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THIRUVANANTHAPURAM - 695 018

DISCOVERY AND USE OF ZERO

Gaayathre shadsankhyaamardhe
apaneethe dvayanke avasishtasthrayastheshu roopamapaneeya
dvayankaadha: soonyam sthaapyam

In gayatri chandas, one pada has six letters. When this number is made half, it becomes three (i.e the pada can be divided into two). Remove one from three and make it half to get one. Remove one from it, thus gets the zero (Soonya).

PINGALACHARYA IN CHANDA SASTRA 200 B.C.

CALCULATIONS WITH ZERO

Vikaaramaayaanthi dhanarunakhaani na soonya samyoga viyogathasthu soonyaaddhi suddham swamrunam kshayam swam vadhaadinaa kham khaharam vibhakthaa:

Nothing happens (to the number) when a positive or negative number is added with 0. When +ve and -ve numbers are subtracted from 0, the +ve number becomes negative and -ve number becomes +ve. When multiplied with 0, the values of both +ve and -ve numbers become 0, when divided by 0, it becomes infinity (khahara).

SRIPATI IN SIDDHANTHA SEKHARA 1039 AD

Yathaa ekarekhaa sathasthaane satham dasasthane dasaiam chaikasthaane yathaa cha ekathvepi sthree mathaa cha uchyathe duhithaa svasaa cha ithi

In the unit place the digit has the same value, in 10th place, 10 times the value and in 100th place 100 times the value, is given.

VYASA BHASHAYA TO YOGA SUTRA 650 AD

DISCOVERY OF PLACE VALUES - II

Yathaachaikaapi rekha sthaananyathvena nivisamaanaika dasa satha sahasraadi sabda prathyaya bhedhamanubhavathi

One and the same numerical sign when occupying different places is conceived as measuring 1, 10, 100, 1000 etc.

SANKARACHARYA VEDANTA SUTRA BHASHAYA

KNOWLEDGE ON INFINITY

Asmin vikara khahare na raasaavapi praveshteshvapi ni: srutheshu bahushvapi syaallaya srushtikaale nanthe chyuthe bhoothaganeshu yaddhath

Nothing happens to the (huge number) infinity, when any number enters (added) or leaves (subtrated) the infinity. During pralaya many things get dissolved in Mahavishnu and after pralaya, during srushti all those things get out of him. This happens without affecting the lord himself. Like that, whatever number is added to infinity or whatever is subtracted from it, the infinity remains unchanged.

BRAHMAGUPTHA IN BRAHMASPHUTA SIDDHANTA 600 AD

BHAKARACHARYA II - BEEJAGANITA 1148 AD

USE OF AVERAGE VALUES

Ganayithva visthaaram bahushusthaneshu thadyuthirbhaayyaa sthaanakamithyaa samamithirevam dairgye cha vedhe cha

(For length, breadth and depth) the measurements should be taken at many places and the sum should be divided by the number of times (places) the measurement is taken.

BHASKARACHARYA II IN LILAVATI 1150 AD

USE OF FRACTIONS

Drammaardha thrilavadvayasya sumathe paadathrayam yadbhaveth that panchaamsaka shoda saamsa charana: sampraarthithenaa- rthinaa datto yenavaraatakaa: kathi kadaryenarpithastena me broohithvam yadi vetsi vatsaganitha jaathim prabhagaabhidhaam

One man has given to a beggar fraction of 1 dramma (a unit of money). That fraction is one fourth of the one sixth of one fifth of the three fourth of the two third of the half of a dramma. Then tell how much kowdi (a unit fraction of the amount dramma) was given to the beggar?

BHASKARACHARYA I - ARYABHATEEYA BHASHAYA 628 AD

USE OF RATIO AND PROPORTION

Ashtow daanthaa sthryo damyaa ithi gaava: prakeerthi thaa: ekaagrasya sahasrasya kathi daanthaa: katheetharai:

(Out of 11 cattle) Eight are tamed and 3 are to be tamed and (how many are) to be tamed) if the number of cows is 1001?

BHASKARACHARYA I - ARYABHATEEYA BHASHAYA 628 AD

PERMUTATIONS AND COMBINATION - I

Katukathiktha kashaayaamla lavana madhurai: sakhe rasai: shadbhi: vidadhaathi soopakaaro vyanchanamaachakshva kathibhedam

Friend, a cook prepared varieties of food with 6 savours: pungent, bitter, astringent, acid, saline and sweet. Say what is the possible number of varieties of food that can be made with these savours.

SRIDHARACHARYA IN PATIGANITA 990 AD

PERMUTATIONS AND COMBINATION - II

Paasankusaahi damarooka kapaala soolai: khadvangasakthi sara chaapayuthairbhavanthi anyonya hastha kalithai: kathi moorthibhedaa: sambho haririva gadaari saroja sankachakrai:

Pasa, ankusa, serpant, damaru, kapala, soola, khatvanga, sakti, chapa, sara with these (ten) items how many permutations and combinations are possible for Lord Siva. Similarly with the four items, sanku, chakra, gadha and padma holding in the hands, how many combinations are possible for Lord Vishnu?

BHASKARACHARYA II IN LILAVATI 1114 AD

PARTNERSHIP AND SHARES

Samavaayakaasthu vanija: panchaikaikottharaadhi mooladhanaa: laabha: sahasra sankhyo vada kasmai thathra kim deyam

Five partners collaborate in a business. The capital invested by them are (in the ratio) one and the same number increasing successively by one (i.e 1,2,3,4, & 5) respectively. Profit that accrued amounts to 1000. Say what should be given to whom.

BHASKARACHARYA I - IN ARYABHATEEYA BHASHYA 628 AD

LOANS AND INTERESTS

Kutumbaarthamasakthena gruheetham vyaadhithena vaa upaplava nimittham cha vidyaathaapalkrutham thath kanyaavaivahikam chaiva prethakaaryeshu yathkrutham ethath sarvam pradaathavyam kutumbena krutham prabho

Loans are taken for meeting the expenditure connected with economic problems due to family burden, health problems, treatment, education, expenditure during accident, marriage of daughter, for performing rituals connected with the demise of the family members, etc.

