c$$

$$\times dx^2 + ex + f$$

$$ad \cdot x^4 + bd \cdot x^3 + cd \cdot x^2 + ae \cdot x^3 + be \cdot x^2 + ce \cdot x + af \cdot x^2 + bf \cdot x + cf$$

$$= ad \cdot x^4 + (bd + ae) \cdot x^3 + (cd + be + af) \cdot x^2 + (ce + bf)x + cf$$

Note the following points :

i) The coefficient of x^4 , i.e., ad is obtained by the vertical multiplication of the first coefficient from the left side :

$$\begin{array}{r} \downarrow ax^2 + bx + c \\ \downarrow dx^2 + ex + f \\ \hline ad x^4 \end{array}$$

ii) The coefficient of x^3 , i.e., $(ae + bd)$ is obtained by the cross-wise multiplication of the first two coefficients and by the addition of the two products;

$$\begin{array}{r} ax^2 + bx + c \\ \swarrow \quad \searrow \\ dx^2 + ex + f \\ \hline aex^3 + bdx^3 \\ = (ae + bd) x^3 \end{array}$$

iii) The coefficient of x^2 is obtained by the multiplication of the first coefficient of the multiplicand $(ax^2 + bx + c)$ i.e., a ; by the last coefficient of the multiplier $(dx^2 + ex + f)$ i.e., f ; of the middle one i.e., b of the multiplicand by the middle one i.e., e of the multiplier and of the last one i.e., c of the multiplicand by the first one i.e., d of the multiplier and by the addition of all the three products i.e., $af + be + cd$:

$$\begin{array}{r}
 ax^2 + bx + c \\
 \swarrow \quad \downarrow \quad \searrow \\
 dx^2 + ex + f \\
 \hline
 afx^2 + bex^2 + cdx^2 \\
 = (af + be + cd)x^2
 \end{array}$$

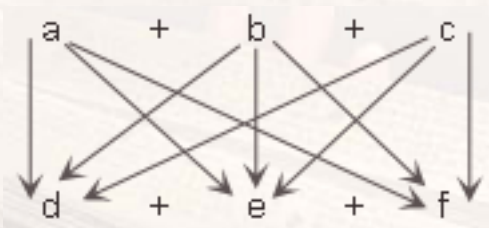
iv) The coefficient of x is obtained by the cross wise multiplication of the second coefficient i.e., b of the multiplicand by the third one i.e., f of the multiplier, and conversely the third coefficient i.e., c of the multiplicand by the second coefficient i.e., e of the multiplier and by addition of the two products, i.e., $bf + ce$;

$$\begin{array}{r}
 ax^2 + bx + c \\
 \quad \quad \swarrow \quad \searrow \\
 dx^2 + ex + f \\
 \hline
 bf.x + ce.x \\
 = (bf + ce)x
 \end{array}$$

v) And finally the last (independent of x) term is obtained by the vertical multiplication of the last coefficients c and f i.e., cf

$$\begin{array}{r}
 ax^2 + bx + c \\
 dx^2 + ex + f \\
 \hline
 cf
 \end{array}$$

Thus the process can be put symbolically as (from left to right)



Consider the following example

$$124 \times 132.$$

Proceeding from right to left

i) $4 \times 2 = 8$. First digit = 8

ii) $(2 \times 2) + (3 \times 4) = 4 + 12 = 16$. The digit 6 is retained and 1 is carried over to left side. Second digit = 6.

iii) $(1 \times 2) + (2 \times 3) + (1 \times 4) = 2 + 6 + 4 = 12$. The carried over 1 of above step is added i.e., $12 + 1 = 13$. Now 3 is retained and 1 is carried over to left side. Thus third digit = 3.

iv) $(1 \times 3) + (2 \times 1) = 3 + 2 = 5$. the carried over 1 of above step is added i.e., $5 + 1 = 6$. It is retained. Thus fourth digit = 6

v) $(1 \times 1) = 1$. As there is no carried over number from the previous step it is retained. Thus fifth digit = 1

$$124 \times 132 = 16368.$$

Let us work another problem by placing the carried over digits under the first row and proceed.

$$\begin{array}{r} 234 \\ \times 316 \\ \hline 61724 \\ 1222 \\ \hline 73944 \end{array}$$

i) $4 \times 6 = 24$: 2, the carried over digit is placed below the second digit.

ii) $(3 \times 6) + (4 \times 1) = 18 + 4 = 22$; 2, the carried over digit is placed below third digit.

iii) $(2 \times 6) + (3 \times 1) + (4 \times 3) = 12 + 3 + 12 = 27$; 2, the carried over digit is placed below fourth digit.

Example 3 : Find $(3x^2 + 4x + 7)(5x + 6)$

$$\begin{array}{r} \text{Now} \quad 3.x^2 + 4x + 7 \\ \quad \quad 0.x^2 + 5x + 6 \\ \hline \end{array}$$

i) $7 \times 6 = 42$

ii) $(4 \times 6) + (7 \times 5) = 24 + 35 = 59$ i.e., $59x$

iii) $(3 \times 6) + (4 \times 5) + (7 \times 0) = 18 + 20 + 0 = 38$ i.e., $38x^2$

iv) $(3 \times 5) + (0 \times 4) = 15 + 0 = 15$ i.e., $15x^3$

v) $3 \times 0 = 0$

Hence the product is $15x^3 + 38x^2 + 59x + 42$

Find the products using urdhva tiryagbhyam process.

1) 25×16

2) 32×48

3) 56×56

4) 137×214

5) 321×213

6) 452×348

7) $(2x + 3y)(4x + 5y)$

8) $(5a^2 + 1)(3a^2 + 4)$

9) $(6x^2 + 5x + 2)(3x^2 + 4x + 7)$

10) $(4x^2 + 3)(5x + 6)$

Urdhva – tiryak in converse for division process:

As per the statement it is used as a simple argumentation for division process particularly in algebra.

Consider the division of $(x^3 + 5x^2 + 3x + 7)$ by $(x - 2)$ process by converse of urdhva – tiryak :

i) x^3 divided by x gives x^2 . $x^3 + 5x^2 + 3x + 7$
 It is the first term of the Quotient. $\frac{\quad\quad\quad}{x - 2}$
 $Q = x^2 + \text{-----}$

ii) $x^2 \times -2 = -2x^2$. But $5x^2$ in the dividend hints $7x^2$ more since $7x^2 - 2x^2 = 5x^2$. This 'more' can be obtained from the multiplication of x by $7x$. Hence second term of Q is $7x$.

$$\begin{array}{r} x^3 + 5x^2 + 3x + 7 \\ \hline x - 2 \end{array} \quad \text{gives } Q = x^2 + 7x + \text{-----}$$

iii) We now have $-2 \times 7x = -14x$. But the 3rd term in the dividend is $3x$ for which '17x more' is required since $17x - 14x = 3x$.

Now multiplication of x by 17 gives $17x$. Hence third term of quotient is 17

Thus

$$\begin{array}{r} x^3 + 5x^2 + 3x + 7 \\ \hline x - 2 \end{array} \quad \text{gives } Q = x^2 + 7x + 17$$

iv) Now last term of Q , i.e., 17 multiplied by -2 gives $17 \times -2 = -34$ but the relevant term in dividend is 7 . So $7 + 34 = 41$ 'more' is required. As there no more terms left in dividend, 41 remains as the remainder.

$$\begin{array}{r} x^3 + 5x^2 + 3x + 7 \\ \hline x - 2 \end{array} \quad \text{gives } Q = x^2 + 7x + 17 \text{ and } R = 41.$$

Find the Q and R in the following divisions by using the converse process of urdhva – tiryagbhyam method :

1) $\begin{array}{r} 3x^2 - x - 6 \\ \hline \end{array}$

$$3x - 7$$

2) $\begin{array}{r} 16x^2 + 24x + 9 \\ \hline \end{array}$

$$4x + 3$$

3) $\begin{array}{r} x^3 + 2x^2 + 3x + 5 \\ \hline \end{array}$

$$x - 3$$

4) $\begin{array}{r} 12x^4 - 3x^2 - 3x + 12 \\ \hline \end{array}$

$$x^2 + 1$$

3 4



PAR VARTYA – YOJAYET

'Paravartya – Yojayet' means '**transpose and apply**'

(i) Consider the division by divisors of more than one digit, and when the divisors are slightly greater than powers of 10.

Example 1 : Divide 1225 by 12.

Step 1 : (From left to right) write the Divisor leaving the first digit, write the other digit or digits using negative (-) sign and place them below the divisor as shown.

$$\begin{array}{r} 12 \\ -2 \\ \hline \end{array}$$

Step 2 : Write down the dividend to the right. Set apart the last digit for the remainder.

$$\text{i.e., } \begin{array}{r} 12 \quad 122 \quad 5 \\ -2 \end{array}$$

Step 3 : Write the 1st digit below the horizontal line drawn under the dividend. Multiply the digit by -2 , write the product below the 2nd digit and add.

$$\text{i.e., } \begin{array}{r} 12 \quad 122 \quad 5 \\ -2 \quad -2 \\ \hline \quad \quad 10 \end{array}$$

$$\text{Since } 1 \times -2 = -2 \text{ and } 2 + (-2) = 0$$

Step 4 : We get second digits' sum as '0'. Multiply the second digits' sum thus obtained by -2 and writes the product under 3rd digit and add.

$$\begin{array}{r} 12 \quad \quad 122 \quad 5 \\ -2 \quad \quad -20 \\ \hline \end{array}$$

$$\begin{array}{r}
 1\ 1\ 2\ 1\ 3 \\
 -1-2-1-3 \\
 \hline
 \end{array}
 \qquad
 \begin{array}{r}
 2\ 3\ 9\ 4\ 7\ 9 \\
 -2\ -4-2-6 \\
 \hline
 -1-2-1-3 \\
 \hline
 2\ 1\ 4\ 0\ 0\ 6
 \end{array}
 \qquad
 \begin{array}{l}
 \text{with 2} \\
 \text{with 1}
 \end{array}$$

Hence $Q = 21$, $R = 4006$.

Example 5 : Divide 13456 by 1123

$$\begin{array}{r}
 1\ 1\ 2\ 3 \\
 -1-2-3 \\
 \hline
 \end{array}
 \qquad
 \begin{array}{r}
 1\ 3\ 4\ 5\ 6 \\
 -1-2-3 \\
 \hline
 -2-4\ -6 \\
 \hline
 1\ 2\ 0-2\ 0
 \end{array}$$

Note that the remainder portion contains -20 , i.e., a negative quantity. To overcome this situation, take 1 over from the quotient column, i.e., 1123 over to the right side, subtract the remainder portion 20 to get the actual remainder.

Thus $Q = 12 - 1 = 11$, and $R = 1123 - 20 = 1103$.

Find the Quotient and Remainder for the problems using paravartya – yojayet method.

1) $1234 \div 112$

2) $11329 \div 1132$

3) $12349 \div 133$

4) $239479 \div 1203$

Now let us consider the application of paravartya – yojayet in algebra.

Example 1 : Divide $6x^2 + 5x + 4$ by $x - 1$

$$\begin{array}{r}
 X - 1 \\
 \hline
 1
 \end{array}
 \qquad
 \begin{array}{r}
 6x^2 + 5x + 4 \\
 \hline
 6 + 11
 \end{array}$$

$6x + 11 + 15$ Thus $Q = 6x+11$, $R=15$.

Example 2 : Divide $x^3 - 3x^2 + 10x - 4$ by $x - 5$

$$\begin{array}{r}
 X - 5 \\
 \hline
 \end{array}
 \qquad
 \begin{array}{r}
 x^3 - 3x^2 + 10x - 4 \\
 \hline
 \end{array}$$

$$\begin{array}{r}
 \text{-----} \\
 5 \qquad \qquad \qquad 5 \quad + \quad 10 \quad 100 \\
 \text{-----} \\
 x^2 + 2x + 20, + 96
 \end{array}$$

Thus $Q = x^2 + 2x + 20$, $R = 96$.

The procedure as a mental exercise comes as follows :

- i) x^3 / x gives x^2 i.e., 1 the first coefficient in the Quotient.
- ii) Multiply 1 by + 5, (obtained after reversing the sign of second term in the Quotient) and add to the next coefficient in the dividend. It gives $1 \times (+5) = +5$, adding to the next coefficient, i.e., $-3 + 5 = 2$. This is next coefficient in Quotient.
- iii) Continue the process : multiply 2 by +5, i.e., $2 \times +5 = 10$, add to the next coefficient $10 + 10 = 20$. This is next coefficient in Quotient. Thus Quotient is $x^2 + 2x + 20$
- iv) Now multiply 20 by + 5 i.e., $20 \times 5 = 100$. Add to the next (last) term, $100 + (-4) = 96$, which becomes R, i.e., $R = 96$.

Example 3:

$$\begin{array}{r}
 x^4 - 3x^3 + 7x^2 + 5x + 7 \\
 \text{-----} \\
 x + 4
 \end{array}$$

Now thinking the method as in example (1), we proceed as follows.

$$\begin{array}{r}
 x + 4 \qquad \qquad \qquad x^4 - 3x^3 + 7x^2 + 5x + 7 \\
 \text{-----} \\
 -4 \qquad \qquad \qquad - 4 + 28 - 140 + 540 \\
 \text{-----} \\
 x^3 - 7x^2 + 35x - 135 \quad 547
 \end{array}$$

Thus $Q = x^3 - 7x^2 + 35x - 135$ and $R = 547$.

or we proceed orally as follows:

x^4 / x gives 1 as first coefficient.

i) $-4 \times 1 = -4$: add to next coefficient $-4 + (-3) = -7$ which gives next coefficient in Q.

ii) $-7 \times -4 = 28$: then $28 + 7 = 35$, the next coefficient in Q.

iii) $35 \times -4 = -140$: then $-140 + 5 = -135$, the next coefficient in Q.

iv) $-135 \times -4 = 540$: then $540 + 7 = 547$ becomes R.

Thus $Q = x^3 - 7x^2 + 35x - 135$, $R = 547$.

Note :

1. We can follow the same procedure even the number of terms is more.

2. If any term is missing, we have to take the coefficient of the term as zero and proceed.

Now consider the divisors of second degree or more as in the following example.

Example :4 $2x^4 - 3x^3 - 3x + 2$ by $x^2 + 1$.

Here x^2 term is missing in the dividend. Hence treat it as $0 \cdot x^2$ or 0 . And the x term in divisor is also absent we treat it as $0 \cdot x$. Now

$$\begin{array}{r}
 x^2 \quad \quad + 1 \quad \quad \quad 2x^4 - 3x^3 + 0 \cdot x^2 - 3x + 2 \\
 x^2 + 0 \cdot x + 1 \quad \quad \quad \quad \quad \quad 0 \quad - 2 \\
 \hline
 \quad \quad 0 \quad - 1 \quad \quad \quad \quad \quad \quad 0 \quad + 3 \\
 \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad \quad 0 \quad + 2 \\
 \hline
 \quad \quad \quad \quad \quad \quad 2 \quad - 3 \quad - 2 \quad \quad \quad 0 \quad 4
 \end{array}$$

Thus $Q = 2x^2 - 3x - 2$ and $R = 0 \cdot x + 4 = 4$.

Example 5 : $2x^5 - 5x^4 + 3x^2 - 4x + 7$ by $x^3 - 2x^2 + 3$.

We treat the dividend as $2x^5 - 5x^4 + 0 \cdot x^3 + 3x^2 - 4x + 7$ and divisor as $x^3 - 2x^2 + 0 \cdot x + 3$ and proceed as follows :

$$\begin{array}{r}
 x^3 - 2x^2 + 0 \cdot x + 3 \quad \quad 2x^5 - 5x^4 + 0 \cdot x^3 + 3x^2 - 4x + 7 \\
 \hline
 \end{array}$$

$$\begin{array}{r}
 2 \quad 0 \quad -3 \quad \quad 4 \quad 0 \quad -6 \\
 \quad \quad \quad \quad \quad \quad \quad -2 \quad 0 \quad +3 \\
 \quad \quad \quad \quad \quad \quad \quad \quad -4 \quad 0 \quad +6 \\
 \hline
 2 \quad -1 \quad -2 \quad -7 \quad -1 \quad +13
 \end{array}$$

Thus $Q = 2x^2 - x - 2$, $R = -7x^2 - x + 13$.

You may observe a very close relation of the method paravartya in this aspect with regard to REMAINDER THEOREM and HORNER PROCESS of Synthetic division. And yet paravartya goes much farther and is capable of numerous applications in other directions also.

Apply paravartya – yojayet to find out the Quotient and Remainder in each of the following problems.

- 1) $(4x^2 + 3x + 5) \div (x+1)$
- 2) $(x^3 - 4x^2 + 7x + 6) \div (x - 2)$
- 3) $(x^4 - x^3 + x^2 + 2x + 4) \div (x^2 - x - 1)$
- 4) $(2x^5 + x^3 - 3x + 7) \div (x^3 + 2x - 3)$
- 5) $(7x^6 + 6x^5 - 5x^4 + 4x^3 - 3x^2 + 2x - 1) \div (x-1)$

Paravartya in solving simple equations :

Recall that 'paravartya yojayet' means 'transpose and apply'. The rule relating to transposition enjoins invariable change of sign with every change of side. i.e., + becomes - and conversely ; and X becomes \div and conversely. Further it can be extended to the transposition of terms from left to right and conversely and from numerator to denominator and conversely in the concerned problems.

Type (i) :

Consider the problem $7x - 5 = 5x + 1$

$$7x - 5x = 1 + 5$$

$$\text{i.e., } 2x = 6 \quad x = 6 \div 2 = 3.$$

Observe that the problem is of the type $ax + b = cx + d$ from which we get by 'transpose' $(d - b)$, $(a - c)$ and

$$x = \frac{d - b}{\quad \quad \quad}$$

$$a - c$$

In this example $a = 7, b = -5, c = 5, d = 1$

Hence

$$x = \frac{1 - (-5)}{7 - 5} = \frac{1+5}{7-5} = \frac{6}{2} = 3$$

Example 2: Solve for $x, 3x + 4 = 2x + 6$

$$x = \frac{d - b}{a - c} = \frac{6 - 4}{3 - 2} = \frac{2}{1} = 2$$

Type (ii) : Consider problems of the type $(x + a)(x + b) = (x + c)(x + d)$. By paravartya, we get

$$x = \frac{cd - ab}{(a + b) - (c + d)}$$

It is trivial from the following steps

$$\begin{aligned}(x + a)(x + b) &= (x + c)(x + d) \\ x^2 + bx + ax + ab &= x^2 + dx + cx + cd \\ bx + ax - dx - cx &= cd - ab \\ x(a + b - c - d) &= cd - ab\end{aligned}$$

$$x = \frac{cd - ab}{a + b - c - d} \quad x = \frac{cd - ab}{(a + b) - (c + d)}$$

Example 1 : $(x - 3)(x - 2) = (x + 1)(x + 2)$.

By paravartya

$$\begin{aligned}x &= \frac{cd - ab}{a + b - c - d} = \frac{1(2) - (-3)(-2)}{-3 - 2 - 1 - 2} \\ &= \frac{2 - 6}{-8} = \frac{-4}{-8} = \frac{1}{2}\end{aligned}$$

Example 2 : $(x + 7) (x - 6) = (x + 3) (x - 4)$.

$$\begin{aligned} \text{Now} \quad x &= \frac{cd - ab}{a + b - c - d} = \frac{(3) (-4) - (7) (-6)}{7 + (-6) - 3 - (-4)} \\ &= \frac{-12 + 42}{7 - 6 - 3 + 4} = \frac{30}{2} = 15 \end{aligned}$$

Note that if $cd - ab = 0$ i.e., $cd = ab$, i.e., if the product of the absolute terms be the same on both sides, the numerator becomes zero giving $x = 0$.

For the problem $(x + 4) (x + 3) = (x - 2) (x - 6)$

Solution is $x = 0$ since $4 \times 3 = -2 \times -6 = 12$

Type (iii) :

Consider the problems of the type $\frac{ax + b}{cx + d} = \frac{m}{n}$

By cross – multiplication,

$$\begin{aligned} n (ax + b) &= m (cx + d) \\ nax + nb &= mcx + md \\ nax - mcx &= md - nb \\ x(na - mc) &= md - nb \end{aligned}$$

$$x = \frac{md - nb}{na - mc}$$

Now look at the problem once again

$$\frac{ax + b}{cx + d} = \frac{m}{n}$$

paravartya gives $md - nb, na - mc$ and

$md - nb$

$$x = \frac{\quad}{na - mc}$$

Example 1:
$$\frac{3x + 1}{4x + 3} = \frac{13}{19}$$

$$x = \frac{md - nb}{na - mc} = \frac{13(3) - 19(1)}{19(3) - 13(4)} = \frac{39 - 19}{57 - 52} = \frac{20}{5} = 4$$

Example 2:
$$\frac{4x + 5}{3x + 13/2} = \frac{7}{8}$$

$$x = \frac{(7)(13/2) - (8)(5)}{(8)(4) - (7)(3)}$$

$$= \frac{(91/2) - 40}{32 - 21} = \frac{(91 - 80)/2}{32 - 21} = \frac{11}{2 \times 11} = \frac{1}{2}$$

Type (iv) : Consider the problems of the type
$$\frac{m}{x + a} + \frac{n}{x + b} = 0$$

Take L.C.M and proceed.

$$\frac{m(x+b) + n(x+a)}{(x+a)(x+b)} = 0$$

$$\frac{mx + mb + nx + na}{(x+a)(x+b)} = 0$$

$$(m + n)x + mb + na = 0 \quad \therefore (m + n)x = -mb - na$$

$$x = \frac{-mb - na}{(m + n)}$$

Thus the problem $\frac{m}{x + a} + \frac{n}{x + b} = 0$, by paravartya process

gives directly

$$x = \frac{-mb - na}{(m + n)}$$

Example 1 :

$$\frac{3}{x + 4} + \frac{4}{x - 6} = 0$$

gives

$$x = \frac{-mb - na}{(m + n)} \quad \text{Note that } m = 3, n = 4, a = 4, b = -6$$

$$= \frac{-(3)(-6) - (4)(4)}{(3 + 4)} = \frac{18 - 16}{7} = \frac{2}{7}$$

Example 2 :

$$\frac{5}{x + 1} + \frac{6}{x - 21} = 0$$

gives

$$x = \frac{-(5)(-21) - (6)(1)}{5 + 6} = \frac{105 - 6}{11} = \frac{99}{11} = 9$$

I . Solve the following problems using the sutra Paravartya – yojayet.

