# Relevance of values to science: The sublime and the ridiculous

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*Very few among us have the courage to set up our own standard of values and abide by it.*

*Oscar Wilde*

In the last century, all branches of science were referred to as Natural Philosophy. During this century, science was broken up into main branches like: Mathematics, Physics, Chemistry and Biology and each branch further divided into different areas of specialization. A dictionary[1] meaning of Science reads: 'specifically natural science; the study and investigation of phenomena of external nature, and the laws and principles which determine these, as distinguished from, and in contrast to, those branches of knowledge which are concerned with man as an intellectual, ethical or social being.'

Astrology is not a science since it has not gone through rigorous stages of testing. In science, initially experimental observations give a lead to an empirical law which would account for the data. A theory is then proposed which would fit all the known data and it would make predictions too. Then starts an exciting interplay between theory and experiment, which will both be improved upon, until a satisfactory state of understanding is reached. Only in pure mathematics, theorems developed and arrived at in the abstract have been applied decades later to explain natural phenomenon.

Consider the evolution of physics to the status of an exact or pure science. Four centuries ago, the Danish astronomer, Tycho Brahe (1546–1601), recorded the most comprehensive observations of the positions of heavenly bodies, including the planets. His able assistant Johannes Kepler (1571–1630) analysed the data and proposed the laws of planetary motion:

- Every planet moves around the Sun in an elliptic orbit with the Sun at one of its foci.
- The radius vector from the Sun to a planet sweeps out equal areas in equal intervals of time.
- The squares of the periods ($T$) of any two planets are proportional to the cubes of the semi-major axis $a$ of their respective orbits; i.e. $T^2 \propto a^3$ or $T \propto a^{3/2}$.

These laws led Isaac Newton to his *Universal law of gravitation* – *universal* in the sense that the law which is valid on the Earth is equally valid on the Moon or any other planet. It was Newton's work which formed the foundation for the General Theory of Relativity of Albert Einstein, in 1915, which we require when we deal with the cosmos, black holes, etc. This theory was vindicated on May 29, 1919, by the experiment of Arthur Eddington who measured the bending of light from a distant star by the gravitational pull of the Sun as observed on our planet on a total solar eclipse day.

Even though a dictionary[1] look-up will reveal that by value is meant: 'worth that quality or property of anything which renders it desirable or useful'; or, 'worth of anything as compared with that of other things', the specific pluralistic usage, 'values' refers to relative ethical standards.

Pursuit of science is essentially a search for the eternal truth: 'Analysing the characteristics of a healthy scientific community, Jacob Bronowski has stated that by the worldly standards of public life, members of such a community are oddly virtuous in their work. They do not make wild claims, they do not cheat, they do not try to persuade at any cost, they appeal neither to prejudice nor to authority, they are often frank about their ignorance, their disputes are fairly decorous, they do not confuse what is being argued with race, politics, sex or age, they listen patiently to the young and to the old. ··· Independence and originality, dissent and freedom, and tolerance, are the first needs of science. Truth is the drive at the center of science. ··· Only by these means can science pursue its steadfast object to explore truth. If these values did not exist, then the society of scientists would have to invent them to make the practice of science possible'. (quotation from A. S. Paintal[2])

Such nobility in scientists, if universally present, would obviate the necessity for seminars[3] on scientific values or, for that matter, the formation of a 'Society for scientific values' to monitor scientists and the word 'plagiarism' – viz. act of plagiarizing (Plagiarize: 'to adopt and reproduce as one's own, to appropriate to one's own use, and incorporate in one's own work, without acknowledgement, the ideas of others, passages from their writing etc.) – and acrimonious exchanges on priorities in scientific discoveries would be unheard of.

