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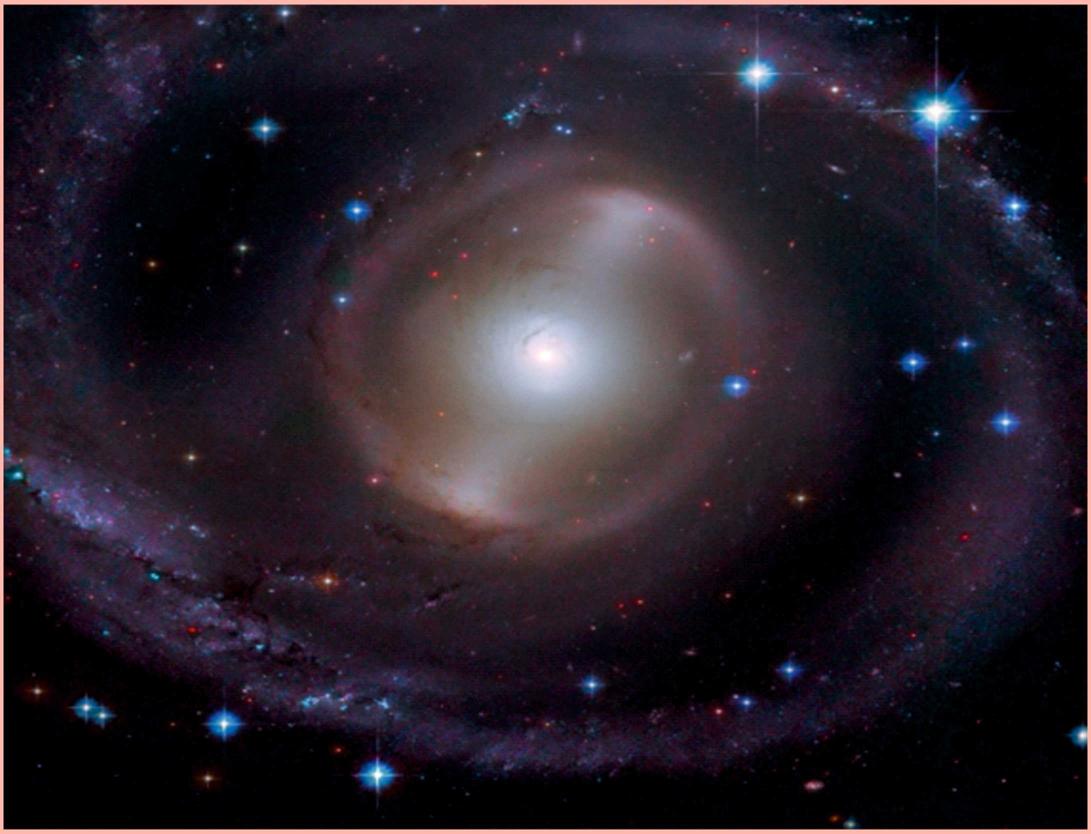

The magnificent central bar of NGC 2217 (also known as AM 0619-271) shines bright in the constellation of Canis Major (The Greater Dog), in this image taken by the NASA/ESA Hubble Space Telescope. Roughly 65 million light-years from Earth, this barred spiral galaxy is a similar size to our Milky Way at 100,000 light-years across. Many stars are concentrated in its central region forming the luminous bar, surrounded by a set of tightly wound spiral arms.

The central bar in these types of galaxies plays an important role in their evolution, helping to funnel gas from the disk into the middle of the galaxy. The transported gas and dust are then either formed into new stars or fed to the supermassive black hole at the galaxy's center. Weighing from a few hundred to over a billion times the mass of our Sun, supermassive black holes are present in almost all large galaxies.

This image was colorized with data from the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS).

Link: https://www.nasa.gov/image-article/hubble-spots-a-magnificent-barred-galaxy/

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The Bulletin is the official organ of the IAPT. It is a monthly journal devoted to upgrading physics education at all levels through dissemination of didactical information of physics and related areas. Further, the Bulletin also highlights information about the activities of IAPT.

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Editorial

India as a Science Powerhouse

"India will not be able to achieve 10-12 percent economic growth, if we don't do our own science and produce our own technologies". This statement was given by Dr. Ajay Kumar Sood, Principal Scientific Advisor of the Indian Government, in his recent interview with the Indian Express. He further added that India had missed the bus on certain critical technologies in the past and must not allow that situation to repeat in areas like **artificial intelligence, quantum technologies, clean energy solutions or semiconductors.**

Echoing this sentiment, a recent editorial in the esteemed journal **'Nature'**, dated April 18, 2024, asserts India's ascent as the world's fifth-largest economy and predicts its trajectory towards becoming the third-largest economy, trailing only behind China and the United States. Along with being an economic power, India is also ready to take the next step towards becoming a **Science Powerhouse**. Notably, from 2014 to 2021, India witnessed the establishment of 353 new universities, 7 new Indian Institutes of Technology (IITs), and 2 new Indian Institutes of Science Education and Research (IISERs). Remarkably, this was achieved with a modest investment of just 0.64% of GDP allocated to research and development in 2020-21, however China allocated 2.4% of its GDP to R&D in 2021. Furthermore, India relies heavily on government funding with only around 40% coming from the private sector as compared to the Organisation for Economic Co-operation and Development (OECD) nations where the private sector contributes 74% to research expenditure.