VISHNUSMRUTHI 100 BC

INTEREST CALCULATION

Maasena sathasya phalam panchaiko bhavyake□rdhamaya vruttho lekhakapaado varshe panchaadika navasatheemisram

The rate of interest being 5% per month, the commission of surety 1% per month, fee for accountant ½% and charges of the scribe 1/4% per month, certain sum amounts to 905 a year. Find the capital, the interest and the shares of the surety?

SRIDHARACHARYA IN PATIGANITA 990 AD

RULES OF CHARGING INTEREST

Atha utthamarna: adhamarnaadyathaa datthamartham gruhneeyaath dvikam thrikam chathushkam panchakam cha satham prathimaasam

The loans can be given and taken between borrower and lender. Generally charged interest rates are 2, 3, 4, or 5% per month.

Sa paadapanaa dharmyaa maasavruddhi: panassathasya panchapanaa vyaavaharikee

Reasonable (dharmic) rate of interest is 1.25% per month (i.e 15% per annum) on the transactions with common man for non commercial purposes. But for commercial purposes (for making profit out of it) interest rate can be 5% per month.

VISHNU SMRUTHI 100 B.C

RULES OF BODIES IN MOTION

Bhakthe vilomavivare gathiyogenaanulomavivare dvow gathyantharena labdow dviyogakaalaavatheethaishyow

Whenever two bodies are travelling in the opposite directions, the distance between them is to be divided by the sum of their speeds. If they move in the same direction, the distance is to be divided by the difference of their speeds. This gives the time required for meeting of the bodies or the time elapsed after meeting of the moving bodies.

ARYABHATA I - ARYABHATEEYA 499 AD

Ekow naa yojananyashtow yaathyanyo yojanadvayam yojanaanaan satham panthaa: sangama: kva gamaagame

One man travels at 8 yojana speed per day. Another travels at 2 yojana per day, starting simultaneously from the same place. After reaching the destination, the first man comes back. If the length of the track is 100 yojana. Say where is the meeting place of the two? (One going forward and the other traveller returning).

SREEDHARACHARYA PATIGANITHA 990 AD

PROGRESSION OF THE TYPE

$1^2 + 2^2 + 3^2 + 4^2 + ...$

Sapthaanaam ashtaanaam saptadasaanaam chathurbhu jaaschithaya: ekavidyaanaam vaachyam padastharaasthaa hi vargaakhyaa:

There are (three pyramidal) piles on square bases having 7, 8 and 17 layers which are also squares. Say the number of units there in.

BHASKARACHARYA I - ARYABHATEEYA BHASHYA 628 AD

PROGRESSION OF THE TYPE $1^3 + 2^3 + 3^3 + 4^3 +$

Chathurasraghanaschithaya: panchachathurnavastharaa vinirdesyaa: ekaavaghatithaasthaa: samachathura sreshtakaa: kramasa:

There are three pyramidal piles having 5, 4 and 9 cuboidal layers. They are cuboidal bricks (of unit dimension) with one brick in the topmost layer. Find the number of bricks used in them.

BHASKARACHARYA I - ARYABHATEEYA BHASHYA 628 AD

PROGRESSION OF THE TYPE

$\square n + \square n^2 + \square n^3 + \square n^4$

Sankalithakruthighanaanaam sankalithasamaasamaanaam me kathaya shannaam sakhe padaanaam ganayithvaa yadivijaanaasi

Friend, if you know, then say after calculation (i) the sum of successive sum of 6 natural numbers (ii) the sum of the squares of the first 6 natural numbers and (iii) the sum of the cubes of first 6 natural numbers.

SREEDHARACHARYA - IN PATIGANITHA 900 AD

FIRST DEGREE INDETERMINATE EQUATION

Mudgaanaam kudavaa: saptha labhyanthe navabhi: pane: panena kudavasyaardham thandulaanaamavaapyathe thatha: panathrayam saardham gruheethvaa asu vaningmama thandulaanaam prayacchaamsa mudgaanaam cha dvisangunam

7 kudavas (unit of measurement) of mudga are obtained for 9 panas and ½ kudava of rice is obtained for one pana. Then O! merchant take 3½ panas and quickly give me one part of rice and two parts of mudga.

SREEDHARACHARYA - IN PATIGANITHA 900 AD

FIRST ORDER EQUATION - I

Ye nirjaraa dinadinaardha thrutheeya shashtai: sampoorayanthi pruthak pruthakeva mukthaa: vaapeem yadaa yugapadeva sakhe vimukthaasthe kenavaasaralavena thadaa vadaasu

By opening 4 inlets separately, one pond gets filled respectively within 1, ½, 1/3, and 1/6 days. If all the four inlets are opened together, how much time (in fraction of the day) is required to fill the pond ?

BHASKARACHARYA II - IN LILVATI 1114 AD

FIRST ORDER EQUATION - II

Nava gulikaa saptha (cha) roopakasamaasthrayaanaam (thu) gulikaanaam thrayodasaanaam cha roopakaanaam thadaa kim gulikaa moolyam

If 9 gulika and 7 rupaka are equal to 3 gulika and 13 rupaka, what is the price of one gulika? (the answer can be determined through the same method followed above)

SREEDHARACHARYA PATIGANITHA 990 AD

EQUATIONS OF HIGHER ORDER- I

Vaanarakulathribhaga: svathryamsa samanvi1tha: sara: prayayow moolam cha pipaasathi dvow choothathale sthithow seshow

One third of a troop of monkey with one third of itself has gone to the tank; the square root of the whole troop is afflicted with thirst, and the remaining 2 monkeys are sitting under the mango tree. What is the total number of monkeys? $^1/_3$ a + $^1/_9$ a + □a + 2 = a

REEDHARACHARYA - PATIGANITHA 990 AD

EQUATIONS OF HIGHER ORDER- II

Bale maralakula mooladalaani saptha theere vilaasabhara manthara gaanyapasyam kurvancha keleekalaham kalahamsayugmam sesham jale vada maraalakula pramaanam

I saw that one half of 7 times of the square root of the total number of swans were slowly moving away in the river. Remaining 2 are playing in water. What is the number of total swans? (equation: 7/2 □a+2=a)

BHASKARACHARYA - LILAVATI 1114 AD

PYTHAGORUS THEOREM

DISCOVERED BY BOUDHAYANA

Samachathurasrasyakshnayaa rajju dvishtavathim bhoomim karothi

The diagonal of a square produces double the area of the square.