## The sublime

Srinivasa Ramanujan (1887–1920), hailed as an all-time great mathematician, like Euler, Gauss or Jacobi, for his natural genius, has left behind 4000 original theorems, despite his lack of formal education and a short life-span (of 32 years, 4 months and 4 days). In his formative years, after having failed in his First examination in Arts (F. A.), Ramanujan ran from pillar to post in search of a benefactor. It is during this period, 1903–1914, that he kept a record of the final results of his original research work in the form of entries in two large-sized note books. These were the ones which he showed to everyone who mattered and eventually convinced them of his abilities as a mathematician. The orchestrated efforts of his admirers, culminated in the encouragement he received from G. H. Hardy of Trinity College, Cambridge, whose warm response to the historic letter of Ramanujan which contained about 100 theorems, resulted in inducing the Madras University, to rise to the occasion thrice – first in offering him a research scholarship in May 1913; then in offering him a scholarship and financial support to go to England in 1914; and

[1]Based on a lecture given on 29th July 1995, in the Seminar on Value Education, conducted by the Hindu Senior Secondary School, Madras 600 020.

finally, by granting him an allowance, in April 1919, soon after his triumphant return from Cambridge 'with a scientific standing and reputation such as no Indian has enjoyed before'.

That science is truly international and knows no boundaries is well exemplified in the case of Ramanujan: he was awarded in 1916 the B.A. degree by research of the Cambridge University; was elected a Fellow of the Royal Society of London in February 1918; was elected to a Trinity College Fellowship, in October 1918; the *Collected Papers of Ramanujan* were edited by G. H. Hardy, P. V. Seshu Aiyer and B. M. Wilson and published by Cambridge University Press in 1927; his 'Lost' Notebook was discovered in 1976 by George Andrews; his bust, sculpted by Paul Granlund, was commissioned by R. Askey, S. Chandrasekhar, G. E. Andrews, Bruce C. Berndt and more than one hundred scientists; his Note Books were edited in a series of five volumes by Bruce C. Berndt[4], devoting attention to each of the three to four thousand theorems; and Robert Kanigel was commissioned to write a delightfully readable biography entitled[5], *The Man Who Knew Infinity: A Life of the Genius Ramanujan*.

The integrity of Ramanujan is transparent from the following statement of Hardy: All of Ramanujan's manuscripts passed through my hands, and I edited them very carefully for publication. The earlier ones I wrote completely. I had no share of any kind in the results, except of course when I was actually a collaborator, or when explicit acknowledgement was made. Ramanujan was almost absurdly scrupulous in his desire to acknowledge the slightest help. During his five year stay in Cambridge, he published 21 papers, five of which were in collaboration with Hardy. Though Ramanujan took his Notebooks with him, he had no time to delve deep into them. He was ailing after about two years' stay in England and in India after his return from England (March 1919 – April 26, 1920) but he never wrote to Hardy about his illness. The only letter he wrote to Hardy, from India, after his return, in January 1920, contained information about his latest work: 'I discovered very interesting functions recently which I call "Mock" theta-functions. Unlike the "false" theta-functions (studied partially by Rogers in his interesting paper) they enter into mathematics as beautifully as ordinary theta-functions. I am sending you with this letter some examples ...'. The 600 theorems he jotted down on loose sheets of papers, during his 'deathly ill' period in India, are the contents of the 'Lost' Notebook. Richard Askey observes: 'Try to imagine the quality of Ramanujan's mind, one which drove him to work unceasingly while deathly ill, and one great enough to grow deeper while his body became weaker. I stand in awe of his accomplishments; understanding is beyond me. We would admire any mathematician whose life's work was half of what Ramanujan found in the last year of his life while he was dying.'

Arnold Sommerfeld who headed a Dynasty of Nobel Prize winners visited the Presidency College, Madras, in 1928. His lecture on the new physics (Quantum Mechanics) and Fermi–Dirac statistics was an eye-opener for young S. Chandrasekhar who was then a teenaged student. Two years later, on his passage to Cambridge, Chandrasekhar started working on what happens to a star in the final stages of its evolution. Fowler assumed the core of a star to be a non-relativistic, degenerate Fermi (electron) gas and that white dwarf stars – viz. stars in which the thermonuclear reactions had ceased became faint planet-sized remnants known as white dwarfs – did not collapse due to the (outward) degeneracy pressure of the electrons. Chandrasekhar studied this problem in great detail, taking relativistic effects into account and from the equation of state for a relativistic degenerate Fermi (electron) gas, he derived the dramatic result that stars with a mass greater than 1.44 times the solar mass, would eventually collapse past the white dwarf stage into an object of enormous density and speculated the existence of extremely dense neutron stars and black holes, discovered many years later. This limiting mass (1.44 times the solar mass) is called the Chandrasekhar limit today.