The Indian parliament recently approved the establishment of the **Anusandhan National Research Foundation (ANRF)**, with a mandate to disburse 500 billion rupees over five years, to the universities and laboratories, with **70% of its funding sourced from non-government channels.**

Now what should be the role of IAPT in the context of above scenario?

The organization like the Indian Association of Physics Teachers (IAPT) with nearly 10,000 dedicated members, has been at the forefront of promoting science and physics learning/teaching for more than 40 years. The month of April 2024 marked a significant milestone for IAPT, with a series of high-quality workshops and webinars covering cutting-edge topics such as artificial intelligence and quantum computing. It indicates that we are moving in the right direction and of course higher impetus is needed.

Regarding the financial aspect, the recent success in crowd funding for the International Young Physicists' Tournament (INYPT) serves as a testament to the community's willingness to support scientific endeavours.

Furthermore, avenues for major financial support from various organizations must be actively pursued. Continuous efforts and rigorous analysis are imperative to ensure that IAPT remains on the course towards its goals with unwavering momentum.

Sanjay Kr Sharma

PHYSICS NEWS

Large Hadron Collider experiment zeroes in on magnetic monopoles

At the LHC, pairs of magnetic monopoles could be produced in interactions between protons or heavy ions. In collisions between protons, they could be formed from a single virtual photon or the fusion of two virtual photons. Pairs of magnetic monopoles could also be produced from the vacuum in the enormous magnetic fields created in near-miss heavy-ion collisions, through a process called the Schwinger mechanism. In their latest scanning of the trapping volumes, the MoEDAL team found no magnetic monopoles or HECOs, but it set bounds on the mass and production rate of these particles for different values of particle spin, an intrinsic form of angular momentum. The MoEDAL detector will soon be joined by the MoEDAL Apparatus for Penetrating Particles, MAPP for short, which will allow the experiment to cast an even broader net in the search for new particles.

Read more at: https://phys.org/news/2024-04-large-hadron-collider-zeroes-magnetic.html

Original paper: arxiv (2023). DOI: 10.48550/arxiv.2311.06509

First experimental proof for brain-like computer with water and salt

Theoretical physicists at Utrecht University, together with experimental physicists at Sogang University in South Korea, have succeeded in building an artificial synapse. This synapse works with water and salt and provides the first evidence that a system using the same medium as our brains can process complex information. In the pursuit of enhancing the energy efficiency of conventional computers, scientists have long turned to the human brain for inspiration. They aim to emulate its extraordinary capacity in various ways. These efforts have led to the development of brain-like computers, which diverge from traditional binary processing to embrace analog methods akin to our brains. Kamsma underscores the fundamental nature of the research, highlighting that iontronic neuromorphic computing, while experiencing rapid growth, is still in its infancy. The envisioned outcome is a computer system vastly superior in efficiency and energy consumption compared to present-day technology. It represents a crucial advancement toward computers not only capable of mimicking the communication patterns of the human brain but also utilizing the same medium.

Read more at: https://phys.org/news/2024-03-scientists-evidence-quantum-gravity-south.html

Original paper: Nature Physics (2024) DOI: 10.1038/s41567-024-02436-w

Saving memory in the Quantum World using Drum

The data have been sent using light in its Sonic Vibration and could rewind it when required again.Memory based on the Optomechanically induced that achieve long storage time leveraging the ultralow dissipation on soft damped mechanical membrane like Drum.The quantum drum made of ceramic ,glass like material with holes placed in an ordered manner .There have been an Auxillary laser , used to maintain the sensitivity of drum ,the quantum data from a quantum computer is emitted as light signal and they are transmitted to the Drum .It can store optical quantum memories by storing optical information in photonic mode and the future network of quatum computer can be enhanced.

Read more at: http://nbi.ku.dk/english/news/news24/internet-can-achieve-quantum-speed-with-light-saved-as sound/

Original paper: Physical Review Letters (2024) DOI:10.1103/PhysRevLett.132.100802

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Revisiting the Saha Equation

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Abstract

This paper revisits the Saha equation which has had a profound influence on our understanding of stellar universe.

I. Saha before his equation

In the early twentieth century, the Calcutta School of Physics was blooming. Meghnad Saha came to Calcutta (now Kolkata) after attending school in Dhaka. The becoming of the Indian school of physics is credited to the work that happened in Calcutta in the first part of the twentieth century. Sir Ashutosh Mukherjee became the Vice-Chancellor, succeeding Sir Nilratan Sarkar, who was among the founding fathers of the Science College of the University of Calcutta. The Indian Association for the Cultivation of Science was holding the reigns of Western science in India.