1) $3x + 5 = 5x - 3$

6) $(x + 1)(x + 2) = (x - 3)(x - 4)$

2) $(2x/3) + 1 = x - 1$

7) $(x - 7)(x - 9) = (x - 3)(x - 22)$

3) $7x + 2 = \frac{5}{\quad}$

8) $(x + 7)(x + 9) = (x + 3)(x + 21)$

$$3x - 5 \quad 8$$

$$4) \frac{x + 1}{3x - 1} = 1$$

$$5) \frac{5}{x + 3} + \frac{2}{x - 4} = 0$$

II)

1. Show that for the type of equations

$$\frac{m}{x + a} + \frac{n}{x + b} + \frac{p}{x + c} = 0, \quad \text{the solution is}$$

$$x = \frac{-mbc - nca - pab}{m(b + c) + n(c + a) + p(a + b)}, \quad \text{if } m + n + p = 0.$$

2. Apply the above formula to set the solution for the problem

$$\text{Problem} \quad \frac{3}{x + 4} + \frac{2}{x + 6} - \frac{5}{x + 5} = 0$$

some more simple solutions :

$$\frac{m}{x + a} + \frac{n}{x + b} = \frac{m + n}{x + c}$$

Now this can be written as,

$$\frac{m}{x + a} + \frac{n}{x + b} = \frac{m}{x + c} + \frac{n}{x + c}$$

$$\frac{m}{x+a} - \frac{m}{x+c} = \frac{n}{x+c} - \frac{n}{x+b}$$

$$\frac{m(x+c) - m(x+a)}{(x+a)(x+c)} = \frac{n(x+b) - n(x+c)}{(x+c)(x+b)}$$

$$\frac{mx + mc - mx - ma}{(x+a)(x+c)} = \frac{nx + nb - nx - nc}{(x+c)(x+b)}$$

$$\frac{m(c-a)}{x+a} = \frac{n(b-c)}{x+b}$$

$$\begin{aligned} m(c-a).x + m(c-a).b &= n(b-c).x + n(b-c).a \\ x [m(c-a) - n(b-c)] &= na(b-c) - mb(c-a) \\ \text{or } x [m(c-a) + n(c-b)] &= na(b-c) + mb(a-c) \end{aligned}$$

Thus

$$x = \frac{mb(a-c) + na(b-c)}{m(c-a) + n(c-b)}.$$

By paravartya rule we can easily remember the formula.

Example 1 : solve $\frac{3}{x+1} + \frac{4}{x+2} = \frac{7}{x+3}$

In the usual procedure, we proceed as follows.

$$\frac{3}{x+1} + \frac{4}{x+2} = \frac{7}{x+3}$$

$$\frac{3(x+2) + 4(x+1)}{(x+1)(x+2)} = \frac{7}{x+3}$$

$$\frac{3x + 6 + 4x + 4}{\quad\quad\quad} = \frac{7}{\quad\quad\quad}$$

$$x^2 + 2x + x + 2 \quad x + 3$$

$$\frac{7x + 10}{x^2 + 3x + 2} = \frac{7}{x + 3}$$

$$(7x + 10)(x + 3) = 7(x^2 + 3x + 2)$$

$$7x^2 + 21x + 10x + 30 = 7x^2 + 21x + 14.$$

$$31x + 30 = 21x + 14$$

$$31x - 21x = 14 - 30$$

$$\text{i.e., } 10x = -16$$

$$x = -16 / 10 = -8 / 5$$

Now by **Paravartya** process

$$\frac{3}{x + 1} + \frac{4}{x + 2} = \frac{7}{x + 3} \quad (\dots N_1 + N_2 = 3 + 4 = 7 = N_3)$$

$$x = \frac{mb(a - c) + na(b - c)}{m(c - a) + n(c - b)} \quad \text{here } N_1 = m = 3, N_2 = n = 4; \\ a = 1, b = 2, c = 3$$

$$= \frac{3 \cdot 2(1 - 3) + 4 \cdot 1(2 - 3)}{3(3 - 1) + 4(3 - 2)}$$

$$= \frac{6(-2) + 4(-1)}{3(2) + 4(1)} = \frac{-12 - 4}{6 + 4} = \frac{-16}{10} = \frac{-8}{5}$$

Example 2 :

$$\frac{3}{x - 2} + \frac{5}{x - 6} = \frac{8}{x + 3} \quad \text{Here } N_1 + N_2 = 3 + 5 = 8.$$

$$x = \frac{mb(a-c) + na(b-c)}{m(c-a) + n(c-b)}$$

$$= \frac{3 \cdot (-6)(-2-3) + 5 \cdot (-2)(-6-3)}{3(3-(-2)) + 5(3-(-6))}$$

$$= \frac{3(-6)(-5) + 5(-2)(-9)}{3(3+2) + 5(3+6)}$$

$$= \frac{90 + 90}{15 + 45} = 180 / 60 = 3.$$

Solve the problems using the methods explained above.

$$1) \quad \frac{2}{x+2} + \frac{3}{x+3} = \frac{5}{x+5}$$

$$2) \quad \frac{4}{x+1} + \frac{6}{x+3} = \frac{10}{x+4}$$

$$3) \quad \frac{5}{x-2} + \frac{2}{3-x} = \frac{3}{x-4}$$

$$4) \quad \frac{4}{2x+1} + \frac{9}{3x+2} = \frac{15}{3x+1}$$

Note : The problem (4) appears to be not in the model said above.

$$\text{But } \frac{3(4)}{3(2x+1)} + \frac{2(9)}{2(3x+2)} = \frac{2(15)}{2(3x+1)} \text{ gives}$$

$$\frac{12}{6x + 3} + \frac{18}{6x + 4} = \frac{30}{6x + 2} \quad \text{Now proceed.}$$

Simultaneous simple equations:

By applying Paravartya sutra we can derive the values of x and y which are given by two simultaneous equations. The values of x and y are given by ration form. The method to find out the numerator and denominator of the ratio is given below.

Example 1: $2x + 3y = 13, 4x + 5y = 23.$

i) To get x, start with y coefficients and the independent terms and cross-multiply forward, i.e., right ward. Start from the upper row and multiply across by the lower one, and conversely, the connecting link between the two cross-products being a minus. This becomes numerator.

$$\begin{array}{l} \text{i.e.,, } 2x + 3y = 13 \\ \quad \quad 4x + 5y = 23 \end{array}$$

Numerator of the x – value is $3 \times 23 - 5 \times 13 = 69 - 65 = 4$

ii) Go from the upper row across to the lower one, i.e.,, the x-coefficient but backward, i.e.,, leftward.

$$\begin{array}{l} \text{Denominator of the x – value is } 3 \times 4 - 2 \times 5 = 12 - 10 = 2 \\ \text{Hence value of x} = 4 \div 2 = 2. \end{array}$$

iii) To get y, follow the cyclic system, i.e.,, start with the independent term on the upper row towards the x-coefficient on the lower row. So numerator of the y-value is

$$13 \times 4 - 23 \times 2 = 52 - 46 = 6.$$

iv) The denominator is the same as obtained in Step(ii) i.e.,, 2. Hence value of y is $6 \div 2 = 3.$

Thus the solution to the given equation is $x = 2$ and $y = 3.$

Example 2: $5x - 3y = 11$
 $6x - 5y = 09$

Now Nr. of x is $(-3) (9) - (5) (11) = -27 + 55 = 28$

Dr. of x is $(-3) (6) - (5) (-5) = -18 + 25 = 07$

$$x = Nr \div Dr = 28 \div 7 = 4$$

and for y, Nr is $(11)(6) - (9)(5) = 66 - 45 = 21$
 Dr is 7

$$\text{Hence } y = 21 \div 7 = 3.$$

Example 3: solve $3x + y = 5$
 $4x - y = 9$

Now we can straight away write the values as follows:

$$x = \frac{(1)(9) - (-1)(5)}{(1)(4) - (3)(-1)} = \frac{9 + 5}{4 + 3} = \frac{14}{7} = 2$$

$$y = \frac{(5)(4) - (9)(3)}{(1)(4) - (3)(-1)} = \frac{20 - 27}{4 + 3} = \frac{-7}{7} = -1$$

Hence $x = 2$ and $y = -1$ is the solution.

Algebraic Proof:

$$ax + by = m \dots\dots\dots (i)$$

$$cx + dy = n \dots\dots\dots (ii)$$

Multiply (i) by d and (ii) by b, then subtract

$$adx + bdy = m.d$$

$$cbx + dby = n.b$$

$$(ad - cb) .x = md - nb$$

$$x = \frac{md - nb}{ad - cb} = \frac{bn - md}{bc - ad}$$

Multiply (i) by c and (ii) by a, then subtract

$$acx + bcy = m.c$$

$$cax + day = n.a$$

$$\frac{\quad}{(bc - ad) \cdot y = mc - na}$$

$$y = \frac{mc - na}{bc - ad}$$

You feel comfort in the Paravartya process because it avoids the confusion in multiplication, change of sign and such other processes.

Find the values of x and y in each of the following problems using Paravartya process.

$$1. \quad \begin{aligned} 2x + y &= 5 \\ 3x - 4y &= 2 \end{aligned}$$

$$2. \quad \begin{aligned} 3x - 4y &= 7 \\ 5x + y &= 4 \end{aligned}$$

$$3. \quad \begin{aligned} 4x + 3y &= 8 \\ 6x - y &= 1 \end{aligned}$$

$$4. \quad \begin{aligned} x + 3y &= 7 \\ 2x + 5y &= 11 \end{aligned}$$

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Vedic Mathematics | **Sunyam Samyasamuccaye****S NYAM S MYASAMUCCAYE**

The Sutra 'Sunyam Samyasamuccaye' says the 'Samuccaya is the same, that Samuccaya is Zero.' i.e., it should be equated to zero. The term 'Samuccaya' has several meanings under different contexts.

i) We interpret, 'Samuccaya' as a term which occurs as a common factor in all the terms concerned and proceed as follows.

Example 1: The equation $7x + 3x = 4x + 5x$ has the same factor 'x' in all its terms. Hence by the sutra it is zero, i.e., $x = 0$.

Otherwise we have to work like this:

$$\begin{aligned} 7x + 3x &= 4x + 5x \\ 10x &= 9x \\ 10x - 9x &= 0 \\ x &= 0 \end{aligned}$$

This is applicable not only for 'x' but also any such unknown quantity as follows.

Example 2: $5(x+1) = 3(x+1)$

No need to proceed in the usual procedure like

$$\begin{aligned} 5x + 5 &= 3x + 3 \\ 5x - 3x &= 3 - 5 \\ 2x = -2 \quad \text{or} \quad x &= -2 \div 2 = -1 \end{aligned}$$

Simply think of the contextual meaning of 'Samuccaya'

Now Samuccaya is $(x + 1)$
 $x + 1 = 0$ gives $x = -1$

ii) Now we interpret 'Samuccaya' as product of independent terms in expressions like $(x+a)(x+b)$

Example 3: $(x + 3)(x + 4) = (x - 2)(x - 6)$

Here Samuccaya is $3 \times 4 = 12 = -2 \times -6$
 Since it is same , we derive $x = 0$

This example, we have already dealt in type (ii) of Paravartya in solving simple equations.

iii) We interpret ' Samuccaya ' as the sum of the denominators of two fractions having the same numerical numerator.

Consider the example.

$$\frac{1}{3x-2} + \frac{1}{2x-1} = 0$$

for this we proceed by taking L.C.M.

$$\frac{(2x-1) + (3x-2)}{(3x-2)(2x-1)} = 0$$

$$\frac{5x-3}{(3x-2)(2x-1)} = 0$$

$$5x - 3 = 0 \quad 5x = 3$$

$$x = \frac{3}{5}$$

Instead of this, we can directly put the Samuccaya i.e., sum of the denominators

$$\text{i.e., } 3x - 2 + 2x - 1 = 5x - 3 = 0$$

giving $5x = 3 \quad x = 3 / 5$

It is true and applicable for all problems of the type

$$\frac{m}{ax+b} + \frac{m}{cx+d} = 0$$

Samuccaya is $ax+b+cx+d$ and solution is ($m \neq 0$)

$$x = \frac{-(b+d)}{(a+c)}$$

iii) We now interpret 'Samuccaya' as combination or total.

If the sum of the numerators and the sum of the denominators be the same, then that sum = 0.

Consider examples of type

$$\frac{ax+b}{ax+c} = \frac{ax+c}{ax+b}$$

In this case, $(ax+b)(ax+b) = (ax+c)(ax+c)$
 $a^2x^2 + 2abx + b^2 = a^2x^2 + 2acx + c^2$
 $2abx - 2acx = c^2 - b^2$
 $x(2ab - 2ac) = c^2 - b^2$

$$x = \frac{c^2-b^2}{2a(b-c)} = \frac{(c+b)(c-b)}{2a(b-c)} = \frac{-(c+b)}{2a}$$

As per Samuccaya $(ax+b) + (ax+c) = 0$
 $2ax+b+c = 0$
 $2ax = -b-c$

$$x = \frac{-(c+b)}{2a} \quad \text{Hence the statement.}$$

Example 4:

$$\frac{3x+4}{3x+5} = \frac{3x+5}{3x+4}$$

Since $N_1 + N_2 = 3x + 4 + 3x + 5 = 6x + 9$,

And $D_1 + D_2 = 3x + 4 + 3x + 5 = 6x + 9$

We have $N_1 + N_2 = D_1 + D_2 = 6x + 9$

Hence from Sunya Samuccaya we get $6x + 9 = 0$

$$6x = -9$$

$$x = \frac{-9}{6} = \frac{-3}{2}$$

Example 5:

$$\frac{5x + 7}{5x + 12} = \frac{5x + 12}{5x + 7}$$

Hence $N_1 + N_2 = 5x + 7 + 5x + 12 = 10x + 19$

And $D_1 + D_2 = 5x + 12 + 5x + 7 = 10x + 19$

$N_1 + N_2 = D_1 + D_2$ gives $10x + 19 = 0$

$$10x = -19$$

$$x = \frac{-19}{10}$$

Consider the examples of the type, where $N_1 + N_2 = K (D_1 + D_2)$, where K is a numerical constant, then also by removing the numerical constant K, we can proceed as above.

Example 6:

$$\frac{2x + 3}{4x + 5} = \frac{x + 1}{2x + 3}$$

Here $N_1 + N_2 = 2x + 3 + x + 1 = 3x + 4$

$$\begin{aligned} D_1 + D_2 &= 4x + 5 + 2x + 3 = 6x + 8 \\ &= 2 (3x + 4) \end{aligned}$$

Removing the numerical factor 2, we get $3x + 4$ on both sides.

$$3x + 4 = 0 \quad 3x = -4 \quad x = -4 / 3.$$

v) 'Samuccaya' with the same meaning as above, i.e., case (iv), we solve the problems leading to quadratic equations. In this context, we take the problems as follows;

If $N_1 + N_2 = D_1 + D_2$ and also the differences

$N_1 \sim D_1 = N_2 \sim D_2$ then both the things are equated to zero, the solution gives the two values for x .

Example 7:

$$\frac{3x + 2}{2x + 5} = \frac{2x + 5}{3x + 2}$$

In the conventional text book method, we work as follows :

$$\frac{3x + 2}{2x + 5} = \frac{2x + 5}{3x + 2}$$

$$(3x + 2)(3x + 2) = (2x + 5)(2x + 5)$$

$$9x^2 + 12x + 4 = 4x^2 + 20x + 25$$

$$9x^2 + 12x + 4 - 4x^2 - 20x - 25 = 0$$

$$5x^2 - 8x - 21 = 0$$

$$5x^2 - 15x + 7x - 21 = 0$$

$$5x(x - 3) + 7(x - 3) = 0$$

$$(x - 3)(5x + 7) = 0$$

$$x - 3 = 0 \text{ or } 5x + 7 = 0$$

$$x = 3 \text{ or } -7/5$$

Now 'Samuccaya' sutra comes to help us in a beautiful way as follows :

$$\text{Observe } N_1 + N_2 = 3x + 2 + 2x + 5 = 5x + 7$$

$$D_1 + D_2 = 2x + 5 + 3x + 2 = 5x + 7$$

$$\text{Further } N_1 \sim D_1 = (3x + 2) - (2x + 5) = x - 3$$

$$N_2 \sim D_2 = (2x + 5) - (3x + 2) = -x + 3 = -(x - 3)$$

$$\text{Hence } 5x + 7 = 0, x - 3 = 0$$

$$5x = -7, x = 3$$

$$\text{i.e., } x = -7/5, x = 3$$

Note that all these can be easily calculated by mere observation.

Example 8:

$$\frac{3x + 4}{6x + 7} = \frac{5x + 6}{2x + 3}$$

Observe that

$$N_1 + N_2 = 3x + 4 + 5x + 6 = 8x + 10$$

$$\text{and } D_1 + D_2 = 6x + 7 + 2x + 3 = 8x + 10$$

$$\text{Further } N_1 \sim D_1 = (3x + 4) - (6x + 7)$$

$$= 3x + 4 - 6x - 7$$

$$= -3x - 3 = -3(x + 1)$$

$$N_2 \sim D_2 = (5x + 6) - (2x + 3) = 3x + 3 = 3(x + 1)$$

By 'Sunyam Samuccaye' we have

$$8x + 10 = 0$$

$$8x = -10$$

$$x = -10 / 8$$

$$= -5 / 4$$

$$3(x + 1) = 0$$

$$x + 1 = 0$$

$$x = -1$$

vi) 'Samuccaya' with the same sense but with a different context and application .

Example 9:

$$\frac{1}{x-4} + \frac{1}{x-6} = \frac{1}{x-2} + \frac{1}{x-8}$$

Usually we proceed as follows.

$$\frac{x-6+x-4}{(x-4)(x-6)} = \frac{x-8+x-2}{(x-2)(x-8)}$$

$$\frac{2x-10}{x^2-10x+24} = \frac{2x-10}{x^2-10x+16}$$

$$\begin{aligned}
 (2x - 10)(x^2 - 10x + 16) &= (2x - 10)(x^2 - 10x + 24) \\
 2x^3 - 20x^2 + 32x - 10x^2 + 100x - 160 &= 2x^3 - 20x^2 + 48x - 10x^2 + 100x - 240 \\
 2x^3 - 30x^2 + 132x - 160 &= 2x^3 - 30x^2 + 148x - 240 \\
 132x - 160 &= 148x - 240 \\
 132x - 148x &= 160 - 240 \\
 -16x &= -80 \\
 x &= -80 / -16 = 5
 \end{aligned}$$

Now 'Samuccaya' sutra, tell us that, if other elements being equal, the sum-total of the denominators on the L.H.S. and their total on the R.H.S. be the same, that total is zero.

$$\text{Now } D_1 + D_2 = x - 4 + x - 6 = 2x - 10, \text{ and}$$

$$D_3 + D_4 = x - 2 + x - 8 = 2x - 10$$

By Samuccaya, $2x - 10$ gives $2x = 10$

$$x = \frac{10}{2} = 5$$

Example 10:

$$\frac{1}{x-8} + \frac{1}{x-9} = \frac{1}{x-5} + \frac{1}{x-12}$$

$$D_1 + D_2 = x - 8 + x - 9 = 2x - 17, \text{ and}$$

$$D_3 + D_4 = x - 5 + x - 12 = 2x - 17$$

$$\text{Now } 2x - 17 = 0 \text{ gives } 2x = 17$$

$$x = \frac{17}{2} = 8\frac{1}{2}$$

Example 11:

$$\frac{1}{x+7} - \frac{1}{x+10} = \frac{1}{x+6} - \frac{1}{x+9}$$

This is not in the expected form. But a little work regarding transposition makes the above as follows.

$$\frac{1}{x+7} + \frac{1}{x+9} = \frac{1}{x+6} + \frac{1}{x+10}$$

Now 'Samuccaya' sutra applies

$$D_1 + D_2 = x + 7 + x + 9 = 2x + 16, \text{ and}$$

$$D_3 + D_4 = x + 6 + x + 10 = 2x + 16$$

Solution is given by $2x + 16 = 0$ i.e., $2x = -16$.

$$x = -16 / 2 = -8.$$

Solve the following problems using Sunyam Samya-Samuccaye process.