Deerghachathurasrasyakshnayaarajju: paarsvamaani thiryanmaani cha yatpruthakbhoothe kuruthasthadubhayam karoti

Areas produced separately by the length and breadth of rectangle together equal to the area of the (square) produced by the diagonal.

BOUDHAYANA BOUDHAYANA SULBASUTRA 700 BC

EXPLANATION OF BINOMIAL THEOREM

If a three syllablic Madhya Chanda based on guru and lakhu sounds were followed, then variation of guru and lakhu sound will be on the following pattern: 3 guru sound occur once, 2 guru and 1 lakhu occur thrice, 1 guru and 2 lakhu sounds occur thrice, 3 lakhu occur once. The equation can be derived easily. If guru is g and lakhu is 1 then,

$(g+1)^3 = g^3+3g^21+3g1^2+1^3$. This equation is the same as $(x+y)^3$. Similarly for finding the pratishta Chanda, in the Chanda sastra of Pingalacharya, the following equation can be indirectly applied in this form: $(g+1)^4$ which is expanded as $g^4+4g^31+4g^21^2+4g1^3+1^4$ I.e 4 guru sound occur once, 3 guru and 1 lakhu occur four times, 2 guru and 2 lakhu occur four times, 1 guru and 3 lakhu occur four times and 4 lakhu occur once.

PINGALACHARYA - CHANDASASTRA 200 BC

GEOMETRY IN SULBASUTRA-II

Thaasaam trika chathushkayordvaadasikapanchikayo: panchadasikaashti kayo: saaptikachathurimsathikayo: dvaadasika panchathrimsathikayo: panchadasikashad- thrimsikayo: ithyethaasoopalabdhi:

Hypotenuse in rectangles having sides 3 and 4 (= 5), 12 and 5 (= 13), 15 and 8 (= 17), 7 and 24 (= 25), 12 and 35 (= 37) and 15 and 36 (= 39) (I.49).

BOUDHAYANA BOUDHAYANA SULBASUTRA 700 BC

ANGULAR DIMENSIONS

Angagunavedahuthaasaa: kalikaa vikalaa: samudrajaladhaya: svalpajalakhaashtasasi dhruthisasina: kalikaa: saraagnayo vikalaa: thrijyaakruthivarashta navathribhuvo visve jinaamsajyaa.

Thribhujasya phalasareeram samadalakoti bhujaardha samvarga:

The area of a triangle is the product of the prependicular and half the base.

ARYABHATTA I ARYABHATEEYA 499 AD

Karnasthrayodasa syaath panchadasaanyo mahee drisapthaiva vishamasthri bhujasya sakhe phalasankhyaa kaa bhavedasya

What is the area of a scalene traingle in which one lateral side is 13 units, other 15 unit and the base is 14 units.

Ashtaadasakocchrayovamso vaathena paathithomoolaath shadgathvaavasow pathithaasthribhujam kruthvaa kva bhaghna: syaath

A bamboo of beight 18 cubits fell by the wind, it falls at a distance of 6 cubits from the root, thus forming a right triangle, where is the break?

BHASKARA I COMMENTARY TO ARYABHATEEYA 628 AD

POLYGONAL

Thribdhyankaagninabha schandraisthri bhaanaa shtayugaashtabhi: vedaagni baanakhaaschaicha khakhaabhraa bhrarasai: kramaath baaneshu nakha baanai schadvidvi nandeshu saagarai: kuraamadasavedaischa vruthhavyaase samaahathe khakhakhaabhraarka sambhakthe labhyanthe kramasobhujaa: vrutthaantha sthraya poorvaanaam navaasraantham pruthak pruthak

For cyclic equilateral triangle, cyclic square, cyclic equilateral pentagon,.... to cyclic equilateral nonagon, (cyclic figures having 3 to

9 sides with equal side measurements) their sides can be calculated respectively when diameter is multiplied separetely with 103923 (triangle) 84854 (quadrilateral) 70534 (pentagon), 60000 (hexagon) 52055 (septagon) 45922 (octagon) and 41031 (nonagon) and divided by 120000, the value will be the measurements of the sides of cyclic equilateral triangles to cyclic equilateral nonagon. Bhaskaracharya has given the example: If 2000 is the diameter of circle, equilateral geometrical figures inscribed inside that circle will have sides as follows:

Geometrical figure	Bhaskara's value	Modern value
Triangle	1732 + .05	1732.043
Square	1414 + .021	1414.211
Pentagon	1175 + .056	1175.5619
Hexagon	1000 + .00	999.996
Septagon	867 + .58	867.5799
Octagon	765 + .36	765.3636
Nonagon	683 + .85	683.85

BHASKARA II - LILAVATI 1114 AD

CIRCLE - VALUE OF Π

Chathuradhikam sathatmashtagunam dvaashashtisthathaa sahasraanaam ayuthadvya vishkambasyaasannoo vruthhaparinaaha:

When 100 increased by 4 multiplied by 8 and added to 62,000 gives an approximate value for the circumference of a circle having diameter 20,000 units.

ARYABHATA I ARYABHATEEYA 499 AD

Ashtadvaadasa shadkaa: vishkambhasthathvatho mayaa drushtaa: theshaam samavrutthaanaam parithiphalam me pruthak broohi

Diameter of 3 circles are correctly seen by me to be 8, 12 and 6 units respectively. Tell me separately the circumference and areas of the circles.

BHASKARACHARYA I - 628 AD

SOMAYAJI'S THEOREMS

Vyaasaath vanasangunithaath pruthagaaptam thryaadyayugvimoola ghanai: thrigunavygaase svamrunam kramasa: kruthvaapi paridhiraaneyu:

Multiply the diameter of a circle with 4 and keep it at different places and divide each with the odd numbers beginning from 3, 5, 7,... as their cubes subtracted by the same value. Repeat this and add/subtract alternatively the results to three times the diameter of the circle to get the circumference with the highest degree of accuracy. This theorem can be mathematically represented as follows:

Circumference = $3D+4D/(3^3-3)-4D/(5^3-5)+4D/7^3\ 7)$-..