The historian Gyan Prakash [1] has argued that even though colonial science came to India as a cultural civilizational mission and to establish European supremacy, as Western science propagated in India, the more it proved counterproductive for the colonial masters. The colonial science, he argues, was turned against the colonizer by the Indian elite, who used this knowledge to counter British imperialism. Amid the upcoming nationalist science, Saha joined the Presidency College in 1911, where Satyendra Nath Bose and Nikhil Ranjan Sen were his classmates. Bose became the famous proponent of Bose-Einstein statistics, and Nikhil Ranjan Sen, a mathematician, founded the school of applied mathematics in India and popularised science in the vernacular language. Lesser known in the popular discourse, Sen also did pioneering work on stellar interiors. The statistician who established the Indian Statistical Institute, Prasanta Chandra Mahalanobis was Saha's senior, and the freedom movement leader Subhash Chandra Bose was his junior [2,3].

In 1913, Sir Asutosh Mukherjee asked Paul Johannes Brühl to join Calcutta University. German-born botanist, Brühl, was at the Indian Institute of Science in Bangalore at the time and had switched to physics because of his fragile health. Bose and Saha became acquainted with Brühl, who generously gave advanced texts in physics of the time, including some by Max Planck but in German. Saha knew German well; however, Bose did not. Bose enrolled in German language classes to overcome this limitation.

The beginning of Saha and Bose's journey thus has the same point of origin. While working on these texts, Saha and Bose divided specialized topics for the convenience of their individual focus. Bose chose electromagnetism and relativity, while Saha took statistical mechanics and thermodynamics. Destiny had it, and they made fundamental and paradigm-shifting contributions in the fields from which they began their inquiry. Bose's first research paper *The Influence of the Finite Volume of Molecules on the Equation of State* [4] was co-authored with Saha. For the benefit of their colleagues and students, Saha and Bose also translated Einstein's book on the theory of relativity from German to English (published by the University of Calcutta), which became the first English version of Einstein's magnum opus. In 1916, Sir Ashutosh Mukherjee restructured the University of Calcutta to become a teaching institution from an affiliating one. Since science was taught in very few colleges at that time, he decided to establish a University College of Science, for which Sir Rash Behari Ghose and Sir Tarak Nath Palit came forward. While this was happening, the Physics Department was facing a crisis. Debendra Mohan Bose, who was the Ghosh Professor of Physics at the University, had gone to Germany for advanced research. The First World War broke out, and Debendra was stuck in Germany for a while. Back home, Mukherjee instilled his faith in organizing the department in Meghnad Saha, Satyendra Nath Bose, Sisir Kumar Mitra (who later contributed to radio and atmospheric physics), and a few others. A year before Debendra Mohan Bose's return from Germany in 1918, Chandrashekhar Venkata Raman (who was then working at the Financial Department of the Government of India and was an honorary associate of the Indian Association for the Cultivation of Science) was appointed the Palit Professor of Physics by Ashutosh Mukherjee. The department was organized in such a seamless and meticulous fashion by Saha and his associates that when Raman joined, the department was functioning smoothly [3].

Einstein received much skepticism from many of his European colleagues on his proposition of the light-quantum hypothesis to account for the photoelectric effect. This work, nonetheless, gave credibility to Planck’s hypothesis of the quantum of electromagnetic radiation. Planck himself, among many others, however, thought of it only as a tentative argument that seemed to work and hoped for a better model to be developed. In India, upon finding the relation fascinating, Saha and Bose began working on it. Two years after Einstein's proposition, Bose postulated intriguing and revolutionary conclusions that light-quantum carried directed momentum, while Saha used it to explain the molecular radiation pressure in 1919 [5]. Planck’s hypothesis received vital support not only from (a) Einstein’s interpretation of the photoelectric effect, which employed light quanta but also from (b) the statistical analysis by Bose, which provided the distribution function in the electromagnetic field. It is well-known that Planck, by his own admission, had introduced the quantum of action only as an *act of desperation,* only to somehow find a curve that fits the black-body intensity distribution curve; he did not quite believe in energy quantization. The photon, in fact, acquired its comprehensive meaning not only after Einstein’s interpretation of the photoelectric effect but Bose’s recognition of photon as a fundamental quantum particle with integer spin. The much-celebrated quantum of action, ‘h’, *therefore*, is best called the PEB constant (for Planck-Einstein-Bose) rather than just Planck’s constant. It cannot be overstated that Saha, Bose, and Raman were among the most significant contributors from the Indian scientific community to the first quantum revolution.