1. $7(x+2) + 3(x+2) = 6(x+2) + 5(x+2)$

2. $(x+6)(x+3) = (x-9)(x-2)$

3. $(x-1)(x+14) = (x+2)(x-7)$

4. $\frac{1}{4x-3} + \frac{1}{x-2} = 0$

5. $\frac{4}{3x+1} + \frac{4}{5x+7} = 0$

6. $\frac{2x+11}{2x+5} = \frac{2x+5}{2x+11}$

7. $\frac{3x+4}{6x+7} = \frac{x+1}{2x+3}$

$$8. \quad \frac{4x - 3}{2x + 3} = \frac{x + 4}{3x - 2}$$

$$9. \quad \frac{1}{x - 2} + \frac{1}{x - 5} = \frac{1}{x - 3} + \frac{1}{x - 4}$$

$$10. \quad \frac{1}{x - 7} - \frac{1}{x - 6} = \frac{1}{x - 10} - \frac{1}{x - 9}$$

Sunyam Samya Samuccaye in Certain Cubes:

Consider the problem $(x - 4)^3 + (x - 6)^3 = 2(x - 5)^3$. For the solution by the traditional method we follow the steps as given below:

$$\begin{aligned} (x - 4)^3 + (x - 6)^3 &= 2(x - 5)^3 \\ x^3 - 12x^2 + 48x - 64 + x^3 - 18x^2 + 108x - 216 & \\ &= 2(x^3 - 15x^2 + 75x - 125) \\ 2x^3 - 30x^2 + 156x - 280 &= 2x^3 - 30x^2 + 150x - 250 \\ 156x - 280 &= 150x - 250 \\ 156x - 150x &= 280 - 250 \\ 6x &= 30 \\ x &= 30 / 6 = 5 \end{aligned}$$

But once again observe the problem in the vedic sense

We have $(x - 4) + (x - 6) = 2x - 10$. Taking out the numerical factor 2, we have $(x - 5) = 0$, which is the factor under the cube on R.H.S. In such a case "Sunyam samya Samuccaye" formula gives that $x - 5 = 0$. Hence $x = 5$

Think of solving the problem $(x - 249)^3 + (x + 247)^3 = 2(x - 1)^3$

The traditional method will be horrible even to think of.

But $(x - 249) + (x + 247) = 2x - 2 = 2(x - 1)$. And $x - 1$ on R.H.S. cube, it is enough to state that $x - 1 = 0$ by the 'sutra'.

$x = 1$ is the solution. No cubing or any other mathematical operations.

Algebraic Proof :

Consider $(x - 2a)^3 + (x - 2b)^3 = 2(x - a - b)^3$ it is clear that

$$x - 2a + x - 2b = 2x - 2a - 2b$$

$$= 2(x - a - b)$$

Now the expression,

$$\begin{aligned} x^3 - 6x^2a + 12xa^2 - 8a^3 + x^3 - 6x^2b + 12xb^2 - 8b^3 &= \\ 2(x^3 - 3x^2a - 3x^2b + 3xa^2 + 3xb^2 + 6axb - a^3 - 3a^2b - 3ab^2 - b^3) &= \\ = 2x^3 - 6x^2a - 6x^2b + 6xa^2 + 6xb^2 + 12xab - 2a^3 - 6a^2b - 6ab^2 - 2b^3 & \end{aligned}$$

cancel the common terms on both sides

$$\begin{aligned} 12xa^2 + 12xb^2 - 8a^3 - 8b^3 &= 6xa^2 + 6xb^2 + 12xab - 2a^3 - 6a^2b - 6ab^2 - 2b^3 \\ 6xa^2 + 6xb^2 - 12xab &= 6a^3 + 6b^3 - 6a^2b - 6ab^2 \\ 6x(a^2 + b^2 - 2ab) &= 6[a^3 + b^3 - ab(a + b)] \\ x(a - b)^2 &= [(a + b)(a^2 + b^2 - ab) - (a + b)ab] \\ &= (a + b)(a^2 + b^2 - 2ab) \\ &= (a + b)(a - b)^2 \end{aligned}$$

$$\therefore x = a + b$$

Solve the following using "Sunyam Samuccaye" process :

1. $(x - 3)^3 + (x - 9)^3 = 2(x - 6)^3$
2. $(x + 4)^3 + (x - 10)^3 = 2(x - 3)^3$
3. $(x + a + b - c)^3 + (x + b + c - a)^3 = 2(x + b)^3$

Example :

$$\frac{(x + 2)^3}{(x + 3)^3} = \frac{x + 1}{x + 4}$$

with the text book procedures we proceed as follows

$$\frac{x^3 + 6x^2 + 12x + 8}{x^3 + 9x^2 + 27x + 27} = \frac{x + 1}{x + 4}$$

Now by cross multiplication,

$$\begin{aligned} (x + 4)(x^3 + 6x^2 + 12x + 8) &= (x + 1)(x^3 + 9x^2 + 27x + 27) \\ x^4 + 6x^3 + 12x^2 + 8x + 4x^3 + 24x^2 + 48x + 32 &= \\ x^4 + 9x^3 + 27x^2 + 27x + x^3 + 9x^2 + 27x + 27 & \\ x^4 + 10x^3 + 36x^2 + 56x + 32 &= x^4 + 10x^3 + 36x^2 + 54x + 27 \\ 56x + 32 &= 54x + 27 \\ 56x - 54x &= 27 - 32 \\ 2x &= -5 \\ x &= -5/2 \end{aligned}$$

Observe that $(N_1 + D_1)$ with in the cubes on

$$\text{L.H.S. is } x + 2 + x + 3 = 2x + 5 \text{ and}$$

$N_2 + D_2$ on the right hand side

$$\text{is } x + 1 + x + 4 = 2x + 5.$$

By vedic formula we have $2x + 5 = 0 \quad x = -5/2.$

Solve the following by using vedic method :

1.

$$\frac{(x + 3)^3}{(x + 5)^3} = \frac{x + 1}{x + 7}$$

2.

$$\frac{(x - 5)^3}{(x - 7)^3} = \frac{x - 3}{x - 9}$$

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Vedic Mathematics | Sankalana-Vyavakalanabhyam

SA•KALANA – VYAVAKALAN BHYAM

This Sutra means 'by addition and by subtraction'. It can be applied in solving a special type of simultaneous equations where the x - coefficients and the y - coefficients are found interchanged.

Example 1:

$$45x - 23y = 113$$

$$23x - 45y = 91$$

In the conventional method we have to make equal either the coefficient of x or coefficient of y in both the equations. For that we have to multiply equation (1) by 45 and equation (2) by 23 and subtract to get the value of x and then substitute the value of x in one of the equations to get the value of y or we have to multiply equation (1) by 23 and equation (2) by 45 and then subtract to get value of y and then substitute the value of y in one of the equations, to get the value of x. It is difficult process to think of.

From Sankalana – vyavakalanabhyam

add them,

$$\text{i.e., } (45x - 23y) + (23x - 45y) = 113 + 91$$

$$\text{i.e., } 68x - 68y = 204 \quad \therefore x - y = 3$$

subtract one from other,

$$\text{i.e., } (45x - 23y) - (23x - 45y) = 113 - 91$$

$$\text{i.e., } 22x + 22y = 22 \quad \therefore x + y = 1$$

and repeat the same sutra, we get $x = 2$ and $y = - 1$

Very simple addition and subtraction are enough, however big the coefficients may be.

Example 2:

$$1955x - 476y = 2482$$

$$476x - 1955y = -4913$$

Oh ! what a problem ! And still

$$\text{just add, } 2431(x - y) = - 2431 \quad \therefore x - y = -1$$

$$\text{subtract, } 1479 (x + y) = 7395 \quad \therefore x + y = 5$$

$$\text{once again add, } 2x = 4 \quad \therefore x = 2$$

$$\text{subtract - } 2y = -6 \quad \therefore y = 3$$

Solve the following problems using Sankalana – Vyavakalanabhyam.

1. $3x + 2y = 18$
 $2x + 3y = 17$

2. $5x - 21y = 26$
 $21x - 5y = 26$

3. $659x + 956y = 4186$
 $956x + 659y = 3889$

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Vedic Mathematics | Puranapurabhyam

P RAN P RA • BHY M

The Sutra can be taken as Purana - Apuranabhyam which means by the completion or non - completion. Purana is well known in the present system. We can see its application in solving the roots for general form of quadratic equation.

We have : $ax^2 + bx + c = 0$

$$x^2 + (b/a)x + c/a = 0 \quad (\text{dividing by } a)$$

$$x^2 + (b/a)x = -c/a$$

completing the square (i.e., purana) on the L.H.S.

$$x^2 + (b/a)x + (b^2/4a^2) = -c/a + (b^2/4a^2)$$

$$[x + (b/2a)]^2 = (b^2 - 4ac) / 4a^2$$

$$\text{Proceeding in this way we finally get } x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Now we apply purana to solve problems.

Example 1. $x^3 + 6x^2 + 11x + 6 = 0$.

$$\text{Since } (x + 2)^3 = x^3 + 6x^2 + 12x + 8$$

Add $(x + 2)$ to both sides

$$\text{We get } x^3 + 6x^2 + 11x + 6 + x + 2 = x + 2$$

$$\text{i.e., } x^3 + 6x^2 + 12x + 8 = x + 2$$

$$\text{i.e., } (x + 2)^3 = (x + 2)$$

this is of the form $y^3 = y$ for $y = x + 2$

solution $y = 0, y = 1, y = -1$

$$\text{i.e., } x + 2 = 0, 1, -1$$

which gives $x = -2, -1, -3$

Example 2: $x^3 + 8x^2 + 17x + 10 = 0$

$$\text{We know } (x + 3)^3 = x^3 + 9x^2 + 27x + 27$$

So adding on the both sides, the term $(x^2 + 10x + 17)$, we get

$$x^3 + 8x^2 + 17x + x^2 + 10x + 17 = x^2 + 10x + 17$$

$$\text{i.e., } x^3 + 9x^2 + 27x + 27 = x^2 + 6x + 9 + 4x + 8$$

$$\text{i.e., } (x + 3)^3 = (x + 3)^2 + 4(x + 3) - 4$$

$$y^3 = y^2 + 4y - 4 \text{ for } y = x + 3$$

$$y = 1, 2, -2.$$

Hence $x = -2, -1, -5$

Thus purana is helpful in factorization.

Further purana can be applied in solving Biquadratic equations also.

Solve the following using purana – apuranabhyam.

1. $x^3 - 6x^2 + 11x - 6 = 0$
2. $x^3 + 9x^2 + 23x + 15 = 0$
3. $x^2 + 2x - 3 = 0$
4. $x^4 + 4x^3 + 6x^2 + 4x - 15 = 0$

CALANA - KALAN BHY M

In the book on **Vedic Mathematics** Sri Bharati Krishna Tirthaji mentioned the Sutra 'Calana - Kalanabhyam' at only two places. The Sutra means 'Sequential motion'.

i) In the first instance it is used to find the roots of a quadratic equation $7x^2 - 11x - 7 = 0$. Swamiji called the sutra as calculus formula. Its application at that point is as follows. Now by calculus formula we say: $14x-11 = \pm\sqrt{317}$

A Note follows saying every Quadratic can thus be broken down into two binomial factors. An explanation in terms of first differential, discriminant with sufficient number of examples are given under the chapter 'Quadratic Equations'.

ii) At the Second instance under the chapter 'Factorization and Differential Calculus' for factorizing expressions of 3rd, 4th and 5th degree, the procedure is mentioned as 'Vedic Sutras relating to Calana – Kalana – Differential Calculus'.

Further other Sutras 10 to 16 mentioned below are also used to get the required results. Hence the sutra and its various applications will be taken up at a later stage for discussion.

But sutra – 14 is discussed immediately after this item.

Now the remaining sutras :

10. Y VAD NAM (The deficiency)
11. VYA••ISAMA••IH (Whole as one and one as whole)
12. •E• NYA• KENA CARAME•A (Remainder by the last digit)
13. SOP NTYADVAYAMANTYAM (Ultimate and twice the penultimate)
15. GU•ITASAMUCCAYAH (The whole product is the same)
16. GU•AKA SAMUCCAYAH (Collectivity of multipliers)

The Sutras have their applications in solving different problems in different contexts. Further they are used along with other Sutras. So it is a bit of inconvenience to deal each Sutra under a separate heading exclusively and also independently. Of course they will be mentioned and also be applied in solving the problems in the forth coming chapter wherever necessary. This decision has been

taken because up to now, we have treated each Sutra independently and have not continued with any other Sutra even if it is necessary. When the need for combining Sutras for filling the gaps in the process arises, we may opt for it. Now we shall deal the fourteenth Sutra, the Sutra left so far untouched.

3 4

Vedic Mathematics | Adyamadyenantya-mantyaena

DYAM DYEN NTYA - MANTYENA

The Sutra ' adyamadyenantya-mantyaena' means 'the first by the first and the last by the last'.

Suppose we are asked to find out the area of a rectangular card board whose length and breadth are respectively 6ft . 4 inches and 5 ft. 8 inches. Generally we continue the problem like this.

$$\text{Area} = \text{Length} \times \text{Breath}$$

$$= 6' 4" \times 5' 8" \text{ Since } 1' = 12", \text{ conversion}$$

$$= (6 \times 12 + 4) (5 \times 12 + 8) \text{ in to single unit}$$

$$= 76" 68" = 5168 \text{ Sq. inches.}$$

Since 1 sq. ft. = $12 \times 12 = 144$ sq.inches we have area

$$\begin{array}{r} 5168 \\ \text{-----} \\ 144 \end{array} = \begin{array}{r} 144) 5168 (35 \\ \underline{432} \\ 848 \\ \underline{720} \\ 128 \end{array} \text{ i.e., } 35 \text{ Sq. ft } 128 \text{ Sq. inches}$$

By Vedic principles we proceed in the way "the first by first and the last by last"

i.e. 6' 4" can be treated as $6x + 4$ and 5' 8" as $5x + 8$,

Where $x = 1\text{ft.} = 12 \text{ in}$; x^2 is sq. ft.

$$\text{Now } (6x + 4)(5x + 8)$$

$$= 30x^2 + 6.8.x + 4.5.x + 32$$

$$= 30x^2 + 48x + 20x + 32$$

$$= 30x^2 + 68. x + 32$$

$$\begin{aligned}
 &= 30x^2 + (5x + 8) \cdot x + 32 \text{ Writing } 68 = 5 \times 12 + 8 \\
 &= 35x^2 + 8 \cdot x + 32 \\
 &= 35 \text{ Sq. ft.} + 8 \times 12 \text{ Sq. in.} + 32 \text{ Sq. in.} \\
 &= 35 \text{ Sq. ft.} + 96 \text{ Sq. in.} + 32 \text{ Sq. in.} \\
 &= 35 \text{ Sq. ft.} + 128 \text{ Sq. in.}
 \end{aligned}$$

It is interesting to know that a mathematically untrained and even uneducated carpenter simply works in this way by mental argumentation. It goes in his mind like this

$$6' \quad 4''$$

$$5' \quad 8''$$

First by first i.e. $6' \times 5' = 30 \text{ sq. ft.}$

Last by last i.e. $4'' \times 8'' = 32 \text{ sq. in.}$

Now cross wise $6 \times 8 + 5 \times 4 = 48 + 20 = 68.$

Adjust as many '12' s as possible towards left as 'units' i.e. $68 = 5 \times 12 + 8$, 5 twelve's as 5 square feet make the first $30 + 5 = 35 \text{ sq. ft.}$; 8 left becomes $8 \times 12 = 96 \text{ sq. in.}$ towards right gives $96 + 32 = 128 \text{ sq. in.}$

Thus he got area in some sort of 35 squints and another sort of 128 sq. units. i.e. 35 sq. ft 128 sq. in

Another Example:

$$\begin{array}{r|l|l}
 4' & 6'' & \\
 3' & 4'' & \\
 \hline
 4 \times 3 & 4 \times 4 + 6 \times 3 & 6 \times 4 \\
 & = 16 + 18 & \\
 = 12 & = 34 & = 24 \\
 & = 2 \times 12 + 10 &
 \end{array}$$

Now $12 + 2 = 14$, $10 \times 12 + 24 = 120 + 24 = 144$

Thus $4' 6'' \times 3' 4'' = 14 \text{ Sq. ft. } 144 \text{ Sq. inches.}$

Since $144 \text{ sq. in} = 12 \times 12 = 1 \text{ sq. ft}$ The answer is 15 sq. ft .

We can extend the same principle to find volumes of parallelepiped also.

I. Find the area of the rectangles in each of the following situations.

1). $l = 3' 8''$, $b = 2' 4''$ 2). $l = 12' 5''$, $b = 5' 7''$

3). $l = 4 \text{ yard } 3 \text{ ft}$. $b = 2 \text{ yards } 5 \text{ ft}$. (1yard = 3ft)

4). $l = 6 \text{ yard } 6 \text{ ft}$. $b = 5 \text{ yards } 2 \text{ ft}$.

II. Find the area of the trapezium in each of the following cases. Recall $\text{area} = \frac{1}{2} h (a + b)$ where a, b are parallel sides and h is the distance between them.

1). $a = 3' 7''$, $b = 2' 4''$, $h = 1' 5''$

2). $a = 5' 6''$, $b = 4' 4''$, $h = 3' 2''$

3). $a = 8' 4''$, $b = 4' 6''$, $h = 5' 1''$.

Factorization of quadratics:

The usual procedure of factorizing a quadratic is as follows:

$$\begin{aligned} & 3x^2 + 8x + 4 \\ &= 3x^2 + 6x + 2x + 4 \\ &= 3x(x + 2) + 2(x + 2) \\ &= (x + 2)(3x + 2) \end{aligned}$$

But by mental process, we can get the result immediately. The steps are as follows.

i). Split the middle coefficient in to two such parts that the ratio of the first coefficient to the first part is the same as the ratio of the second part to the last coefficient. Thus we split the coefficient of middle term of $3x^2 + 8x + 4$ i.e. 8 in to two such parts 6 and 2 such that the ratio of the first coefficient to the first part of the middle coefficient i.e. $3:6$

and the ratio of the second part to the last coefficient, i.e. 2: 4 are the same. It is clear that $3:6 = 2:4$. Hence such split is valid. Now the ratio $3: 6 = 2: 4 = 1:2$ gives one factor $x+2$.

ii). Second factor is obtained by dividing the first coefficient of the quadratic by the first coefficient of the factor already found and the last coefficient of the quadratic by the last coefficient of the factor.

i.e. the second factor is

$$\frac{3x^2}{x} + \frac{4}{2} = 3x + 2$$

$$\text{Hence } 3x^2 + 8x + 4 = (x + 2)(3x + 2)$$

Eg.1: $4x^2 + 12x + 5$

i) Split 12 into 2 and 10 so that as per rule $4 : 2 = 10 : 5 = 2 : 1$ i.e., $2x + 1$ is first factor.

ii) Now

$$\frac{4x^2}{2x} + \frac{5}{1} = 2x + 5 \text{ is second factor.}$$

Eg.2: $15x^2 - 14xy - 8y^2$

i) Split -14 into $-20, 6$ so that $15 : -20 = 3 : -4$ and $6 : -8 = 3 : -4$. Both are same. i.e., $(3x - 4y)$ is one factor.

ii) Now

$$\frac{15x^2}{3x} + \frac{8y^2}{-4y} = 5x + 2y \text{ is second factor.}$$

$$\text{Thus } 15x^2 - 14xy - 8y^2 = (3x - 4y)(5x + 2y).$$

It is evident that we have applied two sub-sutras '**anurupyena**' i.e. 'proportionality' and '**adhyamadyenantyamantyena**' i.e. 'the first by the first and the last by the last' to obtain the above results.

Factorise the following quadratics applying appropriate vedic maths sutras:

1). $3x^2 + 14x + 15$

2). $6x^2 - 23x + 7$

3). $8x^2 - 22x + 5$

4). $12x^2 - 23xy + 10y^2$

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Vedic Mathematics | Yavadunam Tavadunikritya Varganca Yojayet

Y VAD NAM T VAD N K•TYA VARGAÑCA YOJAYET

The meaning of the Sutra is 'what ever the deficiency subtract that deficit from the number and write along side the square of that deficit'.

This Sutra can be applicable to obtain squares of numbers close to bases of powers of 10.

Method-1 : Numbers near and less than the bases of powers of 10.

Eg 1: 9^2 Here base is 10.

The answer is separated in to two parts by a '/'

Note that deficit is $10 - 9 = 1$

Multiply the deficit by itself or square it

$1^2 = 1$. As the deficiency is 1, subtract it from the number i.e., $9-1 = 8$.

Now put 8 on the left and 1 on the right side of the vertical line or slash i.e., 8/1.

Hence 81 is answer.

Eg. 2: 96^2 Here base is 100.

Since deficit is $100-96=4$ and square of it is 16 and the deficiency subtracted from the number 96 gives $96-4 = 92$, we get the answer 92 / 16 Thus $96^2 = 9216$.

Eg. 3: 994^2 Base is 1000

Deficit is $1000 - 994 = 6$. Square of it is 36.