Vargairyujaam vaa dvigunairnirekair vargeekruthair varji thayugma vargai: vyaasam cha chadghnam vibhajeth phalam svam vyaase thrinighne paridhi sthadaasyaath

Six times the diameter is divided separetely by the square of twice the square of even integers 2,4,6.... minus one, diminished by the squares of even integers themselves. The sum of the resulting quotient by thrice the diameter is the circumference.

This can be mathematically written as follows:Circumference = $3D+6D([1/2x2^2-1]^2-2^2) + ([1/2x4^2-1]^2-4^2)+[(1/2x6^2-1)^2-6^2])+....$

PUTHUMANA SOMAYAJI - KARANAPADDHATI 1450 AD

AREA OF CIRCLE AND SPHERE

Vrutthakshethre paridhigunitha vyaasapaada: phalam thath kshunnam vedairupari paritha:kandukasyeva jaalam golasyaivam thadapi cha phalam prushtajam vyaasanighnam shadbhirbhaktham bhavathi niyatham golagarbhe ghanaakhyam

When circumference is multiplied with diameter and that result divided by 4, that will give the area of a circle. This when

multiplied with 4 gives the surface area of the globe which is like surface of a ball. This when multiplied with diameter and divided by 6 gives the volume of the sphere of globe.

Mathematically it can be written as $2\pi r \times 2r/4 = \pi r^2$

BHASKARACHARYA II - LILAVATI - 1114 A.D

NEWTON GAUSS (1670AD) BACKWARD

INTERPOLATION DISCOVERED BY VATESWARACHARYA

Dhanushaaptha bhuktha jeevaghaathe labdham saroopakam dalitham labdaghna vivarahatham cha samsodhya niyogya vikalajyaa

In modern mathematical form this interpolation formula can be written as $f(x) = f(xi) + (x-xi)1/h\, Df(xi-h) + (x-xi)1/h.\, (x-xi+h)1/h.\, D^2f(xi-h)½$.

VATESWARA VATESWARA SIDDHANTA 904 AD

ARC AND CHORD

Svalpachaapaacchaghanashashta bhaagatho vistaraardhakruthir-bhaktha varjitham sishtachaapamihasinjanee bhaveth thadyuth o□alpaka guno□asakruthdhanu:

The chord of an arc of a circle is obtained from the result of the cube of the length of the arc divided by six times the cube of radius and subtracted from the arc. This can be mathematically presented as follows: Chord (R Sine □) = $s - (s^3 / 6r^3)$. Here length of the arc s is in angular dimensions, r is the radius and □ is the angle of the arc.

PUTHUMANA SOMAYAJI - KARANA PADDHATHI - 1450 AD

Paridhe: shadbhaagajyaa vishkambhaardhena saa thulyaa

The chord of one sixth of circumference is equal to the radius of that circle.

ARYABHATTA I - ARYABHATEEYA 499 AD

LENGTH OF ARC - CHORD

Vyaasaabdhighaathayuthamourvikayaa vibhaktho jeevangghri panchagunitha: paridhesthuvarga: labdhonithaath paridhivarga chathurtha bhaagaadaapte pade vruthidalaath pathithedhanu: syaath.

One fourth of five times the chord multiplied with square of circumference divided by four times the diameter added with the chord. This value is subtracted from one fourth of the square of circumference. Square root of this is taken and subtracted from half of the circumference to get the arc.

BHASKARA II - LILAVATI 1114 AD

ARC AND ARROW

Jyaavyaasayogaanthara ghaathamoolam vyaasasthadoono dalitha: sara: syaath vyaasaaccharonaacchara sangunaa cha moolam dvinighnam bhavatheeha geevaa yeevaardhavarge sarabhaktha yukthe vyaasapramaanam pravadanthi vrutthe

When the sum and differences of diameter and the chord are multiplied, and their square root is taken and if half of that is subtracted from the diameter, the arrow is obtained. The difference of diameter and the arrow multiplied with the arrow, twice the square root of that value gives the chord. The square of half the chord divided by arrow and added with arrow gives the diameter of the circle.

BHASKARA II - LILAVATI 1114 AD

NEWTON'S INFINITE GP CONVERGENT SERIES

DISCOVERED BY NILAKANTA SOMAYAJI

Evam yasthuthya ccheda paramabhaaga paramaparyayaa ananthaayaa api samyoga: thasya ananthaanaam api kalpyamaanasya

yogasyaaddhyaavayavina: parasparama cchedaad ekonacchedaa mamsa saadhyam sarvathraapi samaanam eva...

Thus the sum of an infinite series, whose later terms (after the first) are got by diminishing the preceding or by the same divisor, is always equal to the first term divided by one less than the common mutual divisor.

NILKANTA ARYABHATEEYA BHASHAYA 1444

SINE, COSINE, RADIUS AND ARC

Anyonya kotihathayorabhimatha gunayosthrijeejavayaa hathayo: yogaviyogow syaathaamabhimathagunachaapa yogavivaragunow

The sum of the products of Sin A and Cos B and when angles are exchanged, Sin B and Cos A, gives the Sin of the sum of the angles. Similarly the difference of the above gives the value of the sin of angular difference. Sin (A+B) = Sin A Cos B+Cos A Sin B And Sin (A-B) = Sin A Cos B - Cos A Sin B.

Yadveshta chaapagunatha ccharavargayoga moolaardhamishta dhanurardhaguna: pradishta: jyaanaam nijathriguna vargaviseshamoolam kotisthadoona sahithow thrigunow svabhaanow

Square root, of the square of a chord (R sin □) diminished from squares of radius gives the koti (R cos □). This subtracted from radius gives the (small) arrow of arc. This added to radius is big arrow of the arc.....

PUTHUMANA SOMAYAJI - KARANA PADDHATI 1450

TAYLOR (1685 AD) SERIES OF SINE AND

COSINE DISCOVERED BY NILAKANTA

ista-dohkotidhanushoh svasamipasamirate jye dve saavayave nyasya kuryaad unaadhikam dhanuh dvighna talliptikaptaikasarasailasikhindavah nyasyacchedaaya cha mithastatsamskaaravidhitsaya anyasyam atha taam dvighnaam tathaa syam iti samskriti: santha te krtasamskare svagunau dhanusas tayo:

Placing the sine and cosine chords nearest to the arc, whose sine and cosine chords are required, get the arc difference to be subtracted or added. For making the correction, 13,751 should be divided by twice the arc difference in minutes and the quotient is to be placed as the divisor, divide the one (sine or cosine) by this divisor and add to or subtract from the other (cosine or sine) according as the arc difference is to be added or subtracted. Double this result and do as before. Add or subtract the result to or from the first sine or cosine to get the desired sine or cosine chords.