Chandrasekhar's confidence however had to confront the established authority of Arthur Eddington. (See, the biography of *Chandra* by Kameshwar Wali[6] and the extremely well-written book for the physics student: *Chandrasekhar and his Limit* by G. Venkataraman[7].) When Chandrasekhar wanted to present his results before the Royal Astronomical Society in London, Eddington arranged for a 30-min presentation, instead of the customary 15 min, on January 11, 1915 but scheduled for himself a talk too. After Chandrasekhar's presentation, Eddington opined that 'there should be a law of Nature to prevent a star from behaving in this absurd way'. He literally tore Chandrasekhar's work to shreds with jokes and rhetoric and ridiculed the result. Soon, Chandrasekhar's work was appreciated by his peers – Niels Bohr, Pauli, Fowler, Wilson and Rosenfeld. Chandrasekhar took a decision to ignore the raging controversy after writing a book on the subject. In his book *An Introduction to the Study of Stellar Structure* (1939), he asserts: 'Since the theory is a straightforward consequence of the quantum mechanics and, further, uses Dirac's theory of the electron only in that phase of its application which has been confirmed by laboratory experiments (Klein–Nishina formula, production 'of cosmic ray showers, etc.), there can be little doubt that it is essentially correct.'

In 1939, at a Paris Conference on White Dwarfs and Supernovae, Chandrasekhar got an opportunity to state openly that Eddington was wrong. This historical controversy hindered the progress of research on neutron stars and the collapse of stars for 3 to 4 decades. By the 1950s hundreds of white dwarf stars whose measured masses fall neatly on the now famous Mass–Radius relationship curve predicted by him were observed. No white dwarf star has been found with a mass greater than 1.44 times the solar mass. In October 1982, on the occasion of Eddington's birth centenary, Chandrasekhar was invited by the Cambridge University to deliver a series of lectures. In two lectures[8] which are great classic masterpieces, Chandrasekhar shows how a scientist can be totally objective in his assessment of the scientific works of Eddington – the astrophysicist who could be considered Chandrasekhar's greatest scientific 'adversary'. There was never any rancour between Eddington and Chandrasekhar despite the controversy! Eventually, Chandrasekhar was awarded the Nobel Prize in Physics in 1983 (along with William A. Fowler), more than 50 years after his discovery, and the announcement was made on 19 October 1983, his 73rd birthday (coincidentally?!).

The third example I wish to present is the one regarding priorities. Robert E. Marshak visited India, in 1953, and a young student prepared the Notes for his lectures at the Tata Institute of Fundamental Research, Bombay. Impressed not only by the notes but by the mastery over tensor analysis of E. C. George Sudarshan, Marshak took him to Rochester University and suggested to him the study of weak interactions. A careful, systematic analysis of the experimental data led Sudarshan to propose the Universal (V-A) theory of weak interactions[9] and boldly suggest that four of the experiments, from reputed centers, be repeated since they did not conform to his theory.