Deficiency subtracted from 994 gives $994 - 6 = 988$

Answer is 988 / 036 [since base is 1000]

Eg. 4: 9988^2 Base is 10,000.

$$\text{Deficit} = 10000 - 9988 = 12.$$

$$\text{Square of deficit} = 12^2 = 144.$$

$$\text{Deficiency subtracted from number} = 9988 - 12 = 9976.$$

$$\text{Answer is } 9976 / 0144 \quad [\text{since base is } 10,000].$$

Eg. 5: 88^2 Base is 100.

$$\text{Deficit} = 100 - 88 = 12.$$

$$\text{Square of deficit} = 12^2 = 144.$$

$$\text{Deficiency subtracted from number} = 88 - 12 = 76.$$

$$\text{Now answer is } 76 / 144 = 7744 \quad [\text{since base is } 100]$$

Algebraic proof:

The numbers near and less than the bases of power of 10 can be treated as $(x-y)$, where x is the base and y , the deficit.

Thus

$$(1) 9 = (10 - 1) \quad (2) 96 = (100 - 4) \quad (3) 994 = (1000 - 6)$$

$$(4) 9988 = (10000 - 12) \quad (v) 88 = (100 - 12)$$

$$\begin{aligned} (x - y)^2 &= x^2 - 2xy + y^2 \\ &= x(x - 2y) + y^2 \\ &= x(x - y - y) + y^2 \\ &= \text{Base} (\text{number} - \text{deficiency}) + (\text{deficit})^2 \end{aligned}$$

Thus

$$\begin{aligned} 985^2 &= (1000 - 15)^2 \\ &= 1000(985 - 15) + (15)^2 \\ &= 1000(970) + 225 \\ &= 970000 + 225 \\ &= 970225. \end{aligned}$$

or we can take the identity $a^2 - b^2 = (a + b)(a - b)$ and proceed as

$$a^2 - b^2 = (a + b) (a - b).$$

gives $a^2 = (a + b) (a - b) + b^2$

Thus for $a = 985$ and $b = 15$;

$$a^2 = (a + b) (a - b) + b^2$$

$$\begin{aligned} 985^2 &= (985 + 15) (985 - 15) + (15)^2 \\ &= 1000 (970) + 225 \\ &= 970225. \end{aligned}$$

Method. 2 : Numbers near and greater than the bases of powers of 10.

Eg.(1): 13^2 .

Instead of subtracting the deficiency from the number we add and proceed as in Method-1.

for 13^2 , base is 10, surplus is 3.

Surplus added to the number = $13 + 3 = 16$.

Square of surplus = $3^2 = 9$

Answer is $16 / 9 = 169$.

Eg.(2): 112^2

Base = 100, Surplus = 12,

Square of surplus = $12^2 = 144$

add surplus to number = $112 + 12 = 124$.

Answer is $124 / 144 = 12544$

Or think of identity $a^2 = (a + b) (a - b) + b^2$ for $a = 112$, $b = 12$:

$$\begin{aligned} 112^2 &= (112 + 12) (112 - 12) + 12^2 \\ &= 124 (100) + 144 \\ &= 12400 + 144 \end{aligned}$$

$$= 12544.$$

$$\begin{aligned}(x + y)^2 &= x^2 + 2xy + y^2 \\ &= x (x + 2y) + y^2 \\ &= x (x + y + y) + y^2\end{aligned}$$

$$= \text{Base (Number + surplus)} + (\text{surplus})^2$$

gives

$$\begin{aligned}112^2 &= 100 (112 + 12) + 12^2 \\ &= 100 (124) + 144 \\ &= 12400 + 144 \\ &= 12544.\end{aligned}$$

Eg. 3: 10025^2

$$\begin{aligned}&= (10025 + 25) / 25^2 \\ &= 10050 / 0625 \quad [\text{since base is } 10,000] \\ &= 100500625.\end{aligned}$$

Method - 3: This is applicable to numbers which are near to multiples of 10, 100, 1000 etc. For this we combine the upa-Sutra 'anurupyena' and 'yavadunam tavadunikritya varganca yojayet' together.

Example 1: 388^2 Nearest base = 400.

We treat 400 as 4×100 . As the number is less than the base we proceed as follows

$$\text{Number } 388, \text{ deficit} = 400 - 388 = 12$$

Since it is less than base, deduct the deficit

$$\text{i.e. } 388 - 12 = 376.$$

multiply this result by 4 since base is $4 \times 100 = 400$.

$$376 \times 4 = 1504$$

$$\text{Square of deficit} = 12^2 = 144.$$

Hence answer is $1504 / 144 = 150544$ [since we have taken multiples of

100].

Example 2: 485^2 Nearest base = 500.Treat 500 as 5×100 and proceed

$$\begin{aligned}
 485^2 &= (485 - 15) / 15^2 \quad [\text{since deficit is } 15] \\
 &= 470 / 225 \quad \text{since } 500 \text{ base is taken as } 5 \times 100 \\
 &\quad \times 5 / \quad \text{and } 2 \text{ of } 225 \text{ is carried over} \\
 &= 2350 / 225 \\
 &= 235225
 \end{aligned}$$

Example 3: 67^2 Nearest base = 70

$$\begin{aligned}
 67^2 &= (67 - 3) / 3^2 \quad \text{deficit is } 3 \\
 &= 64 / 9 \\
 &\quad \times 7 / \quad [\text{since } 7 \times 10 = 70] \\
 &= 448 / 9 \\
 &= 4489
 \end{aligned}$$

Example 4: 416^2 Nearest (lower) base = 400Here surplus = 16 and $400 = 4 \times 100$

$$\begin{aligned}
 416^2 &= (416 + 16) / 16^2 \\
 &= 432 / 256 \quad \text{since base is multiple } 100; \\
 &\quad \times 4 / \quad \text{and } 2 \text{ of } 256 \text{ is carried over} \\
 &= 1728 / 256 \\
 &= 173056
 \end{aligned}$$

Example 5: 5012^2 Nearest lower base is $5000 = 5 \times 1000$

Surplus = 12

$$\begin{aligned}
 5012^2 &= (5012 + 12) / 12^2 \\
 &= 5024 / 144 \\
 &\times 5 \\
 &= 25120 / 144 \\
 &= 25120144
 \end{aligned}$$

Apply yavadunam to find the following squares.

- | | | | |
|------------|-------------|--------------|----------------|
| 1. 7^2 | 2. 98^2 | 3. 987^2 | 4. 14^2 |
| 5. 116^2 | 6. 1012^2 | 7. 19^2 | 8. 475^2 |
| 9. 796^2 | 10. 108^2 | 11. 9988^2 | 12. 6014^2 . |

So far we have observed the application of yavadunam in finding the squares of number. Now with a slight modification yavadunam can also be applied for finding the cubes of numbers.

Cubing of Numbers:

Example : Find the cube of the number 106.

We proceed as follows:

- i) For 106, Base is 100. The surplus is 6.

Here we add double of the surplus i.e. $106 + 12 = 118$.

(Recall in squaring, we directly add the surplus)

This makes the left-hand -most part of the answer.

i.e. answer proceeds like $118 / - - - -$

- ii) Put down the new surplus i.e. $118 - 100 = 18$ multiplied by the initial surplus

i.e. $6 = 108$.

Since base is 100, we write 108 in carried over form 108 i.e. .

As this is middle portion of the answer, the answer proceeds like $118 / 108 / \dots$

iii) Write down the cube of initial surplus i.e. $6^3 = 216$ as the last portion

i.e. right hand side last portion of the answer.

Since base is 100, write 216 as 216 as 2 is to be carried over.

Answer is $118 / 108 / 216$

Now proceeding from right to left and adjusting the carried over, we get the answer

$$119 / 10 / 16 = 1191016.$$

Eg.(1): $102^3 = (102 + 4) / 6 \times 2 / 2^3$

$$= 106 \quad = 12 \quad = 08$$

$$= 1061208.$$

Observe initial surplus = 2, next surplus = 6 and base = 100.

Eg.(2): 94^3

Observe that the nearest base = 100. Here it is deficit contrary to the above examples.

i) Deficit = -6. Twice of it $-6 \times 2 = -12$
add it to the number = $94 - 12 = 82$.

ii) New deficit is -18.
Product of new deficit x initial deficit = $-18 \times -6 = 108$

iii) deficit³ = $(-6)^3 = -216$.

Hence the answer is $82 / 108 / \overline{-216}$

Since 100 is base 1 and -2 are the carried over. Adjusting the carried over in order, we get the answer

$$\begin{aligned} & (82 + 1) / (08 - 03) / (100 - 16) \\ & = 83 \quad / \quad = 05 \quad / \quad = 84 \quad = 830584 \end{aligned}$$

$\overline{16}$ becomes 84 after taking 1 from middle most portion i.e. 100. (100-16=84).

Now $08 - 01 = 07$ remains in the middle portion, and $\overline{2}$ or 2 carried to it makes the middle as $07 - 02 = 05$. Thus we get the above result.

Eg.(3):

$$998^3 \text{ Base} = 1000; \text{ initial deficit} = - 2.$$

$$\begin{aligned} 998^3 &= (998 - 2 \times 2) / (- 6 \times - 2) / (- 2)^3 \\ &= 994 \quad / \quad = 012 \quad / \quad = -008 \\ &= 994 / 011 / 1000 - 008 \\ &= 994 / 011 / 992 \\ &= 994011992. \end{aligned}$$

Find the cubes of the following numbers using yavadunam sutra.

- | | | | | |
|--------|--------|---------|------------|-------------|
| 1. 105 | 2. 114 | 3. 1003 | 4. 10007 | 5. 92 |
| 6. 96 | 7. 993 | 8. 9991 | 9. 1000008 | 10. 999992. |

ANTYAYOREVA

'Antyayoreva' means 'only the last terms'. This is useful in solving simple equations of the following type.

The type of equations are those whose numerator and denominator on the L.H.S. bearing the independent terms stand in the same ratio to each other as the entire numerator and the entire denominator of the R.H.S. stand to each other.

Let us have a look at the following example.

Example 1:

$$\frac{x^2 + 2x + 7}{x^2 + 3x + 5} = \frac{x + 2}{x + 3}$$

In the conventional method we proceed as

$$\frac{x^2 + 2x + 7}{x^2 + 3x + 5} = \frac{x + 2}{x + 3}$$

$$\begin{aligned}(x + 3)(x^2 + 2x + 7) &= (x + 2)(x^2 + 3x + 5) \\ x^3 + 2x^2 + 7x + 3x^2 + 6x + 21 &= x^3 + 3x^2 + 5x + 2x^2 + 6x + 10 \\ x^3 + 5x^2 + 13x + 21 &= x^3 + 5x^2 + 11x + 10\end{aligned}$$

Canceling like terms on both sides

$$\begin{aligned}13x + 21 &= 11x + 10 \\ 13x - 11x &= 10 - 21 \\ 2x &= -11 \\ x &= -11 / 2\end{aligned}$$

Now we solve the problem using antyayoreva.

$$\frac{x^2 + 2x + 7}{x^2 + 3x + 5} = \frac{x + 2}{x + 3}$$

Consider

$$\frac{x^2 + 2x + 7}{x^2 + 3x + 5} = \frac{x + 2}{x + 3}$$

Observe that

$$\frac{x^2 + 2x}{x^2 + 3x} = \frac{x(x + 2)}{x(x + 3)} = \frac{x + 2}{x + 3}$$

This is according to the condition in the sutra. Hence from the sutra

$$\frac{x + 2}{x + 3} = \frac{7}{5}$$

$$\begin{aligned} 5x + 10 &= 7x + 21 \\ 7x - 5x &= -21 + 10 \\ 2x &= -11 \\ x &= -11 / 2 \end{aligned}$$

Algebraic Proof:

Consider the equation

$$\frac{AC + D}{BC + E} = \frac{A}{B} \text{ ----- (i)}$$

This satisfies the condition in the sutra since

$$\frac{AC}{BC} = \frac{A}{B}$$

Now cross-multiply the equation (i)

$$\begin{aligned} B(AC + D) &= A(BC + E) \\ BAC + BD &= ABC + AE \\ BD &= AE \text{ which gives} \end{aligned}$$

$$\frac{A}{B} = \frac{D}{E}$$

$$\frac{\quad}{B} = \frac{\quad}{E} \text{ -----(ii)}$$

i.e., the result obtained in solving equation (i) is same as the result obtained in solving equation (ii).

Example 2: solve

$$\frac{2x^2 + 3x + 10}{3x^2 + 4x + 14} = \frac{2x + 3}{3x + 4}$$

Since

$$\frac{2x^2 + 3x}{3x^2 + 4x} = \frac{x(2x + 3)}{x(3x + 4)} = \frac{2x + 3}{3x + 4}$$

We can apply the sutra.

$$\frac{2x + 3}{3x + 4} = \frac{10}{14}$$

Cross-multiplying

$$\begin{aligned} 28x + 42 &= 30x + 40 \\ 28x - 30x &= 40 - 42 \\ -2x &= -2 \quad \therefore x = -2 / -2 = 1. \end{aligned}$$

Let us see the application of the sutra in another type of problem.

Example 3: $(x + 1)(x + 2)(x + 9) = (x + 3)(x + 4)(x + 5)$

Re-arranging the equation, we have

$$\frac{(x + 1)(x + 2)}{(x + 4)(x + 5)} = \frac{x + 3}{x + 9}$$

i.e.,

$$= \frac{x^2 + 3x + 2x + 3}{x^2 + 9x + 20x + 9}$$

Now

$$\frac{x^2 + 3x}{x^2 + 9x} = \frac{x(x + 3)}{x(x + 9)} = \frac{x + 3}{x + 9} \quad \text{gives the solution by antyayoreva}$$

Solution is obtained from

$$\frac{x + 3}{x + 9} = \frac{2}{20}$$

$$20x + 60 = 2x + 18$$

$$20x - 2x = 18 - 60$$

$$18x = -42 \quad \therefore x = -42 / 18 = -7 / 3.$$

Once again look into the problem

$$(x + 1)(x + 2)(x + 9) = (x + 3)(x + 4)(x + 5)$$

Sum of the binomials on each side

$$x + 1 + x + 2 + x + 9 = 3x + 12$$

$$x + 3 + x + 4 + x + 5 = 3x + 12$$

It is same. In such a case the equation can be adjusted into the form suitable for application of antyayoreva.

Example 4: $(x + 2)(x + 3)(x + 11) = (x + 4)(x + 5)(x + 7)$

$$\text{Sum of the binomials on L.H.S.} = 3x + 16$$

$$\text{Sum of the binomials on R.H.S.} = 3x + 16$$

They are same. Hence antyayoreva can be applied. Adjusting we get

$$\frac{(x + 2)(x + 3)}{(x + 4)(x + 7)} = \frac{x + 5}{x + 11} = \frac{2 \times 3}{4 \times 7} = \frac{6}{28}$$

$$28x + 140 = 6x + 66$$

$$28x - 6x = 66 - 140$$

$$22x = -74$$

$$x = \frac{-74}{22} = \frac{-37}{11}$$

Solve the following problems using 'antyaoreva'

1.

$$\frac{3x^2 + 5x + 8}{5x^2 + 6x + 12} = \frac{3x + 5}{5x + 6}$$

2.

$$\frac{4x^2 + 5x + 3}{3x^2 + 2x + 4} = \frac{4x + 5}{3x + 2}$$

3. $(x + 3)(x + 4)(x + 6) = (x + 5)(x + 1)(x + 7)$

4. $(x + 1)(x + 6)(x + 9) = (x + 4)(x + 5)(x + 7)$

5.

$$\frac{2x^2 + 3x + 9}{4x^2 + 5x + 17} = \frac{2x + 3}{4x + 5}$$

LOPANASTH PAN BHY M

Lopana sthapanabhyam means 'by alternate elimination and retention'.

Consider the case of factorization of quadratic equation of type $ax^2 + by^2 + cz^2 + dxy + eyz + fzx$. This is a homogeneous equation of second degree in three variables x, y, z . The sub-sutra removes the difficulty and makes the factorization simple. The steps are as follows:

- i) Eliminate z by putting $z = 0$ and retain x and y and factorize thus obtained a quadratic in x and y by means of 'adyamadyena' sutra.;
- ii) Similarly eliminate y and retain x and z and factorize the quadratic in x and z .
- iii) With these two sets of factors, fill in the gaps caused by the elimination process of z and y respectively. This gives actual factors of the expression.

Example 1: $3x^2 + 7xy + 2y^2 + 11xz + 7yz + 6z^2$.

Step (i): Eliminate z and retain x, y ; factorize
 $3x^2 + 7xy + 2y^2 = (3x + y)(x + 2y)$

Step (ii): Eliminate y and retain x, z ; factorize
 $3x^2 + 11xz + 6z^2 = (3x + 2z)(x + 3z)$

Step (iii): Fill the gaps, the given expression
 $= (3x + y + 2z)(x + 2y + 3z)$

Example 2: $12x^2 + 11xy + 2y^2 - 13xz - 7yz + 3z^2$.

Step (i): Eliminate z i.e., $z = 0$; factorize
 $12x^2 + 11xy + 2y^2 = (3x + 2y)(4x + y)$

Step (ii): Eliminate y i.e., $y = 0$; factorize
 $12x^2 - 13xz + 3z^2 = (4x - 3z)(3x - z)$

Step (iii): Fill in the gaps; the given expression

$$= (4x + y - 3z) (3x + 2y - z)$$

Example 3: $3x^2 + 6y^2 + 2z^2 + 11xy + 7yz + 6xz + 19x + 22y + 13z + 20$

Step (i): Eliminate y and z , retain x and independent term
i.e., $y = 0, z = 0$ in the expression (E).

$$\text{Then } E = 3x^2 + 19x + 20 = (x + 5) (3x + 4)$$

Step (ii): Eliminate z and x , retain y and independent term
i.e., $z = 0, x = 0$ in the expression.

$$\text{Then } E = 6y^2 + 22y + 20 = (2y + 4) (3y + 5)$$

Step (iii): Eliminate x and y , retain z and independent term
i.e., $x = 0, y = 0$ in the expression.

$$\text{Then } E = 2z^2 + 13z + 20 = (z + 4) (2z + 5)$$

Step (iv): The expression has the factors (think of independent terms)

$$= (3x + 2y + z + 4) (x + 3y + 2z + 5).$$

In this way either homogeneous equations of second degree or general equations of second degree in three variables can be very easily solved by applying 'adyamadyena' and 'lopanasthapanabhyam' sutras.

Solve the following expressions into factors by using appropriate sutras:

1. $x^2 + 2y^2 + 3xy + 2xz + 3yz + z^2.$
2. $3x^2 + y^2 - 4xy - yz - 2z^2 - zx.$
3. $2p^2 + 2q^2 + 5pq + 2p - 5q - 12.$
4. $u^2 + v^2 - 4u + 6v - 12.$
5. $x^2 - 2y^2 + 3xy + 4x - y + 2.$
6. $3x^2 + 4y^2 + 7xy - 2xz - 3yz - z^2 + 17x + 21y - z + 20.$

Highest common factor:

To find the Highest Common Factor i.e. H.C.F. of algebraic expressions, the factorization method and process of continuous division are in practice in the conventional system. We now apply 'Lopana - Sthapana' Sutra, the 'Sankalana vyavakalanakam' process and the 'Adyamadya' rule to find out the H.C.F in a more easy and elegant way.

Example 1: Find the H.C.F. of $x^2 + 5x + 4$ and $x^2 + 7x + 6$.

1. Factorization method:

$$x^2 + 5x + 4 = (x + 4)(x + 1)$$

$$x^2 + 7x + 6 = (x + 6)(x + 1)$$

H.C.F. is $(x + 1)$.

2. Continuous division process.

$$\begin{array}{r}
 x^2 + 5x + 4 \) \ x^2 + 7x + 6 \ (\ 1 \\
 \underline{x^2 + 5x + 4} \\
 2x + 2 \) \ x^2 + 5x + 4 \ (\ \frac{1}{2}x \\
 \underline{x^2 + x} \\
 4x + 4 \) \ 2x + 2 \ (\ \frac{1}{2} \\
 \underline{2x + 2} \\
 0
 \end{array}$$

Thus $4x + 4$ i.e., $(x + 1)$ is H.C.F.

3. Lopana - Sthapana process i.e. elimination and retention or alternate destruction of the highest and the lowest powers is as below:

$$\text{Subtract} \left\{ \begin{array}{l} x^2 + 5x + 4 \\ x^2 + 7x + 6 \\ \hline -2) -2x - 2 \\ \hline x + 1 \end{array} \right.$$

i.e., $(x + 1)$ is H.C.F

Example 2: Find H.C.F. of $2x^2 - x - 3$ and $2x^2 + x - 6$

$$\text{Subtract } \left\{ \begin{array}{l} 2x^2 - x - 3 \\ 2x^2 + x - 6 \\ \hline -1) \underline{-2x + 3} \end{array} \right.$$

$2x + 3$ is the H.C.F

Example 3: $x^3 - 7x - 6$ and $x^3 + 8x^2 + 17x + 10$.