II. Saha and the Equation:

In his 1919 paper [6], Saha, upon investigating theoretical requirements for astrophysics, proposed the existence of radiation pressure on atoms/molecules within the quantum theoretical framework. Saha's model consisted of the supposition of localization of '*pulses of light*' instead of the continuous theory of light. Here, he stated that when this *pulse* encounters a molecule, it gets absorbed, thereby imparting to the molecule an impulse of the order of $h\nu/c$. Modeling this as an inelastic collision, Saha estimated the velocity of the molecule to be of the order of $h\nu/mc$, m being the mass of the molecule in this equation. Based on these arguments, Saha calculated that for the absorption of a pulse of hydrogen light corresponding to the H_α line by a hydrogen atom. The velocity turned out to be 60 cm/s. This value is too small to describe the radiation pressure observed in experiments. Saha argued that "the total velocity acquired by a hydrogen atom per second will depend on the number of kicks of light it experiences per second, and provided this is sufficiently great, the velocity acquired may rise to enormous values." [6]

Saha, in the conclusion of this paper, stated that "radiation-pressure may exert an effect on the atoms and molecules which are out of all proportions to their actual sizes." This elucidation that light quanta had a directed momentum $h\nu/c$ was perhaps the first application of Einstein's hypothesis of a quantum of light. It provided the quantum alternative to Poynting's theorem to estimate the radiation pressure.

In 1924, Bose proposed that "the problem of thermodynamic equilibrium of radiation in the presence of material particles can, however, be studied using the methods of statistical mechanics, independently of any special assumption about the mechanism of the elementary processes on which the energy exchange depends." [7] While working on his statistical model, Bose, before dwelling on the intricacies of the probability distribution, had to first determine the number of states of light-quantum in an infinitesimal frequency range. While extending Planck's quantum theory of electromagnetic radiation, he relied on Saha's pioneering work on radiation pressure. The brilliance of Saha found no guide, so he became his own research advisor. If one studies Saha's early papers in the period 1917-1919, one finds that in these two years, he was figuring his interest before striking a genius on his *magnum opus* - the ionization equation. While he was traversing through several key ideas of his time, he primarily concerned himself with the study of astrophysics when he was simultaneously teaching thermodynamics and spectroscopy graduate courses.

As mentioned earlier, 1919 was his breakthrough year in which he reported his works on the theory of radiation pressure. Towards the end of 1919, he came across John Eggert's paper [8] *Uber den Dissoziationzustand der fixsterngase*. Eggert, in his argument, explained that at higher temperatures, high ionization would occur, but he failed to account for the atomic ionization potential. It was a lost piece of the puzzle that Saha eventually discovered by recognizing the importance of introducing ionization potential value in Eggert's formulation. The extension of this work resulted in the famous *Saha's Equation*. [9]

Saha's *annus mirabilis* was 1920. Between March and May 1920, he wrote four pioneering papers: '*Ionization in the Solar Chromosphere'* [10], '*On Elements in the Sun*' [11], '*On the Problems of Temperature-Radiation of Gases*' [12], and ' *On a Physical Theory of Stellar Spectra* ' [13]. Saha had developed the theoretical models and was determined to test them in experiments.

Meghnad Saha's felicitation at University College of Science & Technology, Calcutta, on the eve of his departure for England (1920). From left to right: Standing – H. Mitra, G. Datta, D. D. Banerji, S. K. Mitra, S. K. Acharya, A. C. Saha, A. N. Mukherjee, B. B. Ray. Sitting – S. N. Bose, P. N. Ghosh, C. V. Raman, M. N. Saha, D. M. Bose, B. N. Chakravarti, J. C. Mukherjee. [9]. Photograph included with the kind permission of the Saha Institute of Nucelar Physics (SINP), Kolkata.

Upon getting the Premchand Roychand Studentship, Saha sailed for England in September 1920. Snehamoy Datta, his classmate from Calcutta was in London where Saha met him. Datta advised Saha that he should meet Alfred Fowler, a professor of astrophysics at the Imperial College, London. Fowler allowed Saha to work in his laboratory. The same year, Saha's paper *Ionization in the Solar Chromosphere* [10] appeared in the *Philosophical Magazine* after which Fowler became keenly interested in Saha's work.

Saha took his paper *On the Harvard Classification of Stars* to discuss with Fowler. He suggested to Saha that he must read the works of Norman Lockyer and his students. He also provided Saha with his own work. Fowler had done breakthrough work in spectroscopy and was the first to determine the temperature difference between the sunspots and their surroundings. Saha observed, "*I took about four months in rewriting this paper, and all the time I had the advantage of Professor Fowler's criticism, and access to his unrivalled stock of knowledge of spectroscopy and astrophysics. Though the main ideas and working of the paper remained unchanged, the substance matter was greatly improved on account of Fowler's kindness in placing at my disposal fresh data and offering criticism whenever I went a little astray of mere enthusiasm.*" [14] The title of the paper was changed to '*On a Physical Theory of Stellar Spectra*' [13] upon suggestion from Fowler, who then communicated it to the Royal Society.