NILAKANTA - TANTRA SANGRAHA 1444 AD

NEWTON GAUSS (1670) INTERPOLATION FORMULA DISCOVERED BY GOVINDASWAMI

gacchad-yata-gunantharavapuryathaishya-disvasanaa cchedaabhyaasa-samuha-kaarmukakrti-praapthath tribhisthaadithah vedaihi sadbhir avaaptam antyagunaje rasyo: kramad antyabhe ganthavaahata-varthamaana-gunajaaccha paatham ekaadibhi:antyad utkramatah kramena vishamai: sankhyaviseshai: khsipedbhankthvaptam, yadi maurvikavidhir ayam makhyah kramad vartate sodhyam vyutkramathaa stathakrthaphlam.....

Mathematicaly this formula is summarised as follows: F(x+nh)=□f(x)+nf(x)+½n(n-1)(□f(x)-□f(x-h) Multiply the difference of the last and the current sine differences by the square of the elemental arc and further mutiply by three. Now divide the result so obtained by four in the first rasi, or by six in the second rasi. The final result thus obtained should be added to the portion of the current sine difference (got by linear proportion). In the last rasi, multiply the linearly promotional part of the current sine differences by the remaining part of the elemental arc and divide by the elemental arc. Now, divide the result by the odd numbers according to the current sine difference, when counted from the end in the

reverse order. Add the final result thus obtained to the portion of the current sine difference. These are the rules for computing true sine differences for sines. In the case of versed sines, apply the rules in the reverse order and the above corrections are to be subtracted from the respective differences.

GOVINDASWAMI - COMMENTARY FOR MAHABHASKAREEYA 800 AD

NEWTON'S (1660 AD) POWER SERIES

DISCOVERED BY SOMAYAJI

nihatya chapavargena chapam tatthathphalani cha haret samulayugvargaistrijyavargahatai: kramaat chapam phlani chadhodhonyasyoparyupari tyajet jivaptyai, sangraho syaiva vidvan-ityadina krtha: nihathya chapavargena rupam tattatphalani cha hared vimulayugvargaistrijyavargahatai: kramat kintu vyasadalenaiva dvighnenadyam vibhajyataam phalanyadhodha: kramaso nyasyoparyupari tyajet saraptyai, sangraho asyaiva stenastri-tyadinaa krta:

Multiply repeatedly the arc by its square and divide by the square of even numbers increased by that number and then multiplied by the square of radius. Place the arc and result one below the other and subtract each from what is above it. To derive the arc, which are collected, beginning with the expression *Vidvan* (katapayadi number). Multiply repeatedly, the unit measurement which is the radius, by the square of the arc and divide by the square of even numbers decreased by that number and then multiplied by the square of radius; the first is, however, to be divided by twice the radius. Place the results one below the other and subtract each from the one above it. That is the method to derive the *saras*, which are collected in the beginning with *stena*. (This equation is now known as Newton power series.)

PUTHUMANA SOMAYAJI - KARANAPADDHATI (1450 AD

VOLUMES OF CONES

Samakhaatha phalathryamasai: soochikhathe phalam bhavathi

The one third of the volume of the uniform cylinder is the volume of the cone.

Pardhirbhitthilagrasya raasesthrimsathkara: kila anthakonasthithasyaapi thithithulyakara: sakhe bahishkona sthithasyaapi panchaghnanava sammitha: theshaa ma chakshva me kshipram ghanahasthaath pruthak pruthak

Friend, the food grains are kept at a circumference of 30 cubit in the floor, outside corner of the room, inside corner and side of the wall. Find out the volume of the grain if the height is 45 cubit.

BHASKARA II LILAVATI 1114 AD

LHUILER'S (1782 AD) FORMULA

DISCOVERED BY SOMAYAJI

Doshnamdvayordvayor ghaatayutaanaam tisraanaam vadhaat ekaikonetarattraikyam catushkavadhabhajitam Iabdha mulena yadvrttam vishkambhaardhena nirmitam sarvam caturbhujakshetram tasminneva tisthtahathe

The three sums of the product of sides, taken two at a time are to be multiplied together and divided by the product of the sums of the sides taken three at a time and diminished by the fourth. If a circle is drawn with the square root of this quantity as radius, the whole quadrilateral will be situated inside it.

PARAMESWARA COMMENTARY FOR LILAVATI (1360 AD)

GREGORY'S (1632 AD) SERIES

FOR INVERSE TANGENT

DISCOVERED BY MADHAVA CHARYA

istajya-trijyayorghathath kotyaptam prathamam phalam jyavargam gunakam kritva kotivargam cha haarakam pratha maadiphalebhyo atha neya phalakrtir muhu: eka-tryaady-ojasankhyabhirabhakteshveteshv anukramaat ojanam samyutesthyaktva

yugmayogam dhanur bhavet doh-kotyor alpameveha kalpaniyam iha smrtam labdhinam avasanam syanna thathaapi muhu: krte

Obtain the first result of multiplying the jya (R sine □) by the trijya (radius) and dividing the product by koti (R cos □). Multiply this result by the square of the jya and divide the square by the koti. Thus we obtain a second result a sequence of the further results by repeatedly multiply by the square of the jya and dividing by the square of the koti. Divide the terms of the sequence in order by the odd numbers 1,3,5,...; after this, add all the odd terms and subtract from them all the even terms (without disturbing the order of the terms). Thus is obtained the dhanus whose two elements are the given jya and koti. (Here the smaller of the two elements should be taken as the jya, since other wise the series obtained will be non finite) (use of Tangent)

MADHAVA YUKTI BHASHA? (1350 AD)