Marshak had already established the tradition of the Rochester (High Energy Physics) Conferences – important annual international meetings of physicists. In 1957, due to his commitment not to use the (Seventh) Rochester Conference as a platform, to project the work of himself and his group and considering his work on two nucleon interaction using the Signell–Marshak potential deserved the pride of place, he relegated the work on weak interactions to the background. A few months later, when Marshak was Consultant to the Rand Corporation in California, he invited Sudarshan to a luncheon meeting with Murray Gell-Mann. At that meeting, Sudarshan explained to Gell-Mann their detailed analysis of the V-A theory of weak interactions. Subsequently, Gell-Mann contacted Richard Feynman, then in Brazil, by ham radio and together they worked out the two-component Klein–Gordon derivation of the theory of weak interactions and sent it to the *Physical Review* for publication. Meanwhile, at a Conference in Padua–Venice, in Italy, Marshak presented their work on V-A theory. Once again, due to the high standards and values in science to which Marshak conformed, he did not think it appropriate to publish the work in a regular journal also. However, due to peer pressure, Sudarshan and Marshak submitted a short note to the *Physical Review* on 'Chirality Invariance and the Universal Fermi Interaction'. Unfortunately, it was treated by most physicists as the sole publication of Sudarshan and Marshak on their V-A theory. While this appeared in the *Physical Review* (1958, **109**, 1860–1862) the Feynman and Gell–Mann paper entitled, 'Theory of the Fermi Interaction', appeared ahead in the same volume on pp. 193–198. Recognition came to Sudarshan for his role in this masterpiece of creative research work, when the four experimental groups re-did their experiments and one-by-one came up with corrected results which confirmed the V-A theory. However, the question of priority of the discovery remained unsettled.

In the 1974 Neutrino Conference, Feynman said: 'We have a conventional theory of weak interactions invented by Marshak and Sudarshan, published by Feynman and Gell-Mann, and completed by Cabbibo. I call it the conventional theory of weak interactions the one which is described "as the V-A theory". Both Marshak and Sudarshan grew in stature and won many awards and had distinguished academic careers. On the occasion of the 60th birthday celebrations of George Sudarshan, at the University of Texas at Austin, in October 1991, Marshak gave a lecture entitled, 'The Pain and Joy of a Major Scientific Discovery'. In it, he delineated and placed in proper perspective the work of his with Sudarshan and regarding the three instances detailed above, he had the courage to say: 'Well, George I have recounted the three "cardinal blunders" that your well-intentioned professor committed in the aftermath of your fundamental scientific discovery. I do express my deep regrets for the pain caused by these decisions on my part during the hectic year 1957–58. I sincerely hope that the recital of these miscalculations on the occasion your 60th birthday (16 September 1991) celebration and your forgiveness of them, will purge your soul (and mine) of the pain associated with the V-A theory and enable you to remember with undiluted joy the triumphs of the V-A theory.' Anyone would recognize this disclosure by Marshak as an act which befits a Mahatma!

So far, I have dealt with three instances to illustrate that a passionate love of the subject transcends all hardships; that mathematical 'beauty is truth and truth beauty' and its pursuit will lead to 'triumph' in the end; and that many lessons can be learnt from great scientists regarding integrity and the values which ought to be upheld, transcending petty jealousies and distortions, which abound in our world.

## The ridiculous

While one need not be cautious about praise for the sublime, it is not possible to throw caution to the winds in talking about those who perpetrate the ridiculous, for fear that to uphold their (lack of) 'integrity' they will go to any extent, revel in rhetoric and jejune polemics and drag the honest into the quagmire of litigation. So, let me put to practice extreme caution in the use of language to describe a few examples of the ridiculous.

First we revert to the story of Ramanujan: G. H. Hardy, in 1923 edited Chapter XII of Ramanujan's second Notebook on Hypergeometric series which contained 47 main theorems, many of them followed by a number of corollaries and particular cases. This work had taken him 3–4 months and he felt that if he were to edit the entire Notebooks 'it will take the whole of my lifetime. I cannot do my own work. This would not be proper.' He urged Indian authorities and G. N. Watson and B. M. Wilson to edit the Notebooks. Unfortunately, the premature death of Wilson, in 1935, at the age of 38, aborted this effort. In 1957, the Tata Institute of Fundamental Research published a facsimile edition of the Notebooks of Ramanujan in two volumes, with just an introductory para about them. The formidable task of truly editing the Notebooks was taken up by Bruce C. Berndt of the University of Illinois and his dedicated efforts, since May 1977, has resulted in the *Ramanujan Notebooks: Part I–V* published by Springer-Verlag (1985 onwards, see ref. 4). The questions which ought to strike us are: Why has no concerted effort been made in India to edit the Notebooks of Srinivasa Ramanujan? Why even a bust of Ramanujan was not commissioned (till 1992, in India)? Why there does not exist, *even today*, a fitting memorial (like a National Science Museum) to house his Notebooks, the large-sized slate used by him, his letters and other memorabilia? Is this how we honour one acclaimed as the greatest mathematician of India? Contrast this with what we have done for many of our politicians and communal leaders for their 'achievements'!