III. Importance of the Saha equation in Astro-spectroscopy

In Astrophysics, Maghnad Saha contributed a '*durchburch*' (quantum leap) in 1920 when he developed the theory of thermal ionization in the stellar atmosphere. The genius of Saha lay in recognizing the presence of ionized atoms in the atmosphere of a star and applying chemical kinetics and thermo – dynamics in describing the ionization process. At very high temperatures, the atomic collision rates are considerably high, hence the number of high-energy collisions. Therefore, atoms could get excited, or the valence electrons may break free from the atoms to leave them ionized. These are like reversible reactions; the atomic gas seeks a dynamic equilibrium. To appreciate this process, we consider a monoatomic gas in a state of weakly ionized plasma such that its Debye length, λ_D (distance up to which electrostatic potential of a charge is felt beyond screening effect) given by $\sqrt{\varepsilon_0 k_B T/n_0 e^2}$ is large so that Coulomb interactions between the electrons and the ions can be ignored. In this expression, ε_0 is the electric permittivity of free space, e is an electron's charge, k_B is the Boltzman constant, T is the absolute temperature of the gas, and n_0 is the equilibrium density of the plasma electrons. In this article, we follow the approach of Ralph Howard Fowler [15] to derive Saha's equation. Similar treatments can also be found in the textbooks of L. H. Aller [16] and V. B. Bhatia [17]. An alternative approach to arrive at Saha's equation based on the transition state theory can be found in a recent article by Sushanta Dattagupta [18], which provides an improvised determination of the ionization formula by considering the ionization of sodium in a stellar atmosphere. In this approach, the dynamics of the ionization and electron capture processes during the system's evolution are taken into account, and the ionization equation is arrived at in an asymptotic limit. Below, we provide a simplified derivation of Saha's ionization equation in a manner similar to what was originally adopted by Saha himself [10]. We discuss a refinement of Saha's equation by including the degeneracy of the quantum states [15] in order to determine the ionization fraction of elements in a stellar atmosphere. Also, we discuss the importance of using this phenomenal equation together with the Boltzmann equation to learn more about the composition of stellar systems.

For a chemical reaction under constant volume and temperature, the condition of chemical equilibrium is

$$\sum_i \mu_i \epsilon_i = 0 \tag{1}$$

where μ_i is the chemical potential and ϵ_i is the stoichiometric coefficient of the i^{th} reactant. We shall now use a variable η, as

$$\eta = \frac{\mu}{k_B T} \tag{2}$$

wherein k_B is the Boltzmann constant, and μ the chemical potential.

From Eq. (1),

$$\sum_i \eta_i \epsilon_i = 0 \tag{3a}$$

Now, let us consider an ionization equilibrium between r^{th} and $(r+1)^{th}$ states of ionization $X_r \leftrightarrow X_{r+1} + e^-$, where X_r represents an ion in the r^{th} state of ionization and e^- an electron. Therefore,

$$\eta_{X_r} \times (-1) + \eta_{X_{r+1}} \times (+1) + \eta_{e^-} \times (+1) = 0 \tag{3b}$$

or

$$\eta_{X_r} = \eta_{X_{r+1}} + \eta_{e^-} \tag{3c}$$

The density of the reactant particles per unit volume having momentum between p and $p + dp$ is

$$dn(p) = g\left(\frac{4\pi p^2}{h^3}\right) e^{-\beta(E-\mu)}\, dp \tag{4}$$

where β represents $(k_B T)^{-1}$, g is statistical weight, h is the PEB constant, and E is the energy.

Considering the particles to be non-relativistic, the kinetic energy E_e of the electrons is $p_e^2/2m_e$ and the energy of X_r is

$$E_{r,i} = \frac{p_{r,i}^2}{2m_r} + \chi_{r,i} \tag{5a}$$

and that of X_{r+1} is

$$E_{r+1,j} = \frac{p_{r+1,j}^2}{2m_{r+1}} + \chi_{r+1,j} + I_r \tag{5b}$$

where $\chi_{r,i}$ and $\chi_{r+1,j}$ respectively represent the excitation potentials from r times ionized atom to i^{th} level and from $r+1$ times ionized atom to j^{th} level and I_r is the ionization potential of the r times ionized atom.

Accordingly, using Eqs (4) and (5a), we recognize the number density of r times ionized atoms to be

$$n_r = \sum_i \int_{p_{r,i}=0}^{p_{r,i}=\infty} dn(p_{r,i}) = \sum_i g_{r,i}\, e^{-\beta\chi_{r,i}} e^{\beta\mu_r} \int_{p_{r,i}=0}^{p_{r,i}=\infty} \left(\frac{4\pi}{h^3}\right) p_{r,i}^2\, e^{-\frac{\beta p_{r,i}^2}{2m_r}} dp_{r,i} \tag{6}$$

where m_r is the mass of the r times ionized atom.