Now by Lopana - Sthapana and Sankalana – Vyavakalanabhyam

$$\text{Subtract } \left\{ \begin{array}{l} x^3 - 7x - 6 \\ x^3 + 8x^2 + 17x + 10 \\ \hline -8) \underline{-8x^2 - 24x - 16} \end{array} \right.$$

$x^2 + 3x + 2$

Example 4: $x^3 + 6x^2 + 5x - 12$ and $x^3 + 8x^2 + 19x + 12$.

$$\text{Add } \left\{ \begin{array}{l} x^3 + 6x^2 + 5x - 12 \\ x^3 + 8x^2 + 19x + 12 \\ \hline 2x^3 + 14x^2 + 24x \end{array} \right.$$

$\div 2x$

$x^2 + 7x + 12$

(or)

$$\text{Subtract } \left\{ \begin{array}{l} x^3 + 6x^2 + 5x - 12 \\ x^3 + 8x^2 + 19x + 12 \\ \hline 2x^2 - 14x - 24 \end{array} \right.$$

$\div -2$

$x^2 + 7x + 12$

Example 5: $2x^3 + x^2 - 9$ and $x^4 + 2x^2 + 9$.

By Vedic sutras:

$$\begin{aligned} \text{Add: } & (2x^3 + x^2 - 9) + (x^4 + 2x^2 + 9) \\ & = x^4 + 2x^3 + 3x^2. \end{aligned}$$

$$\div x^2 \text{ gives } x^2 + 2x + 3 \text{ ----- (i)}$$

Subtract after multiplying the first by x and the second by 2.

$$\begin{aligned} \text{Thus } (2x^4 + x^3 - 9x) - (2x^4 + 4x^2 + 18) \\ = x^3 - 4x^2 - 9x - 18 \text{ ----- (ii)} \end{aligned}$$

Multiply (i) by x and subtract from (ii)

$$\begin{aligned} x^3 - 4x^2 - 9x - 18 - (x^3 + 2x^2 + 3x) \\ = -6x^2 - 12x - 18 \end{aligned}$$

$$\div -6 \text{ gives } x^2 + 2x + 3.$$

Thus $(x^2 + 2x + 3)$ is the H.C.F. of the given expressions.

Algebraic Proof:

Let P and Q be two expressions and H is their H.C.F. Let A and B the Quotients after their division by H.C.F.

$$\text{i.e., } \frac{P}{H} = A \text{ and } \frac{Q}{H} = B \text{ which gives } P = A.H \text{ and } Q = B.H$$

$$\begin{aligned} P + Q &= AH + BH \text{ and } P - Q = AH - BH \\ &= (A+B).H \qquad \qquad \qquad = (A-B).H \end{aligned}$$

Thus we can write $P \pm Q = (A \pm B).H$

Similarly $MP = M.AH$ and $NQ = N.BH$ gives $MP \pm NQ = H (MA \pm NB)$

This states that the H.C.F. of P and Q is also the H.C.F. of $P \pm Q$ or $MA \pm NB$.

i.e. we have to select M and N in such a way that highest powers and lowest powers (or independent terms) are removed and H.C.F appears as we have seen in the examples.

Find the H.C.F. in each of the following cases using Vedic sutras:

1. $x^2 + 2x - 8, x^2 - 6x + 8$

2. $x^3 - 3x^2 - 4x + 12, x^3 - 7x^2 + 16x - 12$

3. $x^3 + 6x^2 + 11x + 6, x^3 - x^2 - 10x - 8$

4. $6x^4 - 11x^3 + 16x^2 - 22x + 8,$
 $6x^4 - 11x^3 - 8x^2 + 22x - 8.$

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VILOKANAM

The Sutra 'Vilokanam' means 'Observation'. Generally we come across problems which can be solved by mere observation. But we follow the same conventional procedure and obtain the solution. But the hint behind the Sutra enables us to observe the problem completely and find the pattern and finally solve the problem by just observation.

Let us take the equation $x + (1/x) = 5/2$ Without noticing the logic in the problem, the conventional process tends us to solve the problem in the following way.

$$x + \frac{1}{x} = \frac{5}{2}$$

$$\frac{x^2 + 1}{x} = \frac{5}{2}$$

$$2x^2 + 2 = 5x$$

$$2x^2 - 5x + 2 = 0$$

$$2x^2 - 4x - x + 2 = 0$$

$$2x(x - 2) - (x - 2) = 0$$

$$(x - 2)(2x - 1) = 0$$

$$x - 2 = 0 \text{ gives } x = 2$$

$$2x - 1 = 0 \text{ gives } x = \frac{1}{2}$$

But by Vilokanam i.e., observation

$$x + \frac{1}{x} = \frac{5}{2} \text{ can be viewed as}$$

$$x + \frac{1}{x} = 2 + \frac{1}{2} \text{ giving } x = 2 \text{ or } \frac{1}{2}.$$

Consider some examples.

Example 1 :

$$\frac{x}{x+2} + \frac{x+2}{x} = \frac{34}{15}$$

In the conventional process, we have to take L.C.M, cross-multiplication, simplification and factorization. But Vilokanam gives

$$\frac{34}{15} = \frac{9+25}{5 \times 3} = \frac{3}{5} + \frac{5}{3}$$

$$\frac{x}{x+2} + \frac{x+2}{x} = \frac{3}{5} + \frac{5}{3}$$

gives

$$\frac{x}{x+2} = \frac{3}{5} \quad \text{or} \quad \frac{5}{3}$$

$$\begin{array}{l} 5x = 3x + 6 \quad \text{or} \quad 3x = 5x + 10 \\ 2x = 6 \quad \text{or} \quad -2x = 10 \\ x = 3 \quad \text{or} \quad x = -5 \end{array}$$

Example 2 :

$$\frac{x+5}{x+6} + \frac{x+6}{x+5} = \frac{113}{56}$$

Now,

$$\frac{113}{56} = \frac{49+64}{7 \times 8} = \frac{7}{8} + \frac{8}{7}$$

$$\frac{x+5}{x+6} = \frac{7}{8} \quad \text{or} \quad \frac{x+5}{x+6} = \frac{8}{7}$$

$$\begin{array}{l} 8x + 40 = 7x + 42 \quad 7x + 35 = 8x + 48 \\ \text{or} \\ x = 42 - 40 = 2 \quad -x = 48 - 35 = 13 \\ x = 2 \quad \text{or} \quad x = -13. \end{array}$$

Example 3:

$$\frac{5x + 9}{5x - 9} + \frac{5x - 9}{5x + 9} = 2 \frac{82}{319}$$

At first sight it seems to a difficult problem.

But careful observation gives

$$2 \frac{82}{319} = \frac{720}{319} = \frac{841 - 121}{11 \times 29} = \frac{29}{11} - \frac{11}{29}$$

(Note: $29^2 = 841$, $11^2 = 121$)

$$\frac{5x + 9}{5x - 9} = \frac{29}{11} \quad \text{or} \quad \frac{-11}{29}$$

(Note: $29 = 20 + 9 = 5 \times 4 + 9$; $11 = 20 - 9 = 5 \times 4 - 9$)

i.e.,

$$x = 4 \quad \text{or}$$

$$\frac{5x + 9}{5x - 9} = \frac{-11}{29}$$

$$145x + 261 = -55x + 99$$

$$145x + 55x = 99 - 261$$

$$200x = -162$$

$$x = \frac{-162}{200} = \frac{-81}{100}$$

Simultaneous Quadratic Equations:

Example 1: $x + y = 9$ and $xy = 14$.

We follow in the conventional way that

$$(x - y)^2 = (x + y)^2 - 4xy = 9^2 - 4(14) = 81 - 56 = 25$$

$$x - y = \sqrt{25} = \pm 5$$

$$\left. \begin{array}{l} x + y = 9 \\ x - y = 5 \end{array} \right\} \begin{array}{l} \text{gives } 2x = 14 \\ x = 7 \end{array}$$

$$\begin{aligned} x + y = 9 \text{ gives } 7 + y = 9 \\ y = 9 - 7 = 2. \end{aligned}$$

Thus the solution is $x = 7, y = 2$ or $x = 2, y = 7$.

But by Vilokanam, $xy = 14$ gives $x = 2, y = 7$ or $x = 7, y = 2$ and these two sets satisfy $x + y = 9$ since $2 + 7 = 9$ or $7 + 2 = 9$. Hence the solution.

Example 2: $5x - y = 7$ and $xy = 6$.

$$xy = 6 \text{ gives } x = 6, y = 1; x = 1, y = 6;$$

$$x = 2, y = 3; x = 3, y = 2 \text{ and of course negatives of all these.}$$

Observe that $x = 6, y = 1; x = 1, y = 6$: are not solutions because they do not satisfy the equation $5x - y = 7$.

But for $x = 2, y = 3; 5x - y = 5(2) - 3 = 10 - 3 = 7$ we have $5(3) - 2 \neq 7$.

Hence $x = 2, y = 3$ is a solution.

For $x = 3, y = 2$ we get $5(3) - 2 = 15 - 2 \neq 7$.

Hence it is not a solution.

Negative values of the above are also not the solutions. Thus one set of the solutions i.e., $x = 2, y = 3$ can be found. Of course the other will be obtained from solving $5x - y = 7$ and $5x + y = -13$.

$$\text{i.e., } x = -3/5, y = -10.$$

Partial Fractions:

Example 1: Resolve

$\frac{2x + 7}{(x + 3)(x + 4)}$ into partial fractions.

We write
$$\frac{2x + 7}{(x + 3)(x + 4)} = \frac{A}{(x + 3)} + \frac{B}{(x + 4)}$$

$$= \frac{A(x + 4) + B(x + 3)}{(x + 3)(x + 4)}$$

$$2x + 7 \equiv A(x + 4) + B(x + 3).$$

We proceed by comparing coefficients on either side

coefficient of x : $A + B = 2$ (i) X 3

Independent of x : $4A + 3B = 7$ (ii)

Solving (ii) – (i) x 3

$$\begin{array}{r} 4A + 3B = 7 \\ 3A + 3B = 6 \\ \hline A = 1 \end{array}$$

$A = 1$ in (i) gives, $1 + B = 2$ i.e., $B = 1$

Or we proceed as

$$2x + 7 \equiv A(x + 4) + B(x + 3).$$

Put $x = -3$,

$$2(-3) + 7 \equiv A(-3 + 4) + B(-3 + 3)$$

$$1 = A(1) \quad \therefore A = 1.$$

$x = -4$,

$$2(-4) + 7 = A(-4 + 4) + B(-4 + 3)$$

$$-1 = B(-1) \quad \therefore B = 1.$$

Thus
$$\frac{2x + 7}{(x + 3)(x + 4)} = \frac{1}{(x + 3)} + \frac{1}{(x + 4)}$$

But by Vilokanam $\frac{2x + 7}{(x + 3)(x + 4)}$ can be resolved as

$$(x + 3) + (x + 4) = 2x + 7, \quad \text{directly we write the answer.}$$

Example 2:

$$\frac{3x + 13}{(x + 1)(x + 2)}$$

from $(x + 1), (x + 2)$ we can observe that

$$10(x + 2) - 7(x + 1) = 10x + 20 - 7x - 7 = 3x + 13$$

Thus

$$\frac{3x + 13}{(x + 1)(x + 2)} = \frac{10}{x + 1} - \frac{7}{x + 2}$$

Example 3:

$$\frac{9}{x^2 + x - 2}$$

As $x^2 + x - 2 = (x - 1)(x + 2)$ and
 $9 = 3(x + 2) - 3(x - 1)$
 $(3x + 6 - 3x + 3 = 9)$

We get by Vilokanam,
$$\frac{9}{x^2 + x - 2} = \frac{3}{x - 1} - \frac{3}{x + 2}$$

I. Solve the following by mere observation i.e. vilokanam

1.

$$x + \frac{1}{x} = \frac{25}{12}$$

2.

$$x - \frac{1}{x} = \frac{5}{6}$$

3.

$$\frac{x}{\quad} + \frac{x + 1}{\quad} = 9 \frac{1}{\quad}$$

$$x + 1 \quad x \quad 9$$

4.

$$\frac{x + 7}{x + 9} - \frac{x + 9}{x + 7} = \frac{32}{63}$$

II. Solve the following simultaneous equations by vilokanam.

1. $x - y = 1, xy = 6$ 2. $x + y = 7, xy = 10$

3. $2x + 3y = 19, xy = 15$

4. $x + y = 4, x^2 + xy + 4x = 24.$

III. Resolve the following into partial fractions.

1.

$$\frac{2x - 5}{(x - 2)(x - 3)}$$

2.

$$\frac{9}{(x + 1)(x - 2)}$$

3.

$$\frac{x - 13}{x^2 - 2x - 15}$$

4.

$$\frac{3x + 4}{3x^2 + 3x + 2}$$

GUNIṬA SAMUCCAYAH - SAMUCCAYA GUṆĪTAH

In connection with factorization of quadratic expressions a sub-Sutra, viz. 'Gunita samuccayah-Samuccaya Gunitah' is useful. It is intended for the purpose of verifying the correctness of obtained answers in multiplications, divisions and factorizations. It means in this context:

'The product of the sum of the coefficients **sc** in the factors is equal to the sum of the coefficients **sc** in the product'

Symbolically we represent as **sc** of the product = product of the **sc** (in the factors)

Example 1: $(x + 3)(x + 2) = x^2 + 5x + 6$

Now $(x + 3)(x + 2) = 4 \times 3 = 12$: Thus verified.

Example 2: $(x - 4)(2x + 5) = 2x^2 - 3x - 20$

Sc of the product $2 - 3 - 20 = -21$

Product of the **Sc** = $(1 - 4)(2 + 5) = (-3)(7) = -21$. Hence verified.

In case of cubics, biquadratics also the same rule applies.

We have $(x + 2)(x + 3)(x + 4) = x^3 + 9x^2 + 26x + 24$

Sc of the product = $1 + 9 + 26 + 24 = 60$

Product of the **Sc** = $(1 + 2)(1 + 3)(1 + 4)$

$$= 3 \times 4 \times 5 = 60. \text{ Verified.}$$

Example 3: $(x + 5)(x + 7)(x - 2) = x^3 + 10x^2 + 11x - 70$

$$(1 + 5)(1 + 7)(1 - 2) = 1 + 10 + 11 - 70$$

i.e., $6 \times 8 \times -1 = 22 - 70$

i.e., $-48 = -48$ Verified.

We apply and interpret **So** and **Sc** as sum of the coefficients of the odd powers

and sum of the coefficients of the even powers and derive that $\mathbf{So} = \mathbf{Sc}$ gives $(x + 1)$ is a factor for the concerned expression in the variable x . $\mathbf{Sc} = 0$ gives $(x - 1)$ is a factor.

Verify whether the following factorization of the expressions are correct or not by the Vedic check:

i.e. Gunita. Samuccayah-Samuccaya Gunitah:

1. $(2x + 3)(x - 2) = 2x^2 - x - 6$
 2. $12x^2 - 23xy + 10y^2 = (3x - 2y)(4x - 5y)$
 3. $12x^2 + 13x - 4 = (3x - 4)(4x + 1)$
 4. $(x + 1)(x + 2)(x + 3) = x^3 + 6x^2 + 11x + 6$
 5. $(x + 2)(x + 3)(x + 8) = x^3 + 13x^2 + 44x + 48$
-

So far we have considered a majority of the upa-sutras as mentioned in the Vedic mathematics book. Only a few Upa-Sutras are not dealt under a separate heading . They are

- 2) S'ISYATE S'ESASAMJ ÑAH
- 4) KEVALAIH SAPTAKAMGUNYAT
- 5) VESTANAM
- 6) YAVAD NAM TAVAD NAM and
- 10) SAMUCCAYAGUNITAH already find place in respective places.

Further in some other books developed on Vedic Mathematics DVANDAYOGA, SUDHA, DHVAJANKAM are also given as Sub-Sutras. They are mentioned in the Vedic Mathematics text also. But the list in the text (by the Editor) does not contain them. We shall also discuss them at appropriate places, with these three included, the total number of upa-Sutras comes to sixteen.

We now proceed to deal the Sutras with reference to their variety, applicability, speed, generality etc. Further we think how 'the element of choice in the Vedic system, even of innovation, together with mental approach, brings a new dimension to the study and practice of Mathematics. The variety and simplicity of the methods brings fun and amusement, the mental practice leads to a more agile, alert and intelligent mind and innovation naturally follow' (Prof. K.R. Williams, London).

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III. VEDIC MATHEMATICS – A BRIEFING

In the previous chapters we have gone through the Vedic Mathematics Sutras and upa - Sutras: their application in solving problems. In this approach we have missed to note some points and merits of one method over the other methods at some instances.

Now we take a few steps in this direction. You may question why this book first gives examples and methods and then once again try to proceed as if an introduction to the Vedic Mathematics has been just started. This is because in this approach the reader first feels that it is easy to solve problems using Vedic Mathematics. This is clear from the examples given. But the reader may get doubt why we are doing this way or that way some times very close and almost akin to the conventional textual way; and some times very different from these procedures? why new representations and different meanings for the same Sutra (!) in different contexts? But observe that it is not uncommon to Mathematics.

Question some body showing the symbol Π .

Majority may say it is $22 / 7$ (is it right?) some may say it is a radian measure. Very few may state it is a function or so.

What does the representation $A \times B$ mean?

A boy thinking about numbers may answer that is A multiplied by B and gives the product provided A and B are known. A girl thinking of set notation simply says that it is Cartesian product of the sets A and B . No sort of multiplication at all.

Another may conclude that it is a product of two matrices A and B . No doubt a multiplication but altogether different from above.

Some other may go deep in to elementary number theory and may take ' \times ' to be the symbol ' \times ' (does not divide) and conclude ' A does not divide B '

Now the question arises does a student fail to understand and apply contextual meaning and representation of symbols and such forms in mathematical writings? certainly not. In the same way the contextual meanings of the Sutras also can not bring any problem to the practitioners of Vedic Mathematics.

Again a careful observation brings all of us to a conclusion that even though the Sutras are not like mathematical formulae so as to fit in any context under consideration but they are intended to recognize the pattern in the problems and suggest procedures to solve. Now recall the terms, rules and methods once again to fill in some gaps that occur in the previous attempt.

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TERMS AND OPERATIONS

a) **Ekadhika** means 'one more'

e.g: Ekadhika of 0 is 1
 Ekadhika of 1 is 2

 Ekadhika of 8 is 9

 Ekadhika of 23 is 24

 Ekadhika of 364 is 365-----

b) **Ekanyuna** means 'one less'

e.g: Ekanyuna of 1 2 3 8 1469
 is 0 1 2 713 68

c) **Purak** means 'complement'

e.g: purak of 1 2 3 8., 9 from 10
 is 9 8 7 2 1

d) **Rekhank** means 'a digit with a bar on its top'. In other words it is a negative number.

e.g: A bar on 7 is $\bar{7}$. It is called rekhank 7 or bar 7. We treat purak as a Rekhank.

e.g: $\bar{7}$ is 3 and $\bar{3}$ is 7

At some instances we write negative numbers also with a bar on the top of the numbers as

-4 can be shown as $\bar{4}$.

-21 can be shown as $\bar{21}$.

e) Addition and subtraction using Rekhank.

Adding a bar-digit i.e. Rekhank to a digit means the digit is subtracted.

e.g: $3 + \bar{1} = 2$, $5 + \bar{2} = 3$, $4 + \bar{4} = 0$

Subtracting a bar - digit i.e. Rekhank to a digit means the digit is added.

e.g: $4 - \bar{1} = 5$, $6 - \bar{2} = 8$, $3 - \bar{3} = 6$

1. Some more examples

e.g: $3 + 4 = 7$

$$(-2) + (-5) = \bar{2} + \bar{5} = \bar{7} \text{ or } -7$$

f) Multiplication and Division using rekhank.

1. Product of two positive digits or two negative digits (Rekhanks)

e.g: $2 \times 4 = 8$; $\bar{4} \times \bar{3} = 12$ i.e. always positive

2. Product of one positive digit and one Rekhank

e.g: $3 \times \bar{2} = \bar{6}$ or -6 ; $\bar{5} \times 3 = \bar{15}$ or -15 i.e. always Rekhank or negative.

3. Division of one positive by another or division of one Rekhank by another Rekhank.

e.g: $8 \div 2 = 4$, $\bar{6} \div \bar{3} = 2$ i.e. always positive

4. Division of a positive by a Rekhank or vice versa.

e.g: $\bar{10} \div 5 = \bar{2}$, $6 \div \bar{2} = \bar{3}$ i.e. always negative or Rekhank.

g) Beejank: The Sum of the digits of a number is called Beejank. If the addition is a two digit number, Then these two digits are also to be added up to get a single digit.

e.g: Beejank of 27 is $2 + 7 = 9$.

Beejank of 348 is $3 + 4 + 8 = 15$

Further $1 + 5 = 6$. i.e. 6 is Beejank.

Beejank of 1567 $\longrightarrow 1 + 5 + 6 + 7 \longrightarrow 19 \longrightarrow 1 + 9 \longrightarrow 1$

i.e. Beejank of 1567 is 1.

ii) Easy way of finding Beejank:

Beejank is unaffected if 9 is added to or subtracted from the number. This nature of 9 helps in finding Beejank very quickly, by cancelling 9 or the digits adding to 9 from the number.

eg 1: Find the Beejank of 632174.

As above we have to follow

$632174 \longrightarrow 6 + 3 + 2 + 1 + 7 + 4 \longrightarrow 23 \longrightarrow 2 + 3 \longrightarrow 5$

But a quick look gives 6 & 3 ; 2 & 7 are to be ignored because $6+3=9, 2+7=9$. Hence remaining $1 + 4 \longrightarrow 5$ is the beejank of 632174.

eg 2:

Beejank of 1256847 $\longrightarrow 1+2+5+6+8+4+7 \longrightarrow 33 \longrightarrow 3+3 \longrightarrow 6$.