DE MOIVRE'S (1650 AD) APPROXIMATION

DISCOVERED BY MADHAVA CHARYA

Asmat sukshmataroanyo vilikhyate kashcanapi samskara: ante samasankhyadalavarga saiko guna:, sa eva puna: yugagunito rupayuta: samasankhyadalahato bhaved haara: trisaradivisa mashankhyaharanat param etad eve va karyam

A correction for cirumference still more precise is being stated here. The multiplier is the square of half the even integer increased by unity. This multiplier multiplied by 4, then increased by unity and then multiplied by half the even integer is the divisor. This correction may be applied after the division by odd integers,3, 5, etc. i.e Circumference = 4D (1-1/3+1/5-1/7..... + ..-1/n(½(n+1)^2+1□□□((½(n+1)^2 x 4 +1) (½(n+1))

MADHAVA KRIYA KRAMAKARI (1350 AD)

DE MOIVRE'S (1650 AD) APPROXIMATION

yatsankhyaaatra harane krte nivrtta hrtis tu jamitaya tasya urdhvagatasyas samasankhya taddalam guno ante syat tadvargai rupahato haaro vyasabdhighatata: pragvat tasyam aptam svamrne krte dhane sodhanan cha karaniyam sukhma: paridhi: sa syat bahukrtvo haranato atisukshmas cha

……. Let the process stop at a certain stage, giving rise to a finite sum, multiply four times the diameter by half the even integer subsequent to the last odd integer used as divisor and then divide by the square of the integer increased by unity. The result is the correction to be added to or subtracted from finite sum. The choice of addition or subtraction is depending on sign of the last term in the sum. The final result is the circumference determined more accurately than by taking a large number of terms:

MADHAVA YUKTIBHASHA? (1350 AD)

HORIZON

Aaveshtamaanamatha thaani dalapravruthyaa yadvrutthamathra harijam kshithijam thadaahu: yasmin bhaveth samudayasthamayo akhilaanaam praachyaam kramaadaparadisyudu khecharaanaam

The great circle which goes round them, dividing each of them into two equal parts, is called harija or kshitija. This in modern astronomy is horizon. This is the circle on which rising and setting of stars and planets take place towards east and west respectively.

VATESWARA SIDDHANTA 880 AD

ASTRONOMICAL DEFINITIONS

Urdhvamadho apara poorvamihaadyam praahuridam samamandala manyath thadvadihotthara dakshinadikstham vrutthayugam vidisorapi thadvath

Vertical circle passing through the west and east cardinal points is the first circle: this is called the samamandala. (This circle is the prime vertical. Another similar vertical circle (called the yaamyottara-vrutta) which passes through the north and south cardinal points is called the meridian.

VATESWARA - VATESWARA SIDDHANTA 880 AD

TYCHO BRAHE REDUCTION OF ECLIPTIC

DISCOVERED BY ACHYUTA PISHAROTI

Patonasya vidhostu kotibhujayorjive mithastadayet antyakshepasarahatam vadhamamum vikshepakotyaharet labdham vyasadaloddhrtam himakare svarnam, vipate vidhau yugmaayugmapadopage; vidhurayam spashto bhagole bhavet

Multiply the tabular cosine and sine of the moon minus node and the product by the tabular versine of the maximum latitude of the moon. Divide this by the tabular cosine of the latitude at the particular moment and the quotient is to be divided again by the tabular radius. The result is to be added to or subtracted from the moon's longitude, as the moon minus node is in an even or an odd quadrant, respectively. The true moon measured on the ecliptic is thus obtained.

ACHYUTA PISHAROTI SPHUTANIRNAYA

EQUATOR

Khasvasthikaad dakshinatho akshabhaagow paathaa (la) samjnachha thathottharena naadyankitham vaishuvatham thaduktham vruttham bhagolasya khagolamadhye

The sphere of the asterisms lie within the sphere of the sky. Great circle of the sphere of asterisms which lies towoards the south of the zenith by an amount equal to the degrees of local latitude and towards the north of nadir by the same amount and which is graduated with the division of nadis is the vishuvathvrutta. This circle is called the equator.

VATESWARA SIDDHANTA 880 AD

6 O'CLOCK CIRCLE

Poorvaaparakshithija sangamayorgathamcha yaamyaadadha: palalavai:

kshithijaadvi lagnam soumyaadathopari samadruvamarga samstham unmandalam dinaniso: kshayavruddhikruthaath.

Passing through the two points of intersection of prime vertical and horizon, lying below the south cardinal point by the degrees of local latitude, fastened to the horizon, and lying above the north cardinal point, passing through the north celestial pole, is the Unmandala, the cause of decrease and increase of the day and night. (This in modern astronomy is known as the 6'o clock circle.)

VATESWARA SIDDHANTA 880 AD

CIRCLE OF DIURNAL MOTION

Harije parapoorva mandala dyujaavruthha visesha sinjinee udayaagraguno dyumandale bhoojyothavruttha kujaan tharaamsajeevaa:

R sine of the arc of the horizon lying between the prime vertical and the diurnal circle of the planet is the R sine of agra (now known as the rising point of the planet) and the R sine of the degrees of diurnal circle lying between six o' clock circle and the horizon is bhoojya (bhujya) which is termed as Earthsine.

VATESWARA SIDDHANTA 880 AD

DAY RADIUS

Kraanthijyaa vargonaath thrijyaavargaath padam dyujeevaa syaath thrijyaakraanthi yaanthara samaasa ghaathasya moolam vaa

Day radius is equal to the square root of the difference obtained by subtracting the squares of R sine of the declination from the square of the radius or the square root of the product of the difference and the sum of the radius and the R sine of the declination.

VATESWARA SIDDHANTA 880 AD

ECLIPTIC

Naaddyaahvavrutthaajathulaadilagnam jinaamsakairadakshinatho mrugaadow soumye seetha mandiraadaav apakramaakhyam thadusanthi vruttham

Fastened to the so called nadivrutta or the equator at the points of Aries and Libra and lying 24 degrees of the south (of equator) at the first point of Capricon and 24 degrees to the north (of equator) at the first point of Cancer, there is a great circle called the apakrama vrutta (now known as the ecliptic)

VATESWARA SIDDHANTA 880 AD

DAY DIAMETER

Vishuvajyaa aayaa mardha varga vislesha moolamavalambaka: kranthithrijyaakruthyo rantharapadam dvigunam dinavyaasa

Square the sine of latitude and deduct from the square of the radius. Its square root is the sine of the co-latitude (its arc being the co-latitude). Square the sine of the declination deduct from the square of the radius and find its root. Twice the result is the day diameter.

