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   STATEMENT OF THE PROBLEM

   OBJECTIVES

   HYPOTHESES

   RESEARCH METHODOLOGY

   RESULTS & DISCUSSION

   FINDINGS

   RECOMMENDATIONS/SUGGESTIONS

   CONCLUSIONS

   SCOPE FOR FURTHER RESEARCH

   ACKNOWLEDGMENTS

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   APPENDIX/ANNEXURE

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CONTRIBUTIONS TO BOOKS

- Sharma T., Kwatra, G. (2008) Effectiveness of Social Advertising: A Study of Selected Campaigns, Corporate Social Responsibility, Edited by David Crowther & Nicholas Capaldi, Ashgate Research Companion to Corporate Social Responsibility, Chapter 15, pp 287-303.

JOURNAL AND OTHER ARTICLES

- Schemenner, R.W., Huber, J.C. and Cook, R.L. (1987), "Geographic Differences and the Location of New Manufacturing Facilities," Journal of Urban Economics, Vol. 21, No. 1, pp. 83-104.

CONFERENCE PAPERS

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- Garg, Bhavet (2011): Towards a New Natural Gas Policy, Political Weekly, Viewed on January 01, 2012 http://epw.in/user/viewabstract.jsp

THE GREAT MATHEMATICIAN SRINIVASA RAMANUJAN

G. VIJAYALAKSHMI
ASST. PROFESSOR
R.B.V.R.R. WOMEN'S COLLEGE
OSMANIA UNIVERSITY
HYDERABAD

ABSTRACT

The aim of this paper is to introduce Srinivasa Ramanujan and his work in mathematics .In this paper we have given Introduction,Contributions in Algebra,Geometry,Bernoulli's numbers and so on.. The most significant contributions are Ramanujan Prime, Ramanujan Theta function, Ramanujan-Soldner constant, Ramanujan`s sum etc. In order to calculate the value of `pi` up to 17 million places using a computer, the present day mathematicians actually use Srinivasa Ramanujan`s method.

KEYWORDS

Life of Srinivasa Ramanujan, Contributions, Prominent Mathematician's Views on Ramanujan.

INTRODUCTION

The most prominent Indian mathematician Srinivasa Ramanujan was born on 22nd December 1887, at Erode near Kumbakonam in Tamil Nadu. Ramanujan has a great mathematical ability even as a child. He passed his matriculation examination at Kumbakonam at the age of 16 and secured junior Subramanyam Scholarship for further study at the Government college at Kumbakonam. He was so found of mathematics that he hardly paid any attention to any other subject with the result that he failed in English at the first examination and lost the scholarship. He spent the next few years studying mathematics independently. On the 14th July 1909 he got married to Janaki. Ramanujan joined the University at Madras as the first research scholar of University. On the suggestion of Sheshu Aiyer, Ramanujan wrote to Professor G.H. Hardy at Cambridge. His letter to Hardy dated January 16, 1913. Along with this letter he enclosed about 120 theorems. Hardy sent him an invitation to come to England. On the 17th March 1914, Ramanujan sailed for England and he joined as a research scholar on an annual scholarship of 250 pounds.

In 1916 Ramanujan was awarded the B. A. degree of the University of Cambridge on the basis of his research work. While in England Ramanujan was honoured in several ways. In 1918 he was the first mathematician whose name was accepted for Fellowship of the Royal Society at the first proposal. In the same year he was elected a Fellow of the Trinity College, Cambridge. He was the first Indian to have been so elected. Ramanujan lived in England for five years. These were the most fruitful years of his life. He collaborated with Hardy and Littlewood to produce some of the most outstanding work.

In 1917 Ramanujan fell ill and the cold climate of Cambridge did not suit him. The illness grew from bad to worse and it was decided in 1919 that he should be sent back to India where the warm climate might help in his recovery The cold climate of Cambridge did not suit him. The illness grew from bad to worse and it was decided in 1919 that he should be sent back to India where the warm climate might help in his recovery and passed away a year later, on the 26th April 1920.