Defining $\beta p_{r,i}^2/2m_r = x$ and $\beta\mu_r = \eta_r$, one obtains

$$n_r = \left(\frac{2m_r\pi k_B T}{h^2}\right)^{3/2} e^{\eta_r} \sum_i g_{r,i}\, e^{-\beta\chi_{r,i}} \tag{7}$$

where we used the properties of the Gamma function:

$$\int_0^\infty x^{3/2-1}\, e^{-x} dx = \Gamma\left(\frac{3}{2}\right) = \frac{\sqrt{\pi}}{2} \tag{8}$$

Eq. (7) can be written as

$$n_r = B_r(T) e^{\eta_r} \left(\frac{2\pi m_r k_B T}{h^2}\right)^{3/2} \tag{9a}$$

where

$$B_r(T) = \sum_i g_{r,i}\, e^{-\beta\chi_{r,i}} \tag{9b}$$

is called the *partition function*, g's represent the statistical weights and χ's are the excitation potentials.

Similarly, using Eqs (4) and (5b), we find the number density of $r+1$ times ionized particles to be

$$n_{r+1} = B_{r+1}(T) e^{\eta_{r+1}} \left(\frac{2\pi m_{r+1} k_B T}{h^2}\right)^{3/2} e^{-I_r/k_B T} \tag{10}$$

Dividing Eq. (10) by (9a) and multiplying n_e, we get,

$$\frac{n_{r+1} n_e}{n_r} = n_e\, e^{-\eta_e -} \frac{B_{r+1}(T)}{B_r(T)} \left(\frac{m_{r+1}}{m_r}\right)^{3/2} e^{-I_r/k_B T} \tag{11}$$

In the case of Bosons (particles of integer spin) and Fermions (particles having half-integer spin), the distribution of particles between energy E and $E + dE$ (or, equivalently, with momentum between p and $p + dp$) per unit volume is given by

$$dn = \frac{dg}{e^{\beta(E-\mu)} \pm 1} \tag{12a}$$

where '$-$' sign is for Bosons and '$+$' for Fermions, and the expression for dg, the statistical weight is

$$dg = g\frac{4\pi p^2}{h^3}dp \tag{12b}$$

where g is the statistical weight of internal states.

In the case of free fermionic particles, particularly electrons in non-degenerate states characterized by *degeneracy parameter*, $\Theta = k_BT/\mu \gg 1$, we shall have from Eqs (12a) and (12b) (since the smallest value possible for $e^{\beta E} = 1$ for $E = 0$)

$$dn_e = ge^{\eta_{e^-}}e^{-\frac{\beta p^2}{2m_e}}\left(\frac{4\pi p^2}{h^3}\right)dp \tag{12c}$$

where we used $E = p^2/2m_e$. Integrating Eq. (12c) for electrons with statistical weight $g = 2$, we get the number density of electrons in non-degenerate states as

$$n_e = 2e^{\eta_{e^-}}\left(\frac{2\pi m_e k_B T}{h^2}\right)^{3/2} \tag{13}$$

Inserting Eq. (13) in Eq. (11), we get

$$\frac{n_{r+1}n_e}{n_r} = 2\frac{B_{r+1}(T)}{B_r(T)}\left(\frac{2\pi m k_B T}{h^2}\right)^{3/2} e^{-I_r/k_BT} \tag{14}$$

where $m = m_e m_{r+1}/m_r$. To a good approximation $m \approx m_e$ and since the electron pressure P_e is $n_e k_B T$, we have

$$\frac{n_{r+1}P_e}{n_r} = 2\frac{B_{r+1}(T)}{B_r(T)}\left(\frac{2\pi m}{h^2}\right)^{3/2} (k_BT)^{5/2}\, e^{-I_r/k_BT} \tag{15a}$$

This is commonly known as Saha's equation of ionization.

In terms of the average de-Broglie wavelength of particles, also called as the *thermal de-Broglie wavelength* $\lambda = h/(2\pi m_e k_B T)^{1/2}$, Eq. (15a) takes the form

$$\frac{n_{r+1}P_e}{n_r} = \frac{2}{\lambda^3}k_BT\frac{B_{r+1}(T)}{B_r(T)}e^{-I_r/k_BT}$$

Using logarithm on both sides and the approximation $m \approx m_e$, Eq (15a) can be expressed as

$$\log_{10}\left(\frac{n_{r+1}}{n_r}P_e\right) = \log_{10}\left(\frac{2B_{r+1}}{B_r}\right) + 2.5\log_{10}T - \frac{5040}{T}I_r - 6.5 \tag{15b}$$

where the electron pressure (P_e) is expressed in atm and ionization potential (I_r) per atom/ion in eV. In Saha's original paper [10], the above relation appears in the following equivalent form:

$$\log_{10}K = \log\left(\frac{x^2}{1-x^2}P\right) = -\frac{U}{4.571T} + 2.5\log_{10}T - 6.5 \tag{16a}$$