PANCHASIDDHANTIKA 4-23 - VARAHA MIHIRA 505 AD

S E T T I N G P O I N T O F E C L I P T I C

Praachyaam kuja apakrama vrutthasanga praaglagnamaahu (paritho asthalagnam) (lagnaadbhaveth) sa (pta) ma (raa) si (ra) stha thasyaa (stha) kaalo abhyudayosya bhooyath

Point of intersection of horoizon and the ecliptic in the eastern half of the celestial sphere is called praglagna. I.e. the rising point of ecliptic; the same in the western half is called astalagna, known as setting point of ecliptic.

VATESWARA SIDDHANTA 880 AD

R I S I N G - S E T T I N G L I N E

Vyaasaardha vrutthe antharam ethayo: syaaccharaardha jeevaa parapoorvayosthath agraagrayoryad harijenibaddham soothram grahaanaam udayaastha samjnam

The arcual distance between the six o'clock circle and the horizon measure, along the R circle trijyavrutta known as great circle of the celestial sphere, supposed to be of radius 3438' (minute of angle) is the charardhajya. It is called the R sine of the Ascensional difference. A thread tied to the extremities of the agra on the eastern and western halves of the horizon is called the udayaastasutra. (In moderen astronomy it is known as the rising - setting line of planets).

TESWARA SIDDHANTA 880 AD

DAY RADIUS AND EARTHSINE

Kraanti thribhaantharajyaa dyujyaa vaa charadalajeevayaa hruthaa thrijyaa kshithi jeevaghnaa svaahoraathraardhajeevaa vaa

Rsine of the difference between the three signs and the declination is also equal to the day radius. Day radius multiplied by earthsine and divided by the R sine of the Ascensional difference gives the day radius.

VATESWARA SIDDHANTA 3(4)-3) - 880 AD

SUN'S PRIME VERTICAL

Urdhvamadho aparapoorvamihaadyam praahuridam samamandala manyath thadvathihottharadakshina dikstham vrutthayugam vidisorapi thadvath.

Vertical circle passing through the west and east cardinal points is the first circle called samamandala or the prime vertical.

VATESWARA SIDDHANTA- GOLA. 3-1, 2 - 880 AD

PARALLAX-I

Thithernathasya kramasinjanee hathaa khamadhya lagnaprabhavena sankunaa kshamaashadangkaabhi saraankanethrahrud vilambane syaad ghatikaadi vaa phalam.

R sine of the hour angle at the amavasya multiplied by R sine of the altitude of the meridian ecliptic point and divided by 2954961 gives the parallax in ghatikas at mid eclipse (Sishyadhi vruddhi Tantra 6-8)

LALLACHARYA SISHYADHI VRUDDHI TANTRA

PARALLAX-II

Thriraasijeevaa valanajyakaa hruthaa sileemukhai rankulathaam vrajanthi thaa: dvisankunaa drushtigathi: saraachalairvibhaajithaa lambana naadikaa phalam

Radius and the valanajya when divided by 5, are converted into angulas. The R sine of driggati multiplied by 2 and divided by 75 gives ghatika of the parallax in longitude. (Sishyadhi vruddhi Tantra 13-11)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

PARALLAX-III

Nathakramajyaambara sankunighnaa syaallambanam thathvarase shuhrudvaa drukshepabhukthyanthara yoscha ghaatha: khabaanayugmaa kshihrutho nathi: syaath

R sine of the hour angle multiplied by Rsine of altitude of the merdian ecliptic point and divided by 5625 gives parallax in longitude. The Difference of true motions of the Sun and the moon multiplied by the Rsine of drikshepa and divided by 2250 gives the parallax in latitude. (Sishyadhi vruddhi Tantra 13-12)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

APOGEE, PERIGEE AND ORBIT OF EARTH

Svochhaath shadbhaagaadhyadhiko yadaa thadaa bhavathi svaneechastha: doorenochhaga urvyaa: karnavasaannochhago nikate

When a planet is at a distance of 6 signs from its apogee, it is said to be at the perigee or neecha. When a planet is at the apogee, it is farthest from the earth when at the perigee, it is nearest to the earth. This is so because of the length of the hypotenuse in each case (Sishyadhi vruddhi Tantra 14-10)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

VELOCITY OF PLANETS PER DAY

Sun 59’ 8” 10’’’13’’’’

(gopaajnayaa dinadhaama)

34” 51’’’36’’’’

(Chandikeso bharga snigdhosow)

Mars 31’ 26” 29’’’42’’’’

(Prabhurdharaachakra paala)

Mercury 245’ 32” 36’’’ 32’’’’

(Rageethumbururganeswara)

Jupiter 4’ 59” 7’’’ 2’’’’

(Prajnaasanoo dharmavaan)

: Venus 96’ 7” 37’’’ 51’’’’

(Kasi saambasanna chola:)

Saturn 2’ 0” 23’’’ 32’’’’

(Prabhalapraajno nara:)

The modern values of angular motions are Earth/Sun 59.14’, Mars 31.45’, Mercury 245.7’, Juptiter 4.99’ Venus 96.13’, and Saturn 2’.

PUTHUMANA SOMAYAJI KARANAPADHATI (1450 AD)

SHAPE OF EARTH

Gaganamarudaagni jalamrunmayo mahaabhootha gunayutha:khastha: kakshaabhiraavrutho ayam bhapan charaanthascha bhoogola

Spherical earth, made of ether, fire, air, water and clay (Panchabhoothas) and thus have all the properties of the five elements, surrounded by the orbits and extending upto the sphere of stars, remain in the space (Sishyadhi vruddhi Tantra 17-1)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

Praguna paridhe: sathaamsako ganithajnaa: kathayanthi drusyathe prathi bhaathi thadaa samaa mahee vishaye yanthra thathaiva gamyathe

Mathematicians say that one hundredth of the cirucumference of the earth appears to be plane. So, that portion of the earth appears to be plane to an observer (Sishyadhi vruddhi Tantra 20-35)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

ROTATION OF EARTH – I

Pranenaithi kalaam bhooryadi tharhi kutho vrajeth kamadhyaanam aavarthana murvyaa schenna pathanthi samucchrayaa: kasmath

If earth rotates at a speed of 1' of an angle in 4 seconds, will not the things on the loft fall? Where does the earth go in this speed? (Brahmasphuta siddhanta 11-17).