CONTRIBUTIONS OF SRINIVASA RAMANUJAN

Indian Vedas ,particularly the Yajurveda has been a repository of various mathematical concepts and principles which find extensive application in the modern day mathematics. Srinivasa Ramanujan through his mathematical genius has brought to light the concepts which were hidden and unknown to the present day civilization.

The squaring of the circle is central to the construction of an AhavanIya and gArhapatya of equal area and a multiple approximations are suggested by different yajurvedic traditions. Similar constructions to these yajurvedic attempts are seen in the Rhind papyrus and the work of Anaxagoras. Several millennia later the 26 year old Ramanujan supplied one of the best approximations for the squaring of the circle – the one shown above. With this he gets a fraction for approximating pi as 355/113 – one which would have made his yajurvedic ancestor proud.

Contribution of Ramanujan is widespread in fields of Algebra, Geometry, Trigonometry, Calculus, Number theory etc. He has also made some extraordinary contributions to the fields like Hyper-geometric series, Elliptic functions, Prime numbers, Bernoulli`s numbers, Divergent series, Continued fractions, Elliptic Modular equations, Highly Composite numbers, Riemann Zeta functions, Partition of numbers, Mock-Theta functions etc. In reality, apart from a few elementary ones, most of the contributions of S. Ramanujan belong to a higher realm of mathematics that is often referred to as Higher Mathematics. But the most significant contributions are Ramanujan Prime, Ramanujan Theta function, Ramanujan-Soldner constant, Ramanujan`s sum etc.

Ramanujan developed the concept of the series S(1/n). He found Bernollii's numbers very intresting ,as a result he began studying Bernolli's numbers with deep intrest,and in 1911 he published an important research paper on Bernoulli's numbers .This important research paper was published in india mathematical Society,a highly reputable scientific journals.

According to eminent mathematicians, all the numbers were actually the intimate friends of S. Ramanujan. In order to calculate the value of `pi` up to 17 million places using a computer, the present day mathematicians actually use S. Ramanujan`s method. The mathematical contributions of S. Ramanujan have also been widely used in solving various problems in higher scientific fields of specialisation. The diverse specialised higher scientific fields include the likes of particle physics, statistical mechanics, computer science, space science, cryptology, polymer chemistry and medical science. Apart from the above fields, S. Ramanujan`s mathematical methods are being used in designing better furnaces for smelting metals and splicing telephone cables for communications, as well. Ramanujan actually belonged to the Formalist School of Mathematics. It is true that Ramanujan had not given much attention to the deeper meaning of Mathematics but he had given the subject a concrete form with the help of formulas, theorems, identities etc. He also searched for forms or patterns in mathematics and he actually worked more by intuition and induction and showed relationships between numbers, something that nobody could even imagine at that time. Ramanujan had found results that were both original and very different in nature.

- **RAMANUJAN PERFECT NUMBER**
- **CONTINUED FRACTION**
- **PARTITION OF NUMBERS**
- **RAMANUJAN'S CONGRUENCES**
- **CIRCLE SQUARING**

RAMANUJAN PERFECT NUMBER

[TAXI CABNUMBER]

The number derives its name from the following story: G. H. Hardy told about Ramanujan. I remember once going to see him when he was ill . I had ridden in taxi cab number 1729 and remarked that the number seemed to me rather dull one, and that I hoped it was not an unfavorable omen. "No," he replied, "it is a very interesting number; it is the smallest number expressible as the sum of two cubes in two different ways."

1729 is the second taxicab number (the first is 2= 1^3 + 1^3). The number was also found in one of Ramanujan's notebooks dated years before the incident. [3]

The two different ways are these:

$1729 = 1^3 + 12^3 = 9^3 + 10^3$

The quotation is sometimes expressed using the term "positive cubes", since allowing negative perfect cubes (the cube of a negative integer) gives the smallest solution as 91 (which is a divisor of 1729):

$91 = 6^3 + (-5)^3 = 4^3 + 3^3$

Of course, equating "smallest" with "most negative", as opposed to "closest to zero" gives rise to solutions like −91, −189, −1729, and further negative numbers. This ambiguity is eliminated by the term "positive cubes".