But we can cancel 1& 8, 2& 7, 5 & 4 because in each case the sum is 9. Hence remaining 6 is the Beejank.

h) Check by Beejank method:

The Vedic sutra - Gunita Samuccayah gives 'the whole product is same'. We apply this sutra in this context as follows. It means that the operations carried out with the numbers have same effect when the same operations are carried out with their Beejanks.

Observe the following examples.

i) 42 + 39

Beejanks of 42 and 39 are respectively $4 + 2 = 6$ and $3 + 9 = 12$ and $1+2=3$

Now $6 + 3 = 9$ is the Beejank of the sum of the two numbers

Further $42 + 39 = 81$. Its Beejank is $8 + 1 = 9$.

we have checked the correctness.

ii) $64 + 125$.

$$64 \longrightarrow 6 + 4 \longrightarrow 10 \longrightarrow 1 + 0 \longrightarrow 1$$

$$125 \longrightarrow 1 + 2 + 5 \longrightarrow 8$$

Sum of these Beejanks $8 + 1 = 9$

Note that

$$64 + 125 = 189 \longrightarrow 1 + 8 + 9 \longrightarrow 18 \longrightarrow 1 + 8 \longrightarrow 9$$

we have checked the correctness.

iii) $134 - 49$

$$134 \longrightarrow 1 + 3 + 4 \longrightarrow 8$$

$$49 \longrightarrow 4 + 9 \longrightarrow 13 \longrightarrow 1 + 3 \longrightarrow 4$$

Difference of Beejanks $8 - 4 \longrightarrow 4$, note that $134 - 49 = 85$

Beejanks of 85 is $8 + 5 \longrightarrow 85 \longrightarrow 8 + 5 \longrightarrow 13 \longrightarrow 1 + 3 \longrightarrow 4$ verified.

iv) $376 - 284$

$$376 \longrightarrow 7 \text{ (" 6 + 3 \longrightarrow 9)}$$

$$284 \longrightarrow 2 + 8 + 4 \longrightarrow 14 \longrightarrow 1 + 4 \longrightarrow 5$$

Difference of Beejanks = $7 - 5 = 2$

$$376 - 284 = 92$$

$$\text{Beejank of } 92 \longrightarrow 9 + 2 \longrightarrow 11 \longrightarrow 1 + 1 \longrightarrow 2$$

Hence verified.

$$\text{v) } 24 \times 16 = 384$$

Multiplication of Beejanks of

$$24 \text{ and } 16 \text{ is } 6 \times 7 = 42 \longrightarrow 4 + 2 \longrightarrow 6$$

$$\text{Beejank of } 384 \longrightarrow 3 + 8 + 4 \longrightarrow 15 \longrightarrow 1 + 5 \longrightarrow 6$$

Hence verified.

$$\text{vi) } 237 \times 18 = 4266$$

$$\text{Beejank of } 237 \longrightarrow 2 + 3 + 7 \longrightarrow 12 \longrightarrow 1 + 2 \longrightarrow 3$$

$$\text{Beejank of } 18 \longrightarrow 1 + 8 \longrightarrow 9$$

$$\text{Product of the Beejanks} = 3 \times 9 \longrightarrow 27 \longrightarrow 2 + 7 \longrightarrow 9$$

$$\text{Beejank of } 4266 \longrightarrow 4 + 2 + 6 + 6 \longrightarrow 18 \longrightarrow 1 + 8 \longrightarrow 9$$

Hence verified.

$$\text{vii) } 24^2 = 576$$

$$\text{Beejank of } 24 \longrightarrow 2 + 4 \longrightarrow 6$$

$$\text{square of it } 6^2 \longrightarrow 36 \longrightarrow 9$$

$$\text{Beejank of result} = 576 \longrightarrow 5 + 7 + 6 \longrightarrow 18 \longrightarrow 1 + 8 \longrightarrow 9$$

Hence verified.

$$\text{viii) } 356^2 = 126736$$

$$\text{Beejank of } 356 \longrightarrow 3 + 5 + 6 \longrightarrow 5$$

$$\text{Square of it} = 5^2 = 25 \longrightarrow 2 + 5 \longrightarrow 7$$

$$\text{Beejank of result } 126736 \longrightarrow 1 + 2 + 6 + 7 + 3 + 6 \longrightarrow 1 + 6 \longrightarrow 7$$

($\therefore 7 + 2 = 9$; $6 + 3 = 9$) hence verified.

ix) Beejank in Division:

Let P, D, Q and R be respectively the dividend, the divisor, the quotient and the remainder.

Further the relationship between them is $P = (Q \times D) + R$

eg 1: $187 \div 5$

we know that $187 = (37 \times 5) + 2$ now the Beejank check.

We know that $187 = (37 \times 5) + 2$ now the Beejank check.

$$187 \longrightarrow 1 + 8 + 7 \longrightarrow 7 (\therefore 1 + 8 = 9)$$

$$(37 \times 5) + 2 \longrightarrow \text{Beejank } [(3 + 7) \times 5] + 2$$

$$\longrightarrow 5 + 2 \longrightarrow 7$$

Hence verified.

eg 2: $7986 \div 143$

$$7896 = (143 \times 55) + 121$$

$$\text{Beejank of } 7986 \longrightarrow 7 + 9 + 8 + 6 \longrightarrow 21$$

$$(\therefore 9 \text{ is omitted}) \longrightarrow 2 + 1 \longrightarrow 3$$

$$\text{Beejank of } 143 \times 55 \longrightarrow (1 + 4 + 3) (5 + 5)$$

$$\longrightarrow 8 \times 10 \longrightarrow 80 \longrightarrow (8 + 0) \longrightarrow 8$$

$$\text{Beejank of } (143 \times 55) + 121 \longrightarrow 8 + (1 + 2 + 1)$$

$$\longrightarrow 8 + 4 \longrightarrow 12 \longrightarrow 1 + 2 \longrightarrow 3$$

hence verified.

Check the following results by Beejank method

$$1. 67 + 34 + 82 = 183$$

$$2. 4381 - 3216 = 1165$$

$$3. 63^2 = 3969$$

$$4. (1234)^2 = 1522756$$

$$5. (86 \times 17) + 34 = 1496$$

$$6. 2556 \div 127 \text{ gives } Q = 20, R = 16$$

i) Vinculum : The numbers which by presentation contains both positive and negative digits are called vinculum numbers.

ii) Conversion of general numbers into vinculum numbers.

We obtain them by converting the digits which are 5 and above 5 or less than 5 without changing the value of that number.

Consider a number say 8. (Note it is greater than 5). Use it complement (purak - rekhank) from 10. It is 2 in this case and add 1 to the left (i.e. tens place) of 8.

$$\text{Thus } 8 = 08 = \overline{12}.$$

The number 1 contains both positive and negative digits

i.e. 1 and $\overline{2}$. Here $\overline{2}$ is in unit place hence it is -2 and value of 1 at tens place is 10.

$$\text{Thus } \overline{12} = 10 - 2 = 8$$

Conveniently we can think and write in the following way

**General
Number**

Conversion

**Vinculum
number**

—

6	10 - 4	14	
97	100 - 3	103	
289	300 - 11	311	etc.,,

The sutras 'Nikhilam Navatascharamam Dasatah' and 'Ekadhikena purvena' are useful for conversion.

eg 1: 289, Edadhika of 2 is 3

Nikhilam from 9 : $8 - 9 = -1$ or $\overline{1}$

Charmam from 10 : $9 - 10 = -1$ or $\overline{1}$

i.e. 289 in vinculum form $\overline{311}$

eg 2: 47768

'Ekadhika' of 4 is 5

'Nikhilam' from 9 (of 776) $\overline{223}$

'Charmam from 10 (of 8) $\overline{2}$

Vinculum of 47168 is 5 $\overline{2232}$

eg 3: 11276.

Here digits 11 are smaller. We need not convert. Now apply for 276 the two sutras Ekadhika of 2 is 3

'Nikhilam Navata' for 76 is $\overline{24}$

$11276 = 113\overline{24}$

i.e. $\overline{11324} = 11300 - 24 = 11276.$

The conversion can also be done by the sutra sankalana vyavakalanabhyam as follows.

eg 4: 315.

sankalanam (addition) = $315 + 315 = 630$.

Vyvakalanam (subtraction) = $630 - 315 = \overline{325}$

Working steps :

$$0 - 5 = \overline{5}$$

$$3 - 1 = 2$$

$$6 - 3 = 3$$

Let's apply this sutra in the already taken example 47768.

Samkalanam = $47768 + 47768 = 95536$

Vyavakalanam = $95536 - 47768$.

$$\left. \begin{array}{l} \text{Steps : } 6 - 8 = \overline{2} \\ 3 - 6 = \overline{3} \\ 5 - 7 = \overline{2} \\ 5 - 7 = \overline{2} \\ 9 - 4 = 5 \end{array} \right\} = \overline{52232}$$

Consider the conversion by sankalanavyavakalanabhyam and check it by Ekadhika and Nikhilam.

eg 5: 12637

1. Sankalana gives, $12637 + 12637 = 25274$

$$25274 - 12637 = (2 - 1) / (5 - 2) / (2 - 6) / (7 - 3) / (4 - 7) = \overline{13443}$$

2. Ekadhika and Nikhilam gives the following.

As in the number 1 2 6 3 7, the smaller and bigger digits (i.e. less than 5 and; 5, greater than 5) are mixed up, we split up in to groups and conversion is made up

as given below.

Split 1 2 6 and 3 7

Now the sutra gives 1 2 6 as $13\bar{4}$ and 3 7 as $4\bar{3}$

Thus $12637 = 13\bar{4}4\bar{3}$

Now for the number 315 we have already obtained vinculum as $325\bar{}$ by "sankalana ... " Now by 'Ekadhika and Nikhilam ...' we also get the same answer.

315 Since digits of 31 are less than 5,

We apply the sutras on 15 only as

Ekadhika of 1 is 2 and Charman of 5 is 5 .

Consider another number which comes under the split process.

eg 6: 24173

As both bigger and smaller numbers are mixed up we split the number 24173 as 24 and 173 and write their vinculum by Ekadhika and Nikhilam sutras as

$24 = 3\bar{6}$ and $173 = 2\bar{2}7$

Thus $24173 = 3\bar{6}2\bar{2}7$

Convert the following numbers into vinculum number by
i. Ekadhika and Nikhilam sutras ii. Sankalana vyavakalana sutra.
Observe whether in any case they give the same answer or not.

1. 64

2. 289

3. 791

4. 2879

5. 19182

6. 823672

7. 123456799

8. 65384738

ii) Conversion of vinculum number into general numbers.

The process of conversion is exactly reverse to the already done. Rekhanks are converted by Nikhilam where as other digits by 'Ekanyunena' sutra. thus:

$$\begin{aligned} \text{i) } \overline{12} &= (1 - 1) / (10 - 2) \text{ Ekanyunena } 1 - 1 \\ &= 08 = 8 \qquad \text{Nikhilam. } \overline{2} = 10 - 2 \end{aligned}$$

$$\begin{aligned} \text{ii) } \overline{326} &= (3 - 1) / (9 - 2) / (10 - 6) \\ &= 274 \end{aligned}$$

$$\begin{aligned} \text{iii) } \overline{3344} &= (3 - 1) / (10 - 3) / (4 - 1) / (10 - 4) \\ &= 2736 \qquad (\text{note the split}) \end{aligned}$$

$$\begin{aligned} \text{iv) } \overline{20340121} &= 2 / (0-1) / (9-3) / (10-4) / (0-1) / (9-1) / (10-2) / 1 \\ &= \overline{21661881} \\ &= \overline{21} / 6 / \overline{61} / 881. \text{ once again split} \\ &= (2 - 1) / (10 - 1) / 6 / (6 - 1) / (10 - 1) / 881 \\ &= 19659881 \end{aligned}$$

$$\begin{aligned} \text{v) } \overline{303212} &= 3 / 0321 / 2 \\ &= 3 / (0-1) / (9-3) / (9-2) / (10-1) / 2 \\ &= 3 / \overline{1} / 6792 \\ &= (3 - 1) / (10 - 1) / 6792 \\ &= 296792. \end{aligned}$$

iii) Single to many conversions.

It is interesting to observe that the conversions can be shown in many ways.

eg 1: 86 can be expressed in following many ways

$$86 = 90 - 4 = \overline{94}$$

$$= 100 - 14 = \overline{114}$$

$$= 1000 - 914 = \overline{1914}$$

$$\text{Thus } 86 = \overline{94} = \overline{114} = \overline{1914} = \overline{19914} = \dots\dots\dots$$

eg 2 :

$$\overline{07} = -10 + 3 = \overline{13}$$

$$\overline{36} = -100 + 64 = \overline{164}$$

$$\overline{978} = -1000 + 22 = \overline{1022}. \text{ etc.,}$$

* Convert by Vedic process the following numbers into vinculum numbers.

1) 274

2) 4898

3) 60725

4) 876129.

* Convert the following vinculum numbers into general form of numbers (normalized form)

1) 283

2) 3619

3) 27216

4) 364718

5) 60391874

(iv) Vedic check for conversion:

The vedic sutra "Gunita Samuctayah" can be applied for verification of the conversion by Beejank method.

Consider a number and find its Beejank. Find the vinculum number by the conversion and find its Beejank. If both are same the conversion is correct.

eg.

$$196 = \overline{216} . \text{ Now Beejank of } 196 \longrightarrow 1 + 9 + 6 \longrightarrow 7$$

Beejank of 216 $\longrightarrow 2 + (-1) + 6 \longrightarrow 7$. Thus verified.

But there are instances at which, if beejank of vinculum number is rekhank i.e. negative. Then it is to be converted to +ve number by adding 9 to Rekhank (already we have practised) and hence 9 is taken as zero, or vice versa in finding Beejank.

eg:

$$\overline{213} = 200 - 13 = 187$$

$$\text{Now Beejank of } \overline{213} = 2 + (-1) + (-3) = -2$$

$$\text{Beejank of } 187 = 1 + 8 + 7 = 16 \longrightarrow 1 + 6 = 7$$

The variation in answers can be easily understood as

$$\overline{2} = \overline{2} + 9 \longrightarrow -2 + 9 = 7 \text{ Hence verified.}$$

Use Vedic check method of the verification of the following result.

$$1. \quad 24 = \overline{36}$$

$$2. \quad 2736 = \overline{3344}.$$

$$3. \quad \overline{326} = 274$$

$$4. \quad \overline{23213} = 17187$$

Addition and subtraction using vinculum numbers.

eg 1: Add 7 and 6 i.e., $7+6$.

i) Change the numbers as vinculum numbers as per rules already discussed.

$$\{ 7 = \overline{13} \text{ and } 6 = \overline{14} \}$$

ii) Carry out the addition column by column in the normal process, moving from top to bottom or vice versa.

$$\text{i.e., } \begin{array}{r} 7 \\ +6 \\ \hline \end{array} \rightarrow \begin{array}{r} \overline{13} \\ \overline{14} \\ \overline{7} \end{array}$$

iii) add the digits of the next higher level i.e., $1 + 1 = 2$

$$\begin{array}{r} \overline{13} \\ \overline{14} \\ \hline \overline{27} \end{array}$$

iv) the obtained answer is to be normalized as per rules already explained. rules already explained.

$$\text{i.e., } \overline{27} = (2 - 1) (10 - 7) = 13 \text{ Thus we get } 7 + 6 = 13.$$

eg 2 : Add 973 and 866.

$$\begin{array}{r} 973 = 1 \overline{0} \overline{3} \overline{3} \\ 866 = 1 \overline{1} \overline{3} \overline{4} \\ \hline 2 \overline{1} \overline{6} \overline{1} \end{array}$$

$$\text{But } \overline{2161} = 2000 - 161 = 1839.$$

Thus $973 + 866$ by vinculum method gives 1839 which is correct.

Observe that in this representation the need to carry over from the previous digit to the next higher level is almost not required.

eg 3 : Subtract 1828 from 4247.

$$\text{i.e., } \begin{array}{r} 4247 \\ -1828 \\ \hline \end{array}$$

Step (i) : write -1828 in Bar form i.e., $\overline{1828}$

(ii) : Now we can add 4247 and 1828 i.e.,

$$\begin{array}{r} 4247 \\ +1828 \\ \hline 3\bar{6}2\bar{1} \end{array}$$

since $7 + \bar{8} = \bar{1}$, $4 + \bar{2} = 2$, $2 + \bar{8} = \bar{6}$, $4 + \bar{1} = 3$

(iii) Changing the answer $3\bar{6}2\bar{1}$ into normal form using Nikhilam, we get

$$3\bar{6}2\bar{1} = 3\bar{6} / 2\bar{1} \text{ split}$$

$$= (3 - 1) / (10 - 6) / (2 - 1) / (10 - 1) = 2419$$

$$\square 4247 - 1828 = 2419$$

Find the following results using Vedic methods and check them

1) $284 + 257$

2) $5224 + 6127$

3) $582 - 464$

4) $3804 - 2612$

ADDITION AND SUBTRACTION

ADDITION:

In the convention process we perform the process as follows.

$$234 + 403 + 564 + 721$$

write as

$$\begin{array}{r} 234 \\ 403 \\ 564 \\ 721 \end{array}$$

Step (i): $4 + 3 + 4 + 1 = 12$ 2 retained and 1 is carried over to left.

Step (ii): $3 + 0 + 6 + 2 = 11$ the carried '1' is added

i.e., Now 2 retained as digit in the second place (from right to left) of the answer and 1 is carried over to left.

step (iii): $2 + 4 + 5 + 7 = 18$ carried over '1' is added

i.e., $18 + 1 = 19$. As the addition process ends, the same 19 is retained in the left hand most part of the answer.

thus

$$\begin{array}{r} 234 \\ 403 \\ 564 \\ +721 \\ \hline 1922 \end{array} \text{ is the answer}$$

we follow sudhikaran process Recall 'sudha' i.e., dot (.) is taken as an upa-sutra (No: 15)

consider the same example

$$\begin{array}{r}
 234 \\
 403 \\
 564 \\
 +721 \\
 \hline
 \end{array}$$

i) Carry out the addition column by column in the usual fashion, moving from bottom to top.

(a) $1 + 4 = 5$, $5 + 3 = 8$, $8 + 4 = 12$ The final result is more than 9. The tenth place '1' is dropped once number in the unit place i.e., 2 retained. We say at this stage sudha and a dot is above the top 4. Thus column (1) of addition (right to left)

$$\begin{array}{r}
 . \\
 4 \\
 3 \\
 4 \\
 1 \\
 \hline
 2
 \end{array}$$

b) Before coming to column (2) addition, the number of dots are to be counted, This shall be added to the bottom number of column (2) and we proceed as above.

Thus second column becomes

$$\begin{array}{r}
 . \\
 3 \\
 0 \\
 6 \\
 2 \\
 \hline
 2
 \end{array}
 \quad
 \begin{array}{l}
 \text{dot}=1, \quad 1 + 2 = 3 \\
 3 + 6 = 9 \\
 9 + 0 = 9 \\
 9 + 3 = 12
 \end{array}$$

2 retained and '.' is placed on top number 3

c) proceed as above for column (3)

$$\begin{array}{l}
 2 \quad \text{i) dot} = 1 \quad \text{ii) } 1 + 7 = 8 \\
 4 \quad \text{iii) } 8 + 5 = 13 \quad \text{iv) Sudha is said.}
 \end{array}$$

$$\begin{array}{r}
 . \\
 5 \quad \text{A dot is placed on 5 and proceed}
 \end{array}$$

7 with retained unit place 3.

$\overline{9}$ v) $3+4=7, 7+2=9$ Retain 9 in 3rd digit i.e., in 100th place.

d) Now the number of dots is counted. Here it is 1 only and the number is carried out left side i.e. 1000th place

Thus $\begin{array}{r} \cdot\cdot \\ 234 \\ 403 \end{array}$

$\begin{array}{r} \cdot \\ 564 \\ +721 \end{array}$

$\overline{1922}$ is the answer.

Though it appears to follow the conventional procedure, a careful observation and practice gives its special use.

eg (1):

$\begin{array}{r} \cdot \\ 437 \\ \cdot\cdot \\ 624 \\ \cdot \\ 586 \\ +162 \\ \hline 1809 \end{array}$

Steps 1:

i) $2 + 6 = 8, 8 + 4 = 12$ so a dot on 4 and $2 + 7 = 9$ the answer retained under column (i)

ii) One dot from column (i) treated as 1, is carried over to column (ii),

thus $1 + 6 = 7, 7 + 8 = 15$ A 'dot'; is placed on 8 for the 1 in 15 and the 5 in 15 is added to 2 above.

$5 + 2 = 7, 7 + 3 = 10$ i.e. 0 is written under column (ii) and a dot for the carried over 1 of 10 is placed on the top of 3.

(iii) The number of dots counted in column (iii) are 2.

Hence the number 2 is carried over to column (ii) Now in column (iii)

$2 + 1 = 3$, $3 + 5 = 8$, $8 + 6 = 14$ A dot for 1 on the number 6 and 4 is retained to be added 4 above to give 8. Thus 8 is placed under column (iii).

iv) Finally the number of dots in column (iii) are counted. It is '1' only. So it carried over to 1000th place. As there is no fourth column 1 is the answer for 4th column. Thus the answer is 1809.