Paul Dirac chose for the title of his lecture, in Moscow, in 1955: 'Physical laws should have mathematical beauty'. A professor of physics at an IIT, often asserted that he could teach physics without resorting to any mathematics!

Some international journals have several Associate Editors, each one a specialist belonging to a branch/area of importance to the journal. The contributors are directed to send their research papers to the concerned (Associate) Editor who is expected to referee the paper and communicate it, if found suitable, for publication. As an Editor of the *Astrophysical Journal*, S. Chandrasekhar refereed thousands of papers but seldom chose this journal for publishing his own research work. Contrast this with cases in our country where the responsibility of an Associate Editorship of an international journal is often used only to communicate ones own papers.

Sometimes, editors of our journals take up considerable space with their own papers. A few favoured authors are also the ones whose articles get published regularly. Ironically, an editor as the main speaker on Scientific Values in Education and Research in Science, at a Seminar[3], states: 'Even journals are being controlled by power groups so that sometimes even for getting your paper published, your must find favour with some power group.'!

Finally, I would like to touch upon the question of internal assessments, particularly of the teachers. In the American Universities, a salary raise or a promotion is not automatic but is merit-oriented. The teacher evaluation by the students, in vogue in those Universities, provides an important input to assess the merit of the teacher. In our country, even after almost five decades of independence, it is only in the IITs that such teacher evaluation by the students is implemented. However, there are some who try to influence this procedure by devious and coercive methods. The worst incident, reported in a campus newspaper, revealed the case of a head of a Department, who coming to know of the negative assessments of his performance by his students, made the students re-do the questionnaires and sneaked them in place of the originals! Taking note of the exposure in the campus newspaper, the Director ordered enquires to be made by the heads of Departments. The offender also convened a meeting and none of his colleagues had the courage to confront him with the truth. The meeting, like all others, ended with a resolution condemning the act and urging that no stone be unturned to find the culprit!

1. *Universal Dictionary of the English Language*, Wordsworth Edition, 1989.
2. Opening Remarks, A. S. Paintal, ref. 4 below.
3. *Scientific Values and Excellence in Science*, Proceedings of a Seminar held at the Indian National Science Academy, New Delhi, on April 18, 1989 and published by the Society for Scientific Values, New Delhi, 1990.
4. *Ramanujan Notebooks: Parts I–V*, Bruce C. Berndt, Springer-Verlag, 1985, 1989, 1991, 1994 and to appear.
5. *The Man Who Knew Infinity: A Life of the Genius Ramanujan*, Robert Kanigel, Scribners, 1991, Indian paperback edition, Rupa and Co., 1993.
6. *Chandra*, Kameshwar Wali, Penguin Books India, New Delhi, 1990.
7. *Chandrasekhar and his Limit*, G. Venkataraman, University Press, 1992.
8. Arthur Stanley Eddington Centenary lectures: 'Eddington: The Most Distinguished Astrophysicist of His Time'; and 'Eddington: The Expositor and the Exponent of General Relativity', by S. Chandrasekhar. These are reprinted in Chapter 6 of *Truth and Beauty*, S. Chandrasekhar, Penguin Books, 1987, on pages 93 and 110, respectively.
9. Thanks to S. Ramaseshan in an issue of *Curr. Sci.*, 1992, vol. 63, all the articles regarding this heart-warming episode are reprinted – viz. the lecture of R. E. Marshak on the occasion of Sudarshan's 60th Birthday, the original Padua-Venice conference paper of Sudarshan and Marshak, as well as their note in the *Physical Review*, and the paper of Feynman and Gell-Mann.

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