Numbers that are the smallest number that can be expressed as the sum of two cubes in *n* distinct ways [4] have been dubbed "taxicab numbers". The number was also found in one of Ramanujan's notebooks dated years before the incident, and was noted by Frenicle de Bessy in 1657.

The same expression defines 1729 as the first in the sequence of "Fermat near misses", defined as numbers of the form $1 + z^3$ which are also expressible as the sum of two other cubes.

1729 is also the third Carmichael number and the first absolute Euler pseudoprime. It is also a sphenic number.

CONTINUED FRACTION

A continued fraction is an expression obtained through an iterative process of representing a number as the sum of its integer part and the reciprocal of another number, then writing this other number as the sum of its integer part and another reciprocal, and so on. [5] In a finite continued fraction (or terminated continued fraction), the iteration/recursion is terminated after finitely many steps by using an integer in lieu of another continued fraction.[6] In contrast, an infinite continued fraction is an infinite expression.

Continued fractions have a number of remarkable properties related to the Euclidean algorithm for integers or real numbers. Every rational number p/q has two closely related expressions as a finite continued fraction, whose coefficients a_i can be determined by applying the Euclidean algorithm to (p, q). The numerical value of an infinite continued fraction will be irrational; it is defined from its infinite sequence of integers as the limit of a sequence of values for finite continued fractions. Each finite continued fraction of the sequence is obtained by using a finite prefix of the infinite continued fraction's defining sequence of integers. Moreover, every irrational number α is the value of a unique infinite continued fraction, whose coefficients can be found using the non-terminating version of the Euclidean algorithm applied to the incommensurable values α and 1. This way of expressing real numbers (rational and irrational) is called their continued fraction representation.

FINITE CONTINUED FRACTIONS

A finite continued fraction is an expression of the form

$$a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2 + \cfrac{1}{\ddots + \cfrac{1}{a_n}}}},$$

where a_0 is an integer, any other a_i members are positive integers, and n is a non-negative integer.

Thus, all of the following illustrate valid finite continued fractions:

Examples of finite continued fractions		
Formula	Numeric	Remarks
a_0	2	All integers are a degenerate case
$a_0 + \cfrac{1}{a_1}$	$2 + \cfrac{1}{3}$	Simplest possible fractional form
$a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2}}$	$-3 + \cfrac{1}{2 + \cfrac{1}{18}}$	First integer may be negative
$a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2 + \cfrac{1}{a_3}}}$	$\cfrac{1}{15 + \cfrac{1}{1 + \cfrac{1}{102}}}$	First integer may be zero

An infinite continued fraction can be written as

$$a_0 + \cfrac{1}{a_1 + \cfrac{1}{a_2 + \cfrac{1}{a_3 + \cfrac{1}{a_4 + \ddots}}}},$$

Every finite continued fraction represents a rational number, and every rational number can be represented in precisely two different ways as a finite continued fraction. These two representations agree except in their final terms. In the longer representation the final term in the continued fraction is 1; the shorter representation drops the final 1, but increases the new final term by 1. The final element in the short representation is therefore always greater than 1, if present. In symbols:

$$[a_0; a_1, a_2, \dots\dots, a_{n-1}, a_n, 1] = [a_0; a_1, a_2, \dots\dots, a_{n-1}, a_n + 1]$$
$$[a_0; 1] = [a_0 + 1]$$

For example,

2.25=2+1/4=[2;4]=2+1/(3+1/1)=[2;3,1],

4.2=-5+4/5=-5+1/(1+1/4)=[-5;1,4]=-5+1/(1+1/(3+1/1))=[-5;1,3,1].