BRAHMAGUPTA BRAHMASPHUTA SIDDHANTA 629 AD

FOUR QUADRANTS OF EARTH

Udayo yo lankaayaam soasthamayo: savithureva siddhapure madhyahno yavakotyaam romake vishaye ardharaathramsyaath

When it is Sunrise in Lanka, the same Sun sets in Siddhapura. (Gautimaala). It is noon in Yavakoti (Korea) and midnight in Romaka (Rome) (Aryabhateeyam 4-13).

ARYABHATA -I ARYABHATEEYA (499 AD)

GLOBE

Samavrutthaprushtamaanam sookshmam golam prasaadhya daarumayam sthagithaarka samaankitha kaala bhogarekaadvaye paridhov

Perfectly circular throughout and spherical, made of wood, marked with degrees and minutes, incorporated with lines both longitude and latitude at ends, is the golayantra. (Panchasiddhantika 14-23)

VARAHAMIHIRA PANCHASIDDHANTIKA (505 AD)

Kaashtamayam samavruthham samanthatha: samagurum laghum golam paaradathaila jalaistham bhramayeth svadhiyaa cha kaalasamam

Made of wood, fully circular, uniform, equally dense throughout and spherical shaped golayantra, which rotates at a fixed rate of time as the earth does by the help of mercury, oil and water, by the application of our intelligent calculation, is the golayantra-Globe.

.....

Nrushiyojanam, njilaa bhoovyaaso

8000 Nr units is equal to one yojana. The diameter of earth is 1050 yojana.

ARYABHATA-I ARYABHATEEYA (499 AD)

ROTATION OF EARTH - II

Ku ngi si bu nlru shru khru praak

Eastward rotations of the earth in one Yuga is 1582237500

Anuulomagathirnoustha: pasyathyachalam vilomagam yadvath achalaani bhaani thadvath samapaschimagaani lankaayaam

Just as a man in a boat moving forward sees the stationary objects as moving backward, so are the stationary stars and celestial bodies seen by the people at equator (Lanka) as moving exactly towards west.

Ku aavarthaaschaapi naakshathraa:

The rotation of the earth is the cause of days (Aryabhateeyam 3-5).

ARYABHATA-I ARYABHATEEYA (499 AD)

MERIDIAN

Lankaayaamekam sankukeelam prathishtaapya thenaikam soothraagram baddhvaa punarmerorupari thadagramanyath baddhvaa yathaayathaa drusyatha..... thadvath bhoomaavapi kaachidrekha lankaatha: kharapuratha..... merumasthakaanavagaahya sthithaa saa punarathra desaanthara vidhaayini syaath

Fix a pole in Lanka, tie thread on that, take the other end to the North pole, tie it there also, then one can see the line of the thread passing through Lanka, Kharapuri, Arctic point and so many other countries upto the top of Meru. This is international meridian line (Sankaranarayana on Laghubhaskareeya I-23)

SANKARANARAYANA I LAGHUBHASKAREEYA (950 AD)

G R A V I T Y

Aakrushti sakthischa mahee thayaa yath khastham guru svaabhimukham svasakthyaa aakrushyathe thathpathatheeva bhaathi same samanthaath kva pathathyayam khe:

This earth attracts whatever solid materials are in the space, by her own force of attraction towards her (earth). All those subjected to this attractional force fall, to the earth. Due to equal force of attraction among the celestial bodies, where can each among them fall? (Siddhanta siromani Bhuvanakosham 6)

BHASKARA II SIDDHANTA SIROMANY (1114 AD)

MERIDIAN AND TIME

Desaanthara ghatee kshunnah madhyaa bhukthir dyuchaarinaam shashtyaa bhaktham runam praachyaam rekhaayaa: paschime dhanam.

The time is calculated based on the meridian. Divide the time by 60... and the longitude is calculated. Towards the east subtract and towards the west add the number (Laghubhaskareeyam 1-31)

BHASKARA I LAGHUBHASKAREEYA (628 AD)

MERIDIAN AND TIME

Panchaasathaa thribhisthryamsaamyuthairyojanaischa naaddyekaa samapoorva paschimasthairnithyam sodhyaa cha deyaa cha

One nadi for every 53 1/3yojanas has to be deducted or added (to Ujjaini) by the people in places east and west, respectively of the Ujjaini meridian. (Panchasiddhantika 9-10)

VARAHAMIHIRA - PANCHASIDDHANTIKA (605 AD)

E C L I P S E - I

Kimartham asura: kaschidraahurnaama saimhikeyoarkam chandram cha grasatha ithi srooyathe sraapi pouraanika sruthireva! ka: punariha raahurithyuchyathe

What does it mean that Asura is responsible for the eclipse? Others say that a snake Rahu swallows the Sun and the Moon! Those are puranic stories! Then what is called the Rahu?

SANKARANARAYANA COMMENTRAY TO LAGHUBHASKAREEYA 950 AD

Cchadayathi sasi sooryam sasinam mahathee cha bhoocchaayaa

Moon covers (shadows) the Sun and the great shadow of the earth covers the moon (which causes the eclipse)

ARYABHATAI ARYABHATEEYA (499 AD)

E C L I P S E - I I

Atha eva bhoocchayaa chandragrahanasya kaaranam

That is why it is said that the shadow of the earth is the cause for the lunar eclipse.

SANKARANARAYANA COMMENTRAY TO LAGHUBHASKAREEYA

Asuro yadi maayayaa yutho niyatho athigrastheethi they mantham ganithena katham sa labhyathe grahakrutha parva vinaa kathanchana

If you are of the opinion that an artifical demon is always the cause of an eclipse by swallowing, then how is it that an eclipse can be determined by means of calculations. Moreover why is then not an eclipse occur on a day other than the day of new or full moon (Sishyadhi vruddhi Tantra 20-22)

LALLACHARYA SISHYADHI VRUDDHI TANTRA 700 AD

such activities.

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