Example 3:

$$\begin{array}{r}
 \overset{\cdot}{3}\overset{\cdot}{6}\overset{\cdot}{4}\overset{\cdot}{7} \\
 \overset{\cdot}{4}\overset{\cdot}{0}\overset{\cdot}{8}\overset{\cdot}{6} \\
 \overset{\cdot}{5}\overset{\cdot}{7}\overset{\cdot}{1}\overset{\cdot}{8} \\
 + \overset{\cdot}{1}\overset{\cdot}{6}\overset{\cdot}{9}\overset{\cdot}{2} \\
 \hline
 15143
 \end{array}$$

Check the result verify these steps with the procedure mentioned above.

The process of addition can also be done in the down-ward direction i.e., addition of numbers column wise from top to bottom

Example 1:

$$\begin{array}{r}
 4326 \\
 \overset{\cdot}{5}\overset{\cdot}{6}\overset{\cdot}{9}\overset{\cdot}{4} \\
 3708 \\
 \hline
 2784
 \end{array}$$

Step 1: $6 + 4 = 10$, 1 dot ; $0 + 8 = 8$; $8 + 4 = 12$;

1 dot and 2 answer under first column - total 2 dots.

Step 2: $2+2$ (2 dots) = 4; $4+9 = 13$: 1 dot and $3+0 = 3$; $3+8 = 11$;

1 dot and 1 answer under second column - total 2 dots.

Step 3: $3+2$ (•• 2 dots) = 5; $5+6 = 11$: 1 dot and $1+7 = 8$; $8+7 = 15$;

1 dot and 5 under third column as answer - total 2 dots.

Step 4: $4 + 2$ (•• 2 dots) = 6; $6 + 5 = 11$:

1 dot and $1+3 = 4$; $4+2 = 6$. - total 1 dot in the fourth 6 column as answer.

Step 5: 1 dot in the fourth column carried over to 5th column (No digits in it) as 1

Thus answer is from **Step5** to **Step1**; 16512

Example 2:

$$\begin{array}{r} 3278 \\ 4619 \\ 3084 \\ \hline 1791 \end{array}$$

Steps

(i): $8 + 9 = 17$; $7 + 4 = 11$; $1 + 1 = (2) \longrightarrow (2\text{dots})$

(ii): $7 + 2 = 9$; $9 + 1 = 10$; $0 + 8 = 8$, $8 + 9 = 17$, $(7) \longrightarrow (2\text{dots})$

(iii): $2 + 2 = 4$; $4 + 6 = 10$; $0 + 0 = 0$; $0 + 7 = (7) \longrightarrow (1\text{ dot})$

(iv): $3 + 1 = 4$; $4 + 4 = 8$; $8 + 3 = 11$; $1 + 1 = (2) \longrightarrow (1\text{ dot})$

(v): 1

Thus answer is 12772.

Add the following numbers use 'Sudhikaran' wherever applicable.

1.

$$\begin{array}{r} 486 \\ 395 \\ 721 \\ +609 \\ \hline \\ \hline \end{array}$$

2.

$$\begin{array}{r} 5432 \\ 3691 \\ 4808 \\ +6787 \\ \hline \\ \hline \end{array}$$

3.

$$\begin{array}{r} 968763 \\ 476509 \\ +584376 \\ \hline \\ \hline \end{array}$$

Check up whether 'Sudhakaran' is done correctly. If not write the correct process. In either case find the sums.

$$\begin{array}{r} 1. \quad 4 \dot{3} \\ \quad \dot{7} \dot{8} \\ + 6 \dot{9} \uparrow \\ \hline \\ \hline \end{array}$$

$$\begin{array}{r} 2. \quad 3 \dot{7} \dot{9} \\ \quad 8 \dot{5} 4 \\ \quad \dot{7} \dot{6} \dot{7} \\ \hline 4 \ 2 \ 6 \\ \hline \end{array}$$

$$\begin{array}{r} 3. \quad 7 \ 8 \ \dot{9} \ 2 \ 4 \downarrow \\ \quad \dot{2} \ \dot{7} \ 2 \ \dot{7} \ 2 \\ + 7 \ 2 \ 6 \ \dot{8} \ 4 \\ \hline \\ \hline \end{array}$$

SUBTRACTION:

The 'Sudha' Sutra is applicable where the larger digit is to be subtracted from the smaller digit. Let us go to the process through the examples.

Procedure:

- i) If the digit to be subtracted is larger, a dot (sudha) is given to its left.
- ii) The purak of this lower digit is added to the upper digit or purak-rekhanak of this lower digit is subtracted.

Example (i): $34 - 18$

$$\begin{array}{r} 34 \\ . \\ -18 \\ \hline \end{array}$$

Steps: (i): Since $8 > 4$, a dot is put on its left i.e. 1

(ii) Purak of 8 i.e. 2 is added to the upper digit i.e. 4

$$2 + 4 = 6. \text{ or Purak-rekhank of } 8 \text{ i.e. } \bar{2} \text{ is}$$

$$\text{Subtracted from i.e. } 4 - \bar{2} = 6.$$

Now at the tens place a dot (means 1) makes the '1' in the number into $1 + 1 = 2$. This has to be subtracted from above digit. i.e. $3 - 2 = 1$. Thus

$$\begin{array}{r} 34 \\ . \\ -18 \\ \hline 16 \end{array}$$

Example 2:

$$\begin{array}{r} 63 \\ . \\ -37 \\ \hline \end{array}$$

Steps: (i) $7 > 3$. Hence a dot on left of 7 i.e., 3

(ii) Purak of 7 i.e. 3 is added to upper digit 3 i.e. $3 + 3 = 6$.

This is unit place of the answer.

Thus answer is 26.

Example (3) :

$$\begin{array}{r} 3274 \\ \dots \\ -1892 \\ \hline \end{array}$$

Steps:

- (i) $2 < 4$. No sudha . $4-2 = 2$ first digit (form right to left)
- (ii) $9 > 7$ sudha required. Hence a dot on left of 9 i.e. $\overset{\cdot}{9}$ 8
- (iii) purak of 9 i.e. 1, added to upper 7 gives $1 + 7 = 8$ second digit
- (iv) Now means $\overset{\cdot}{8} + 1 = 9$.
- (v) As $9 > 2$, once again the same process: dot on left of i.e., $\overset{\cdot}{9}$ 1
- (vi) purak of 9 i.e. 1, added to upper 2 gives $1 + 2 = 3$, the third digit.
- (vii) Now $\overset{\cdot}{1}$ means $1+1 = 2$
- (viii) As $2 < 3$, we have $3-2 = 1$, the fourth digit

Thus answer is 1382

Vedic Check :

Eg (i) in addition : $437 + 624 + 586 + 162 = 1809$.

By beejank method, the Beejanks are

$$437 \longrightarrow 4 + 3 + 7 \longrightarrow 14 \longrightarrow 1 + 4 \longrightarrow 5$$

$$624 \longrightarrow 6 + 2 + 4 \longrightarrow 12 \longrightarrow 1 + 2 \longrightarrow 3$$

$$586 \longrightarrow 5 + 8 + 6 \longrightarrow 19 \longrightarrow 1 + 9 \longrightarrow 10 \longrightarrow 1 + 0 \longrightarrow 1$$

$$162 \longrightarrow 1 + 6 + 2 \longrightarrow 9$$

Now

$$437 + 624 + 586 + 162 \longrightarrow 5 + 3 + 1 + 9 \longrightarrow 18 \longrightarrow 1 + 8 \longrightarrow 9$$

$$\text{Beejank of } 1809 \longrightarrow 1 + 8 + 0 + 9 \longrightarrow 18 \longrightarrow 1 + 8 \longrightarrow 9 \text{ verified}$$

Eg.(3) in subtraction :

$$3274 - 1892 = 1382$$

now beejanks

$$3274 \longrightarrow 3 + 2 + 7 + 4 \longrightarrow 3 + 4 \longrightarrow 7$$

$$1892 \longrightarrow 1 + 8 + 9 + 2 \longrightarrow 2$$

$$3292 - 1892 \longrightarrow 7 - 2 \longrightarrow 5$$

$$1382 \longrightarrow 1 + 3 + 8 + 2 \longrightarrow 5 \text{ Hence verified.}$$

Mixed addition and subtraction using Rekhanks:

Example 1 : $423 - 654 + 847 - 126 + 204$.

In the conventional method we first add all the +ve terms

$$423 + 847 + 204 = 1474$$

Next we add all negative terms

$$- 654 - 126 = -780$$

At the end their difference is taken

$$1474 - 780 = 694$$

Thus in 3 steps we complete the problem

But in Vedic method using Rekhank we write and directly find the answer.

$$423$$

$$\overline{654}$$

$$847$$

$$\overline{126}$$

$$\overline{204}$$

$$\overline{714} \quad \text{This gives } (7 - 1) / (10 - 1) / 4 = 694.$$

Example (2):

$$\begin{aligned} & 6371 - 2647 + 8096 - 7381 + 1234 \\ &= 6371 + \overline{2647} + 8096 + \overline{7381} + 1234 \\ &= (6 + \overline{2} + 8 + \overline{7} + 1) / (3 + \overline{6} + 0 + \overline{3} + 2) / (7 + \overline{4} + 9 + \overline{8} + 3) / (1 + \overline{7} + \overline{6} + 1 + 4) \\ &= 6 / \overline{4} / 7 / 3 \\ &= (6 - 1) / (10 - 4) / 73 \\ &= 5673 \end{aligned}$$

* Find the results in the following cases using Vedic methods.

1) $57 - 39$

3) $384 - 127 + 696 - 549 + 150$

2) $1286 - 968$

4) $7084 + 1232 - 6907 - 3852 + 4286$

* Apply Vedic check for the above four problems and verify the results.

MULTIPLICATION

We have already observed the application of Vedic sutras in multiplication. Let us recall them.

It enables us to have a comparative study of the applicability of these methods, to assess advantage of one method over the other method and so-on.

Example (i) : Find the square of 195.

The Conventional method :

$$\begin{array}{r}
 195^2 = \quad 195 \\
 \quad \quad \times 195 \\
 \hline
 \quad \quad 975 \\
 \quad 1755 \\
 195 \\
 \hline
 38025 \\
 \hline
 \text{-----}
 \end{array}$$

(ii) By Ekadhikena purvena, since the number ends up in 5 we write the answer split up into two parts.

The right side part is 5^2 where as the left side part $19 \times (19+1)$ (Ekadhikena)

$$\text{Thus } 195^2 = 19 \times 20/5^2 = 380/25 = 38025$$

(iii) By Nikhila Navatascaramam Dasatah; as the number is far from base 100, we combine the sutra with the upa-sutra 'anurupyena' and proceed by taking working base 200.

a) Working Base = 200 = 2 X 100.

$$\text{Now } 195^2 = 195 \times 195$$

$$\begin{array}{r}
 195 \quad -5 \\
 195 \quad -5 \\
 \hline
 (195 - 5) \text{ or } -5 \times -5 \\
 = 190 \quad = 25 \\
 \hline
 380 / 025 = 38025
 \end{array}$$

iv) By the sutras "yavadunam tavadunikritya vargamca yojayet" and "anurupyena"

195², base 200 treated as 2 X 100 deficit is 5.

$$\begin{array}{l}
 195^2 = (195 - 5) / 5^2 \\
 = 190 / 25 \\
 \times 2 \quad \text{operating on 100} \\
 = 38025
 \end{array}$$

v) By 'antya-yaor dasakepi' and 'Ekadhikena' sutras

Since in 195 x 195, 5 + 5 = 10 gives

$$195^2 = 19 \times 20 / 5 \times 5 = 380 / 25 = 38025.$$

vi) Now "urdhva-tiryagbhyam" gives

$$\begin{array}{r}
 195 \\
 \times 195 \\
 \hline
 (1 \times 1) / (1 \times 9) + (1 \times 9) / (1 \times 5) + (9 \times 9) + (5 \times 1) / (9 \times 5) + (5 \times 9) / (5 \times 5) \\
 1 \quad / \quad 9 + 9 \quad / \quad 5 + 81 + 5 \quad / \quad 45 + 45 \quad / \quad 25 \\
 = 1 \quad / \quad 8 \quad / \quad 1 \quad / \quad 0 \quad / \quad 5 \\
 \quad \quad 1 \quad \quad 9 \quad \quad 9 \quad \quad 2
 \end{array}$$

By the carryovers the answer is 38025

Example 2 : 98 X 92**i) 'Nikhilam' sutra**

$$\begin{array}{r} 98 \quad -2 \\ \times 92 \quad -8 \\ \hline 90 / 16 = 9016 \end{array}$$

ii) 'Antyayordasakepi' and 'Ekadhikena' sutras.

98 X 92 Last digit sum = 8+2 = 10 remaining digit (s) = 9 same sutras work.

$$\therefore 98 \times 92 = 9 \times (9 + 1) / 8 \times 2 = 90 / 16 = 9016.$$

iii) urdhava-tiryak sutra

$$\begin{array}{r} 98 \\ \times 92 \\ \hline 106 \\ 891 \\ \hline 9016 \end{array}$$

vi) by vinculum method

$$98 = 100 - 2 = 10\bar{2}$$

$$92 = 100 - 8 = 10\bar{8}$$

now

$$\begin{array}{r} 10\bar{2} \\ 10\bar{8} \\ \hline 1000\bar{6} \\ \bar{1} \quad \bar{1} \\ \hline \end{array}$$

$$11016 = 9016$$

Example 3: 493 X 497.

1) 'Nikhilam' Method and 'Anurupyena':

a) Working base is 500, treated as 5 X 100

$$\begin{array}{r}
 493 \quad -7 \\
 497 \quad -3 \\
 \hline
 490 \quad / \quad 21 \\
 \times 5 \quad / \quad \text{since base is } 5 \times 100 \\
 \hline
 2450 \quad / \quad 21 = 245021
 \end{array}$$

b) Working base is 500, treated as 1000 / 2

$$\begin{array}{r}
 493 \quad -7 \\
 497 \quad -3 \\
 \hline
 2) \quad 490 \quad / \quad 021 \\
 \hline
 245 \quad / \quad 021 = 245021
 \end{array}$$

2) 'Urdhva tiryak' sutra.

$$\begin{array}{r}
 493 \\
 497 \\
 \hline
 (4 \times 4) \quad / \quad (4 \times 9) + (9 \times 4) \quad / \quad (4 \times 7) + (9 \times 9) + (4 \times 3) \quad / \quad (9 \times 7) + (3 \times 9) \quad / \quad (3 \times 7) \\
 16 \quad / \quad 72 \quad / \quad 121 \quad / \quad 90 \quad / \quad 21 \\
 \\
 = 16 / 72 / 121 / 90 / 21 = 245021 \quad (\text{adjusting carry overs})
 \end{array}$$

3) Since end digits sum is $3+7 = 10$ and remaining part 49 is same in both the numbers, 'antyayordasakepi' is applicable. Further Ekadhikena Sutra is also applicable.

Thus

$$\begin{aligned}
 493 \times 497 &= 49 \times 50 / 3 \times 7 \\
 &= 2450 / 21 \\
 &= 245021
 \end{aligned}$$

4) With the use of vinculum.

$$493 = 500 - 07 = 5\overline{07}$$

$$497 = 500 - 03 = 5\overline{03}$$

Now 497×497 can be taken as $5\overline{07} \times 5\overline{03}$

$$\begin{array}{r}
 5\overline{07} \\
 \times 5\overline{03} \\
 \hline
 50001 \\
 252 \\
 \hline
 255021 = 245021
 \end{array}$$

Example 4: 99×99

1) Now by **urdhva - tiryak sutra**.

$$\begin{array}{r}
 99 \\
 \times 99 \\
 \hline
 8121 \\
 168 \\
 \hline
 9801
 \end{array}$$

2) By **vinculum method**

$$99 = 100 - 1 = 1\overline{01}$$

Now 99×99 is

$$\begin{array}{r} \overline{101} \\ \times \overline{101} \\ \hline \overline{10201} \end{array} = 9801$$

3) By Nikhilam method

$$\begin{array}{r} 99 \quad -1 \\ 99 \quad -1 \\ \hline 98 \quad / \quad 01 \end{array} = 9801.$$

4) 'Yadunam' sutra : 99^2 Base = 100

Deficiency is 1 : It indicates $99^2 = (99 - 1) / 1^2 = 98 / 01 = 9801$.

In the above examples we have observed how in more than one way problems can be solved and also the variety. You can have your own choice for doing multiplication. Not only that which method suits well for easier and quicker calculations. Thus the element of choice, divergent thinking, insight into properties and patterns in numbers, natural way of developing an idea, resourcefulness play major role in Vedic Mathematics methods.

DIVISION

In the conventional procedure for division, the process is of the following form.

$$\begin{array}{r}
 \text{Quotient} \\
 \hline
 \text{Divisor) Dividend} \\
 \text{-----} \\
 \text{-----} \\
 \hline
 \text{Remainder}
 \end{array}
 \quad \text{or} \quad
 \begin{array}{r}
 \text{Divisor) Dividend (Quotient} \\
 \text{-----} \\
 \text{-----} \\
 \hline
 \text{Remainder}
 \end{array}$$

But in the Vedic process, the format is

$$\begin{array}{r}
 \text{Divisor) Dividend} \\
 \text{-----} \\
 \text{-----} \\
 \hline
 \text{Quotient / Remainder}
 \end{array}$$

The conventional method is always the same irrespective of the divisor. But Vedic methods are different depending on the nature of the divisor.

Example 1: Consider the division $1235 \div 89$.

i) Conventional method:

$$\begin{array}{r}
 89) 1235 (13 \\
 \underline{89} \\
 345 \\
 \underline{267} \\
 78
 \end{array}
 \quad \text{Thus } Q = 13 \text{ and } R = 78.$$

ii) Nikhilam method:

This method is useful when the divisor is nearer and less than the base. Since for 89, the base is 100 we can apply the method. Let us recall the nikhilam division

already dealt.

Step (i):

Write the dividend and divisor as in the conventional method. Obtain the modified divisor (M.D.) applying the Nikhilam formula. Write M.D. just below the actual divisor.

Thus for the divisor 89, the M.D. obtained by using Nikhilam is 11 in the last from 10 and the rest from 9. Now Step 1 gives

$$\begin{array}{r} 89 \) \ 1235 \\ \hline 11 \end{array}$$

Step (ii):

Bifurcate the dividend by by a slash so that R.H.S of dividend contains the number of digits equal to that of M.D. Here M.D. contains 2 digits hence

$$\begin{array}{r} 89 \) \ 12 \ / \ 35 \\ \hline 11 \end{array}$$

Step (iii): Multiply the M.D. with first column digit of the dividend. Here it is 1. i. e. $11 \times 1 = 11$. Write this product place wise under the 2nd and 3rd columns of the dividend.

$$\begin{array}{r} 89 \) \ 12 \ / \ 35 \\ \hline 11 \quad 1 \quad 1 \end{array}$$

Step (iv):

Add the digits in the 2nd column and multiply the M.D. with that result i.e. $2 + 1 = 3$ and $11 \times 3 = 33$. Write the digits of this result column wise as shown below, under 3rd and 4th columns. i.e.

$$\begin{array}{r} 89 \) \ 12 \ / \ 35 \\ \hline 11 \quad 1 \quad 1 \\ \quad \quad \quad 33 \\ \hline \end{array}$$

$$13 / 78$$

Now the division process is complete, giving $Q = 13$ and $R = 78$.

Example 2: Find Q and R for $121134 \div 8988$.

Steps (1+2):

$$\begin{array}{r} 8988 \) \ 12 \ / \ 1134 \\ \hline 1012 \end{array}$$

Step (3):

$$\begin{array}{r} 8988 \) \ 12 \ / \ 1134 \\ \hline 1012 \quad 1 \quad 012 \end{array}$$

Step(4):

$$\begin{array}{r} 8988 \) \ 12 \ / \ 1134 \\ \hline 1012 \quad 1 \quad 012 \quad [\ 2 + 1 = 3 \text{ and } 3 \times 1012 = 3036 \] \\ \quad \quad \quad 3036 \end{array}$$

Now **final Step**

$$\begin{array}{r} 8988 \) \ 12 \ / \ 1134 \\ \hline 1012 \quad 1 \quad 012 \\ \quad \quad \quad 3036 \text{(Column wise addition)} \\ \hline 13 \ / \ 4290 \end{array}$$

Thus $121134 \div 8988$ gives $Q = 13$ and $R = 4290$.

iii) Paravartya method: Recall that this method is suitable when the divisor is nearer but more than the base.

Example 3: $32894 \div 1028$.