CALCULATING CONTINUED FRACTION REPRESENTATIONS

Find the continued fraction for 3.245 (= $3\frac{49}{200}$)						
Step	Real Number	Integer part	Fractional part	Simplified	Reciprocal of f	Simplified
1	$r = 3\frac{49}{200}$	$i = 3$	$f = 3\frac{49}{200} - 3$	$= \frac{49}{200}$	$1/f = \frac{200}{49}$	$= 4\frac{4}{49}$
2	$r = 4\frac{4}{49}$	$i = 4$	$f = 4\frac{4}{49} - 4$	$= \frac{4}{49}$	$1/f = \frac{49}{4}$	$= 12\frac{1}{4}$
3	$r = 12\frac{1}{4}$	$i = 12$	$f = 12\frac{1}{4} - 12$	$= \frac{1}{4}$	$1/f = \frac{4}{1}$	$= 4$
4	$r = 4$	$i = 4$	$f = 4 - 4$	$= 0$	STOP	
Continued fraction form for 3.245 or $3\frac{49}{200}$ is [3; 4, 12, 4]						

$$3\frac{49}{200} = 3 + \cfrac{1}{4 + \cfrac{1}{12 + \cfrac{1}{4}}}$$

The number 3.245 can also be represented by the continued fraction expansion [3; 4, 12, 3, 1];

PARTITION OF NUMBERS

In number theory and combinatorics, a **partition** of a positive integer *n*, also called an **integer partition**, is a way of writing *n* as a sum of positive integers. Two sums that differ only in the order of their summands are considered to be the same partition; if order matters then the sum becomes a composition. For example, 4 can be partitioned in five distinct ways:

4, 3 + 1, 2 + 2, 2 + 1 + 1, 1 + 1 + 1 + 1.

The order-dependent composition 1 + 3 is the same partition as 3 + 1, while 1 + 2 + 1 and 1 + 1 + 2 are the same partition as 2 + 1 + 1.

A summand in a partition is also called a **part**. The number of partitions of *n* is given by the partition function *p*(*n*). So *p*(4) = 5. The notation ***q* ⊢ *n*** means that *q* is a partition of *n*.

Partitions can be graphically visualized with Young diagrams or Ferrers diagrams. They occur in a number of branches of mathematics and physics, including the study of symmetric polynomials, the symmetric group and in group representation theory in general.

The partitions of 4 are:

1. 4
2. 3 + 1
3. 2 + 2
4. 2 + 1 + 1
5. 1 + 1 + 1 + 1

In some sources partitions are treated as the sequence of summands, rather than as an expression with plus signs. For example, the partition 2 + 1 + 1 might instead be written as the tuple (2, 1, 1) or in the even more compact form $(2, 1^2)$ where the superscript indicates the number of repetitions of a term.

RESTRICTED PARTITIONS

Among the 22 partitions for the number 8, 6 contain only *odd parts*:

- 7 + 1
- 5 + 3
- 5 + 1 + 1 + 1
- 3 + 3 + 1 + 1
- 3 + 1 + 1 + 1 + 1 + 1
- 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1

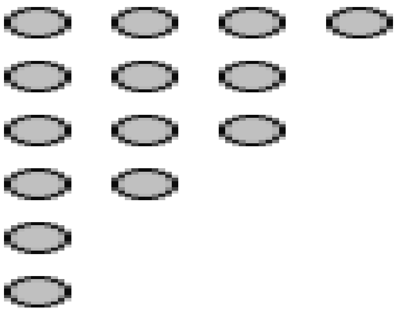
If we count the partitions of 8 with *distinct parts*, we also obtain the number 6:

- 8
- 7 + 1
- 6 + 2
- 5 + 3
- 5 + 2 + 1
- 4 + 3 + 1

It is true for all positive numbers that the number of partitions with odd parts always equals the number of partitions with distinct parts.[7] Some similar results about restricted partitions can be obtained by a **Ferrers graph** also called **Ferrers diagram**.[8]