where x is the fraction of ionized Ca atoms in $Ca \rightleftharpoons Ca^+ + e^-$ reaction (ground state Ca atom is usually written as $Ca\ I$ and Ca^+ as $Ca\ II$). K is the reaction-isobar, defined as $P_eP_{Ca\ II}/P_{Ca\ I}$. P is total pressure in atm, which is equal to $(P_e + P_{Ca\ I} + P_{Ca\ II})$, T is the temperature in K, and U is the heat of dissociation in calories and is calculated for 1 mole of atoms/ions under ionization. It is given by [10]

$$U = \frac{eI_r}{J\times 300}N_A = 2.303\times 10^4 I_r\ Cal \tag{16b}$$

where J is joules to calories conversion factor = 4.186, I_r is ionization potential per atom/ion in eV, e is electronic charge in Coulomb and N_A is Avogadro's number. It is easily noticed that the third term on the RHS of Eq. (15b) is numerically equal to the first term on the RHS of Eq. (16a) when expressed in the same units.

It is worth mentioning that the pressure appearing in Eq. (15b) is the electron pressure P_e, whereas Eq. (16a) has the total pressure P. Since $x = N_{Ca\ II}/(N_{Ca\ I} + N_{Ca\ II})$, the fraction of e^- will be also x and the fraction of $Ca\ I$ species will be $1 - x$. Thus, the total fraction of all species will be $x + x + (1 - x) = 1 + x$. Therefore, the partial pressure due to electrons P_e can be expressed as

$$P_e = \frac{x}{1 + x} P \tag{17}$$

Using Eq. (17) and Eq. (15b), the fraction of Ca_{II} can now be written as

$$x = \sqrt{\frac{10^{y+\log_{10}(2B_{r+1}/B_r)}}{10^{y+\log_{10}(2B_{r+1}/B_r)} + P}} \tag{18}$$

where

$$y = 2.5 \log_{10} T - \frac{5040}{T} I_r - 6.5$$

Similarly, Saha's original equation, i.e., Eq. (16a), can be expressed as

$$x = \sqrt{\frac{10^y}{10^y + P}} \tag{19}$$

where

$$y = 2.5 \log T - \frac{U}{4.571T} - 6.5$$

and U is given by Eq. (16b).

Comparing Eqs (18) and (19), one finds that Saha's original ionization equation didn't include the statistical weight for the electrons. The necessity for such a term expressed in terms of partition functions was first reported by R. H. Fowler (1889-1944) in 1923 [15]. Although Saha's equation in its original form required this correction term, it was one of the earliest and finest theories developed as an application of quantum mechanics. It allows us to calculate the fraction of ionized atoms in a stellar atmosphere at a given temperature and pressure. The equation can provide valuable information about stellar atmospheres in combination with relevant spectroscopic data.

Electrons being fermions obeying Fermi-Dirac (FD) distribution, the average number of particles in the state s is

$$\bar{n}_s = g_s \frac{1}{e^{\beta(\epsilon_s - \mu)} + 1} \tag{20}$$

where g_s and ϵ_s are the statistical weight and the energy of the particle, respectively.

In the case when

$$e^{\beta(\epsilon_s - \mu)} \gg 1 \tag{21}$$

the Fermi-Dirac distribution approaches the Boltzmann distribution:

$$\bar{n}_s \approx g_s e^{-\beta(\epsilon_s - \mu)} \tag{22a}$$

The above relation is named after the famous Austrian physicist and philosopher Ludwig Boltzmann [19].

Expression (22a) holds true for energy $\epsilon_s = 0$, i.e., following Eq. (21), we have

$$e^{\beta\mu} \ll 1 \tag{22b}$$

For a monoatomic ideal gas of particle energy ϵ and mass m per atom, the momentum p is $\sqrt{2m\epsilon}$, and the number of particles of energy ϵ following Eq. (4) is

$$N = \int dN = \frac{g}{h^3}\int d\Gamma\, e^{-(\epsilon-\mu)\beta} \tag{23a}$$

where g is the statistical weight, h^3 is the phase space volume of a unit cell. $d\Gamma$ is the volume element in phase space, equal to $V\,4\pi p^2 dp$, where V is the volume in the 3D co-ordinate space and $4\pi p^2 dp$ is the spherical shell shaped volume element in the momentum space of radius p.