The divisor has 4 digits. So the last 3 digits of the dividend are set apart for the remainder and the procedure follows.

$$\begin{array}{r}
 1 \ 0 \ 2 \ 8 \quad 32 \quad 8 \ 9 \ 4 \\
 0 \ -2 \ -8 \quad 0 \quad -6 \ -24 \\
 \quad \quad \quad 0 \quad -4 \ -16 \\
 \hline
 \quad \quad 32 \quad 2 \ -19 \ -12
 \end{array}$$

i) $3 \times (0, -2, -8)$
 $= 0, -6, -24$

ii) $2 - 0 = 2$ and
 $2 \times (0, -2, -8)$
 $= 0, -4, -16$

iii) $8 - 6 + 0 = 2$
 $9 - 24 - 4 = -19$
 $4 - 16 = -12$

Now the remainder contains -19, -12 i.e. negative quantities. Observe that 32 is quotient. Take 1 over from the quotient column i.e. $1 \times 1028 = 1028$ over to the right side and proceed thus: $32 - 1 = 31$ becomes the Q and $R = 1028 + 200 - 190 - 12 = 1028 - 2 = 1026$.

Thus $3289 \div 1028$ gives $Q = 31$ and $R = 1026$.

The same problem can be presented or thought of in any one of the following forms.

$$\begin{array}{r}
 * \overline{1028} \) \ 32 \ / \ 8 \ 9 \ 4 \\
 \underline{028} \quad 0 \quad \overline{6} \quad \overline{24} \\
 \quad \quad \quad 0 \quad \overline{4} \quad \overline{16} \\
 \hline
 32 \quad 2 \quad \overline{19} \quad \overline{12} \\
 \\
 = 31 / 1028 + 200 - 190 - 12 \\
 = 31 / 1026.
 \end{array}$$

*Converting the divisor 1028 into vinculum number we get $1028 = 10\overline{32}$ Now

$$\begin{array}{r}
 \overline{1032} \overline{) 32} / \overline{8} \overline{9} \overline{4} \\
 \overline{032} \quad \overline{0} \quad \overline{9} \quad \overline{6} \\
 \hline
 \quad \quad \overline{0} \quad \overline{6} \quad \overline{4} \\
 \hline
 \quad \quad \overline{32} / \overline{1} \overline{9} \overline{8} \\
 = 31 / \overline{1032} + \overline{198} \\
 = 31 / \overline{1026}.
 \end{array}$$

*Converting dividend into vinculum number $32894 = 33114$ and proceeding we get

$$\begin{array}{r}
 1028 \overline{) 33} / \overline{1} \overline{1} \quad \overline{4} \\
 \overline{028} \quad \quad \overline{0} \quad \overline{6} \quad \overline{24} \\
 \hline
 \quad \quad \overline{0} \quad \overline{6} \quad \overline{24} \\
 \hline
 \quad \quad \overline{33} / \overline{7} \quad \overline{31} \quad \overline{20} \\
 = 33 / \overline{10} \quad \overline{3} \quad \overline{0} \\
 = 33 + \overline{1} / \overline{0} \quad \overline{3} \quad \overline{0} \\
 \quad \quad \quad \overline{0} \quad \overline{2} \quad \overline{8} \\
 = 32 / \overline{0} \quad \overline{1} \quad \overline{8} \\
 = 31 / \overline{1028} + \overline{18} \\
 = 31 / \overline{1026}
 \end{array}$$

Now we take another process of division based on the combination of Vedic sutras **urdhva-tiryak** and **Dhvjanka**. The word Dhvjanka means "on the top of the flag"

Example 4: $43852 \div 54$.

Step1: Put down the first digit (5) of the divisor (54) in the divisor column as operator and the other digit (4) as flag digit. Separate the dividend into two parts where the right part has one digit. This is because the flag digit is single digit. The representation is as follows.

$$\begin{array}{c}
 4 : 4385 : 2 \\
 5
 \end{array}$$

Step2: i) Divide 43 by the operator 5. Now $Q = 8$ and $R = 3$. Write this $Q = 8$ as

the 1st Quotient - digit and prefix $R=3$, before the next digit i.e. 8 of the dividend, as shown below. Now 38 becomes the gross-dividend (G.D.) for the next step.

$$\begin{array}{r} 4 : 4 \ 3 \ 8 \ 5 : 2 \\ 5 : \quad 3 \\ \hline : \quad 8 \end{array}$$

ii) Subtract the product of flag digit (4) and first quotient digit (8) from the G.D. (38) i.e. $38 - (4 \times 8) = 38 - 32 = 6$. This is the net - dividend (N.D) for the next step.

Step3: Now N.D Operator gives Q and R as follows. $6 \div 5$, $Q = 1$, $R = 1$. So $Q = 1$, the second quotient-digit and $R = 1$, the prefix for the next digit (5) of the dividend.

$$\begin{array}{r} 4 : 4 \ 3 \ 8 \ 5 : 2 \\ 5 : \quad 3 \ 1 \\ \hline : \quad 8 \ 1 \end{array}$$

Step4: Now G.D = 15; product of flag-digit (4) and 2nd quotient - digit (1) is $4 \times 1 = 4$ Hence N.D = $15 - 4 = 11$ divide N.D by 5 to get $11 \div 5$, $Q = 2$, $R = 1$. The representation is

$$\begin{array}{r} 4 : 4 \ 3 \ 8 \ 5 : 2 \\ 5 : \quad 3 \ 1 : 1 \\ \hline : \quad 8 \ 1 \ 2 : \end{array}$$

Step5: Now the R.H.S part has to be considered. The final remainder is obtained by subtracting the product of flag-digit (4) and third quotient digit (2) from 12 i.e., 12 :

Final remainder = $12 - (4 \times 2) = 12 - 8 = 4$. Thus the division ends into

$$\begin{array}{r} 4 : 4 \ 3 \ 8 \ 5 : 2 \\ 5 : \quad 3 \ 1 : 1 \\ \hline : \quad 8 \ 1 \ 2 : 4 \end{array}$$

Thus $43852 \div 54$ gives $Q = 812$ and $R = 4$.

Consider the algebraic proof for the above problem. The divisor 54 can be

represented by $5x+4$, where $x=10$

The dividend 43852 can be written algebraically as $43x^3 + 8x^2 + 5x + 2$

since $x^3 = 10^3 = 1000$, $x^2 = 10^2 = 100$.

Now the division is as follows.

$$\begin{array}{r}
 5x + 4 \) \ 43x^3 + 8x^2 + 5x + 2 \ (\ 8x^2 + x + 2 \\
 \underline{43x^3 + 32x^2} \\
 3x^3 - 24x^2 \\
 = 6x^2 + 5x \quad (\because 3x^3 = 3 \cdot x \cdot x^2 \\
 5x^2 + 4x \quad \quad \quad = 3 \cdot 10x^2 = 30x^2) \\
 \hline
 x^2 + x \\
 = 11x + 2 \quad (\because x^2 = x \cdot x = 10x) \\
 \underline{10x + 8} \\
 x - 6 \\
 = 10 - 6 \\
 = 4.
 \end{array}$$

Observe the following steps:

1. $43x^3 \div 5x$ gives first quotient term $8x^2$, remainder = $3x^3 - 24x^2$ which really mean $30x^2 + 8x^2 - 32x^2 = 6x^2$.

Thus in step 2 of the problem $43852 \div 54$, we get $Q=8$ and $N.D = 6$.

2. $6x^2 \div 5x$ gives second quotient term x , remainder = $x^2 + x$ which really mean $10x + x = 11x$.

Thus in step 3 & Step 4, we get $Q=1$ and $N.D = 11$.

3. $11x \div 5x$ gives third quotient term 2, remainder = $x - 6$, which really mean the final remainder $10-6=4$.

Example 5: Divide $237963 \div 524$

Step1: We take the divisor 524 as 5, the operator and 24, the flag-digit and proceed as in the above example. We now separate the dividend into two parts where the RHS part contains two digits for Remainder.

Thus

$$\begin{array}{r} 24 : 2379 : 63 \\ 5 \end{array}$$

Step2:

i) $23 \div 5$ gives $Q = 4$ and $R = 3$, G.D = 37.

ii) N.D is obtained as

$$37 - \left(\begin{array}{cc} 2 & 4 \\ \swarrow & \searrow \\ 0 & 4 \end{array} \right) \text{ (Flag digits)}$$

$$\begin{aligned} &= 37 - (8 + 0) \\ &= 29. \end{aligned}$$

Representation

$$\begin{array}{r} 24 : 2379 : 63 \\ 5 \quad \quad 3 \\ \hline : 4 \end{array}$$

Step3:

i) $N.D \div \text{Operator} = 29 \div 5$ gives $Q = 5$, $R = 4$ and G.D = 49.

ii) N.D is obtained as

$$49 - \left(\begin{array}{cc} 2 & 4 \\ \swarrow & \searrow \\ 4 & 5 \end{array} \right) \text{ (Flag digits)}$$

$$\begin{aligned} &= 49 - (10 + 16) \\ &= 49 - 26 \\ &= 23. \end{aligned}$$

i.e.,

$$\begin{array}{r} 24 : 2379 : 63 \\ 5 : 34 : \\ \hline : 45 : \end{array}$$

Step 4:

i) N.D ÷ Operator = 23 ÷ 5 gives Q = 4, R = 3 and G.D = 363.

Note that we have reached the remainder part thus 363 is total sub-remainder.

$$\begin{array}{r} 24 : 2379 : 63 \\ 5 : 34 : 3 \\ \hline : 454 : \end{array}$$

Step 5: We find the final remainder as follows. Subtract the cross-product of the two, flag-digits and two last quotient-digits and then vertical product of last flag-digit with last quotient-digit from the total sub-remainder.

i.e.,

$$363 - \left(\begin{array}{cc} 2 & 4 \\ 4 & 5 \end{array} \right) / \begin{array}{c} 4 \\ \downarrow \\ 4 \end{array} = 363 - (8 + 20) / 16 \\ = 363 - 28 / 16 \\ = 363 - 296 = 67.$$

Note that 2, 4 are two flag digits: 5, 4 are two last quotient digits:

$$\left(\begin{array}{c} 4 \\ 4 \end{array} \right)$$

represents the last flag - digit and last quotient digit.

Thus the division $237963 \div 524$ gives Q = 454 and R = 67.

Thus the Vedic process of division which is also called as **Straight division** is a simple application of *urdhva-tiryak* together with *dhvajanka*. This process has many uses along with the one-line presentation of the answer.

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MISCELLANEOUS ITEMS

1. Straight Squaring:

We have already noticed methods useful to find out squares of numbers. But the methods are useful under some situations and conditions only. Now we go to a more general formula.

The sutra Dwandwa-yoga (Duplex combination process) is used in two different meanings. They are i) by squaring ii) by cross-multiplying.

We use both the meanings of Dwandwa-yoga in the context of finding squares of numbers as follows:

We denote the Duplex of a number by the symbol D . We define for a single digit 'a', $D = a^2$. and for a two digit number of the form 'ab', $D = 2(a \times b)$. If it is a 3 digit number like 'abc', $D = 2(a \times c) + b^2$.

For a 4 digit number 'abcd', $D = 2(a \times d) + 2(b \times c)$ and so on. i.e. if the digit is single central digit, D represents 'square': and for the case of an even number of digits equidistant from the two ends D represent the double of the cross- product.

Consider the examples:

Number	DuplexD
3	$3^2 = 9$
6	$6^2 = 36$
23	$2(2 \times 3) = 12$
64	$2(6 \times 4) = 48$
128	$2(1 \times 8) + 2^2 = 16 + 4 = 20$
305	$2(3 \times 5) + 0^2 = 30 + 0 = 30$
4231	$2(4 \times 1) + 2(2 \times 3) = 8 + 12 = 20$
7346	$2(7 \times 6) + 2(3 \times 4) = 84 + 24 = 108$

Further observe that for a n- digit number, the square of the number contains $2n$ or $2n-1$ digits. Thus in this process, we take extra dots to the left one less than the number of digits in the given numbers.

Examples:1 62^2 Since number of digits = 2, we take one extra dot to the left. Thus

$$\begin{array}{r} .62 \\ \hline 644 \\ 32 \\ \hline 3844 \end{array}$$

for 2, $D = 2^2 = 4$
for 62, $D = 2 \times 6 \times 2 = 24$
for 62, $D = 2(0 \times 2) + 6^2 = 36$

$$\therefore 62^2 = 3844.$$

Examples:2 234^2 Number of digits = 3. extradots =2 Thus

$$\begin{array}{r} ..234 \\ \hline 42546 \\ 1221 \\ \hline 54756 \end{array}$$

for 4, $D = 4^2 = 16$
for 34, $D = 2 \times 3 \times 4 = 24$
for 234, $D = 2 \times 2 \times 4 + 3^2 = 25$
for .234, $D = 2.0.4 + 2.2.3 = 12$
for ..234, $D = 2.0.4 + 2.0.3 + 2^2 = 4$

Examples:3 1426^2 . Number of digits = 4, extra dots = 3

i.e

$$\begin{array}{r} ...1426 \\ \hline 1808246 \\ 22523 \\ \hline 2033476 \end{array}$$

6, $D = 36$
26, $D = 2.2.6 = 24$
426, $D = 2.4.6 + 2^2 = 52$
1426, $D = 2.1.6 + 2.4.2 = 28$
.1426, $D = 2.0.6 + 2.1.2 + 4^2 = 20$
..1426, $D = 2.0.6 + 2.0.2 + 2.1.4 = 8$
...1426, $D = 1^2 = 1$

$$\text{Thus } 1426^2 = 2033476.$$

With a little bit of practice the results can be obtained mentally as a single line

answer.

Algebraic Proof:

Consider the first example 62^2

$$\begin{aligned} \text{Now } 62^2 &= (6 \times 10 + 2)^2 = (10a + b)^2 \text{ where } a = 6, b = 2 \\ &= 100a^2 + 2 \cdot 10a \cdot b + b^2 \\ &= a^2 (100) + 2ab (10) + b^2 \end{aligned}$$

i.e. b^2 in the unit place, $2ab$ in the 10th place and a^2 in the 100th place i.e. $2^2 = 4$ in units place, $2 \cdot 6 \cdot 2 = 24$ in the 10th place (4 in the 10th place and with carried over to 100th place). $6^2 = 36$ in the 100th place and with carried over 2 the 100th place becomes $36 + 2 = 38$.

Thus the answer 3844.

**Find the squares of the numbers 54, 123, 2051, 3146.
Applying the Vedic sutra Dwanda yoga.**

2.CUBING

Take a two digit number say 14.

- i) Find the ratio of the two digits i.e. 1:4
- ii) Now write the cube of the first digit of the number i.e. 1^3
- iii) Now write numbers in a row of 4 terms in such a way that the first one is the cube of the first digit and remaining three are obtained in a geometric progression with common ratio as the ratio of the original two digits (i.e. 1:4) i.e. the row is

$$1 \quad 4 \quad 16 \quad 64.$$

- iv) Write twice the values of 2nd and 3rd terms under the terms respectively in second row.

i.e.,

$$\begin{array}{cccc} 1 & 4 & 16 & 64 \\ & 8 & 32 & \end{array} \quad (2 \times 4 = 8, 2 \times 16 = 32)$$

v) Add the numbers column wise and follow carry over process.

$$\begin{array}{cccc} 1 & 4 & 16 & 64 \\ & 8 & 32 & \end{array} \quad \begin{array}{l} \text{Since } 16 + 32 + 6 \text{ (carryover)} = 54 \\ 4 \text{ written and } 5 \text{ (carryover)} + 4 + 8 = 17 \\ \hline 2 \quad 7 \quad 4 \quad 4 \quad 7 \text{ written and } 1 \text{ (carryover)} + 1 = 2. \end{array}$$

This 2744 is nothing but the cube of the number 14

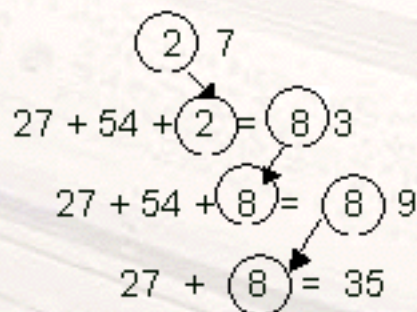
Example 1: Find 18^3

i)	1:8				
i)& iii)	1	8	64	512	
iv)	1	8	64	512	(2x8=16, 2x64=128)
		16	128		
i)	3:3=1:1				$\left[\begin{array}{l} 3^3 = 27 \\ \text{ratio is } 1:1 \end{array} \right]$
ii) & iii)	27	27	27	27	
iv)& (v)	27	27	27	27	(2x27=54)
		54	54)8
<hr/>					
	35	9	3	7	5

i.

Example 2:

Thus $33^3 = 35937$



Algebraic Proof:

Let a and b be two digits.

Consider the row $a^3 \quad a^2b \quad ab^2 \quad b^3$

the first is a^3 and the numbers are in the ratio $a:b$
 since $a^3:a^2b=a^2b:b^3=a:b$

Now twice of a^2b , ab^2 are $2a^2b$, $2ab^2$

$$\begin{array}{r} a^3 + a^2b + ab^2 + b^3 \\ 2a^2b + 2ab^2 \\ \hline a^3 + 3a^2b + 3ab^2 + b^3 = (a + b)^3. \end{array}$$

Thus cubes of two digit numbers can be obtained very easily by using the vedic sutra 'anurupyena'. Now cubing can be done by using the vedic sutra 'Yavadunam'.

Example 3: Consider 106^3 .

i) The base is 100 and excess is 6. In this context we double the excess and then add.

$$\text{i.e. } 106 + 12 = 118. \quad (2 \times 6 = 12)$$

This becomes the left - hand - most portion of the cube.

$$\text{i.e. } 106^3 = 118 / \text{---}$$

ii) Multiply the new excess by the initial excess

$$\text{i.e. } 18 \times 6 = 108 \quad (\text{excess of } 118 \text{ is } 18)$$

Now this forms the middle portion of the product of course 1 is carried over, 08 in the middle.

$$\text{i.e. } 106^3 = 118 / 08 / \text{---} \\ \quad \quad \quad \quad \quad 1$$

iii) The last portion of the product is cube of the initial excess.

$$\text{i.e. } 6^3 = 216.$$

16 in the last portion and 2 carried over.

$$\text{i.e. } 106^3 = 118 / 081 / 16 = 1191016$$

1 2

Example 4: Find 1002^3 .

i) Base = 1000. Excess = 2. Left-hand-most portion of the cube becomes $1002 + (2 \times 2) = 1006$.

ii) New excess x initial excess = $6 \times 2 = 12$.

Thus 012 forms the middle portion of the cube.

iii) Cube of initial excess = $2^3 = 8$.

So the last portion is 008.

Thus $1002^3 = 1006 / 012 / 008 = 1006012008$.

Example 5: Find 94^3 .

i) Base = 100, deficit = -6. Left-hand-most portion of the cube becomes $94 + (2 \times -6) = 94 - 12 = 82$.

ii) New deficit x initial deficit = $-(100 - 82) \times (-6) = -18 \times -6 = 108$

Thus middle portion of the cube = 08 and 1 is carried over.

iii) Cube of initial deficit = $(-6)^3 = -216$

$$\text{Now } 94^3 = 82 / 08 / \overline{16} = 83 / 06 / \overline{16}$$

1 $\overline{2}$

$$= 83 / 05 / (100 - 16) \\ = 830584.$$

Find the cubes of the following numbers using Vedic sutras.

103, 112, 91, 89, 998, 9992, 1014.

3. Equation of Straight line passing through two given points:

To find the equation of straight line passing through the points (x_1, y_1) and (x_2, y_2) , we generally consider one of the following methods.

1. General equation $y = mx + c$.

It is passing through (x_1, y_1) then $y_1 = mx_1 + c$.

It is passing through (x_2, y_2) also, then $y_2 = mx_2 + c$.

Solving these two simultaneous equations, we get 'm' and 'c' and so the equation.

2. The formula

$$y - y_1 = \frac{(y_2 - y_1)}{(x_2 - x_1)} (x - x_1) \text{ and substitution.}$$

Some sequence of steps gives the equation. But the paravartya sutra enables us to arrive at the conclusion in a more easy way and convenient to work mentally.

Example1: Find the equation of the line passing through the points $(9,7)$ and $(5,2)$.

Step1: Put the difference of the y - coordinates as the x - coefficient and vice-versa.

$$\text{i.e. } x \text{ coefficient} = 7 - 2 = 5$$

$$y \text{ coefficient} = 9 - 5 = 4.$$

Thus L.H.S of equation is $5x - 4y$.

Step 2: The constant term (R.H.S) is obtained by substituting the co-ordinates of either of the given points in

L.H.S (obtained through step-1)

i.e. R.H.S of the equation is

$$5(9) - 4(7) = 45 - 28 = 17$$

$$\text{or } 5(5) - 4(2) = 25 - 8 = 17.$$

Thus the equation is $5x - 4y = 17$.

Example 2: Find the equation of the line passing through (2, -3) and (4,-7).

Step 1 : $x[-3-(-7)] - y[2-4] = 4x + 2y$.

Step 2 : $4(2) + 2(-3) = 8 - 6 = 2$.

Step 3 : Equation is $4x + 2y = 2$ or $2x + y = 1$.

Example 3 : Equation of the line passing through the points (7,9) and (3,-7).

Step 1 : $x[9 - (-7)] - y(7 - 3) = 16x - 4y$.

Step 2 : $16(7) - 4(9) = 112 - 36 = 76$

Step 3 : $16x - 4y = 76$ or $4x - y = 19$

Find the equation of the line passing through the points using Vedic methods.

- | | |
|---------------------|-------------------|
| 1. (1, 2), (4,-3) | 2. (5,-2), (5,-4) |
| 3. (-5, -7), (13,2) | 4. (a, o) , (o,b) |