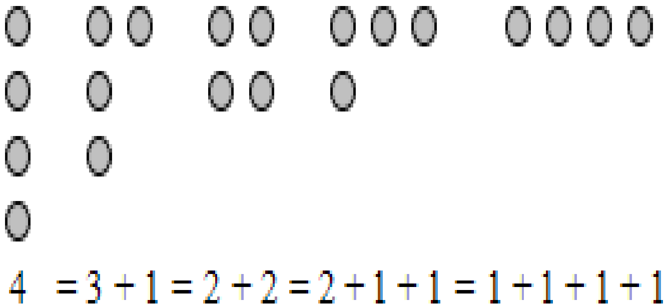
FERRERS DIAGRAM

The partition 6 + 4 + 3 + 1 of the positive number 14 can be represented by the following diagram; these diagrams are named in honor of Norman Macleod Ferrers.

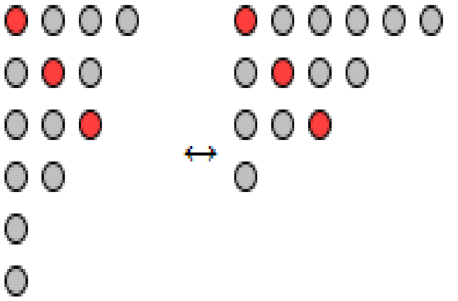


6 + 4 + 3 + 1

The 14 circles are lined up in 4 columns, each having the size of a part of the partition. The diagrams for the 5 partitions of the number 4 are listed below:



If we now flip the diagram of the partition 6 + 4 + 3 + 1 along its main diagonal, we obtain another partition of 14:



6 + 4 + 3 + 1 = 4 + 3 + 3 + 2 + 1 + 1

By turning the rows into columns, we obtain the partition 4 + 3 + 3 + 2 + 1 + 1 of the number 14. Such partitions are said to be *conjugate* of one another.[9] In the case of the number 4, partitions 4 and 1 + 1 + 1 + 1 are conjugate pairs, and partitions 3 + 1 and 2 + 1 + 1 are conjugate of each other. Of particular interest is the partition 2 + 2, which has itself as conjugate. Such a partition is said to be **self-conjugate[10].**

RAMANUJAN'S CONGRUENCES

Congruence is the state achieved by coming together, the state of agreement. The Latin *congruō* meaning "I meet together, I agree". As an abstract term, congruence means similarity between objects. Congruence, as opposed to equivalence or approximation, is a relation which implies a *kind* of equivalence, though not complete equivalence.

In mathematics, Ramanujan's congruences are some remarkable congruences for the partition function $p(n)$.[11]

PARTITION FUNCTION

In number theory, the **partition function** $p(n)$ represents the number of possible partitions of a natural number n, which is to say the number of distinct (and order independent) ways of representing n as a sum of natural numbers. By convention $p(0) = 1$, $p(n) = 0$ for n negative.

The first few values of the partition function are (starting with $p(0)=1$):

1, 1, 2, 3, 5, 7, 11, 15, 22, 30, 42, … .

The value of $p(n)$ has been computed for large values of n, for example $p(100)$=190,569,292 and $p(1000)$ is approximately 2.4×10^{31}.

As of November 2011, the largest known prime number that counts a num of partitions is $p(80036992)$, with 9958 decimal digits, found by Bernardo Boncompagni.

For every type of restricted partition there is a corresponding function for the number of partitions satisfying the given restriction. An important example is $q(n)$=the number of partitions of n into distinct part. As noted above, $q(n)$ is also the number of partition of n into only odd parts. The first few values of the $q(n)$ are (starting with $q(0)=1$):

1, 1, 1, 2, 2, 3, 4, 5, 6, 8, 10, …

The Indian mathematician Srinivasa Ramanujan discovered the following

- $p(5k+4) \equiv 0 \pmod 5$
- $p(7k+5) \equiv 0 \pmod 7$
- $p(11k+6) \equiv 0 \pmod{11}$.

In his 1919 paper (Ramanujan, 1919), he gave proof for the first two congruences using the following identities (using q-Pochhammer symbol notation):

$$\sum_{k=0}^{\infty} p(5k+4)q^k = 5\frac{(q^5)_\infty^5}{(q)_\infty^6}$$

$$\sum_{k=0}^{\infty} p(7k+5)q^k = 7\frac{(q^7)^3_\infty}{(q)^4_\infty} + 49q\frac{(q^7)^7_\infty}{(q)^8_\infty}.$$

then stated that "It appears there are no equally simple properties for any moduli involving primes other than these".

After Ramanujan died in 1920, G. H. Hardy, extracted proofs of all three congruences from an unpublished manuscript of Ramanujan on $p(n)$ (Ramanujan, 1921). The proof in this manuscript employs Eisenstein series.

In 1944, Freeman Dyson defined the rank function and conjectured the existence of a "crank" function for partitions that would provide a combinatorial proof of Ramanujan's congruences modulo 11. Forty years later, George Andrews and Frank Garvan successfully found such a function, and proved the celebrated result that the crank simultaneously "explains" the three Ramanujan congruences modulo 5, 7 and 11.

Extending results of A. O. L. Atkin, Ken Ono in 2000 proved that there are such Ramanujan congruences modulo every integer coprime to 6. For example, his results give

- $p(4063467631k + 30064597) \equiv 0 \pmod{31}.$

Later Ken Ono conjectured that the elusive crank also satisfies exactly the same types of general congruences. This was proved by his Ph.D. student Karl Mahlburg in his 2005 paper *Partition Congruences and the Andrews–Garvan–Dyson Crank*, linked below. This paper won the first Proceedings of the National Academy of Sciences Paper of the Year prize.

A conceptual explanation for Ramanujan's observation was finally discovered in January 2011 by considering the Hausdorff dimension of the following *P* function in the l-adic topology:

$$P_l(b;z) := \sum_{n=0}^{\infty} p\left(\frac{l^b n + 1}{25}\right) q^{\frac{n}{24}}.$$

It is seen to have dimension 0 only in the cases where l = 5, 7 or 11 and since the partition function can be written as a linear combination of these functions this can be considered a formalization and proof of Ramanujan's observation.

Srinivasa Ramanujan is credited with discovering that "congruences" in the number of partitions exist for integers ending in 4 and 9.

$$p(5k+4) \equiv 0 \pmod{5}$$

For instance, the number of partitions for the integer 4 is 5. For the integer 9, the number of partitions is 30; for 14 there are 135 partitions. This is implied by an identity, also by Ramanujan.

$$\sum_{k=0}^{\infty} p(5k+4)x^k = 5\,\frac{(x^5)^5_\infty}{(x)^6_\infty}$$

where the series $(x)_\infty$ is defined as

$$(x)_\infty = \prod_{m=1}^{\infty}(1-x^m).$$

He also discovered congruences related to 7 and 11:

$$p(7k+5) \equiv 0 \pmod{7}$$

$$p(11k+6) \equiv 0 \pmod{11}.$$

Since 5, 7, and 11 are consecutive primes, one might think that there would be such a congruence for the next prime 13, $p(13k+a) \equiv 0 \pmod{13}$ for some a. This is, however, false. It can also be shown that there is no congruence of the form $p(bk+a) \equiv 0 \pmod{b}$ for any prime b other than 5, 7, or 11.

PROMINENT MATHEMATICIAN'S VIEWS ON RAMANUJAN

Hardy : "The limitations of his knowledge were as startling as its profundity. Here was a man who could work out modular equations and theorems... to orders unheard of, whose mastery of continued fractions was... beyond that of any mathematician in the world, who had found for himself the functional equation of the zeta function and the dominant terms of many of the most famous problems in the analytic theory of numbers; and yet he had never heard of a doubly periodic function or of Cauchy's theorem, and had indeed but the vaguest idea of what a function of a complex variable was..."[12]. When asked about the methods employed by Ramanujan to arrive at his solutions, Hardy said that they were "arrived at by a process of mingled argument, intuition, and induction, of which he was entirely unable to give any coherent account." He also stated that he had "never met his equal, and can compare him only with Euler or Jacobi."[13]

K. Srinivasa Rao "As for his place in the world of Mathematics, we quote Bruce C. Berndt: 'Paul Erdős has passed on to us Hardy's personal ratings of mathematicians. Suppose that we rate mathematicians on the basis of pure talent on a scale from 0 to 100, Hardy gave himself a score of 25, J.E. Little wood 30, David Hilbert 80 and Ramanujan 100.'"[14]

John Littlewood *"Every positive integer is one of Ramanujan's personal friends"*, **on hearing of the taxicab incident.**

Jayant Narlikar In his book Scientific Edge, noted physicist Jayant Narlikar spoke of "Srinivasa Ramanujan, discovered by the Cambridge mathematician Hardy, whose great mathematical findings were beginning to be appreciated from 1915 to 1919. His achievements were to be fully understood much later, well after his untimely death in 1920.

For example, his work on the highly composite numbers (numbers with a large number of factors) started a whole new line of investigations in the theory of such numbers."

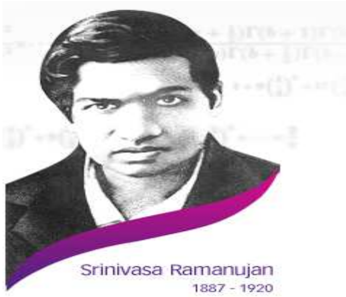
P.K. Srinivasan During his lifelong mission in educating and propagating mathematics among the school children in India, P.K. Srinivasan has continually introduced

Ramanujan's mathematical works.Ramanujan is a Part of a rich,1500 years old Indian heritage of mathematics and astronomy. Lumanaries like Brahmagupta in the 6th century Ad, Bhaskara (600-680AD) Sankara Narayana (840-900 AD) and Vijayanandi (940-1010 AD) created and built u[pon the foundations of science as we know it today.

OUR PRIME MINISTER MANMOHAN SINGH VIEWS

Mathematics, is the "mother science", the universal language of truth through numbers, touching daily use, technology and life - working out time, distance, calendar, the grocery prices and passenger air craft navigation, from algorithms in Internet search engines, to creating secure credit card transactions and planning national budgets.

"Men and women of such dazzling brilliance and deep intellect are born but rarely," declared Prime Minister Manmohan Singh in Chennai at a function on December 26, to celebrate the 125th birth anniversary of Ramanujan (December 22, 1887-April 26, 1920). The Indian government has also announced Ramanujan's birthday would be celebrated every year as "National Mathematics Day". India has declared 2012 as "National Year of Mathematics" as tribute to Srinivasa Ramanujan.



So the soul of immensity dwells in minutia.
And in narrowest limits no limits in here.
What joy to discern the minute in infinity!
The vast to perceive in the small, what divinity!.

CONCLUSION

So long as our planet continues to exist in the Universe, and so long as civilization exists on our planet, Ramanujan will be remembered because of the outstanding research contributions made by him to Number Theory and Real Analysis, and his work has kept first rate mathematicians busy till this date, his work has had a tremendous influence on modern mathematics and has opened up new vistas for research, but also he was able to do so without any formal training, without any means of support, and more so he continued to produce work of the highest order even in the face of death.
Exploratory study on the contributions of Srinivasa Ramanujan in the field of Mathematics and General Science reveal his extradinory genius that finds applications in the present day science specially in the emerging areas of NANO Technology ,Nuclear Physics etc.
His contributions go long way in providing various solutions to many unsolved mysteries in realm of Mathematics.

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With sincere regards

Thanking you profoundly

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