Evaluating the integral, we obtain,

$$\frac{Nh^3}{gV} = e^{\mu\beta}(2\pi m k_B T)^{3/2} \tag{23b}$$

Or $$\mathrm{r}e^{\mu\beta} = \frac{Nh^3}{gV(2\pi m k_B T)^{3/2}} \tag{23c}$$

In accordance with the Eq. (22b), the condition for the MB distribution to hold is

$$e^{\mu\beta} = \frac{Nh^3}{gV(2\pi m k_B T)^{3/2}} \ll 1 \tag{24}$$

Data for the partition function term $\log_{10}(2B_{r+1}/B_r)$ for some important species of atoms and ions of astrophysical importance can be found in [16]. In the case of Ca^+ ions $I_r = 6.12$ eV, $\log_{10}(2B_{r+1}/B_r) = 0.44$. Figure 1 illustrates how the fraction of singly ionized Ca atoms varies as a function of temperature for three different total pressures of the system. For a given pressure, say, at 10 atm, most of the Ca atoms remain in the neutral state at temperatures below 4000 K, whereas at higher temperatures, the ionized Ca dominates. It is also evident that the fraction of ionized atoms is larger at a given temperature when the pressure is lower. Figure 2 depicts the fraction of $Ca\ II$ as a function of temperature for a total pressure of 10 atm plotted using Eqs (18) and

(19). Notice that the lack of the electron statistical weight in Eq (19) results in understimation of the fraction of ionized atoms in the intermediate temperatures.

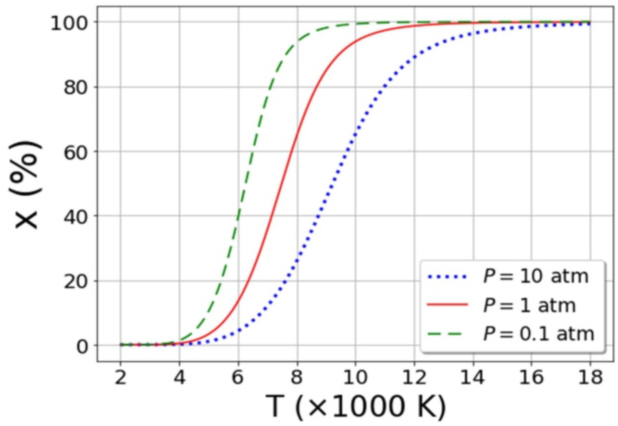

Figure 1: The fraction of $Ca\ II$ ions, $x = N_{Ca\ II}/(N_{Ca\ I} + N_{Ca\ II})$ present in a $Ca\ I + Ca\ II + e^-$ gas mixture, expressed in percentage as a function of temperature for various total pressures. The plots show that at lower temperatures (for instance, < 4000 K at all the pressures considered), most of the species are in the neutral state, whereas, at higher temperatures (say, > 10000 K at $P = 1$ atm), Ca^+ population is more than 90%. At lower pressures, ionization can be achieved at lower temperatures (e.g., with P =0.1 atm, the system will be nearly a fully ionized plasma above 10000 K)

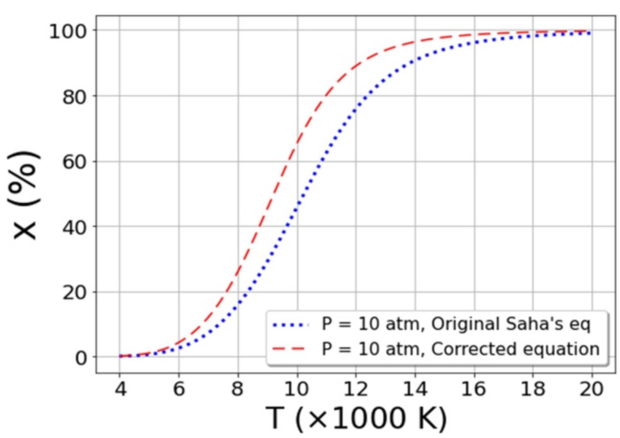

Figure 2: The fraction of $Ca\ II$ ions, $x = N_{Ca\ II}/(N_{Ca\ I} + N_{Ca\ II})$ present in $Ca\ I + Ca\ II + e^-$ gas mixture, expressed in percentage as a function of temperature at a total pressure of 10 atm, as predicted by the original Saha's ionization formula (Eq. 19) compared with the equation corrected by R. H. Fowler (Eq. 18). See the main text for details.

We see that the Fermi-Dirac statistics reduces to the Maxwell-Boltzmann statistics when $Nh^3/gV(2\pi m k_B T)^{3/2} \ll 1$ (see the Box), i.e., for high temperature(T) and low density (N/V). This is a very useful information in stellar astrophysics. Considering two particular excited states of the atoms a, and b, using Eq. (22a), we get

$$\frac{N_a}{N_b} = \frac{g_a}{g_b} e^{-(E_a - E_b)\beta} \tag{25}$$

Eq. (25) represents the temperature-dependent population ratio of two excited states due to Boltzmann law, and Eq. (15a) represents the temperature- and pressure-dependent population ratio of $r + 1$ times and r times ionized atoms as per Saha's equation. These two equations together can be used to explain the relative abundance of certain species in stars, which is a remarkable achievement. Under equilibrium, the ionization rate equals the recombination rate for every species of a particular ion. With increasing temperature, the population of higher energy levels which are to be more populated due to excitations at higher temperatures, is quenched due to ionization at higher temperatures. When one aims to calculate the fraction of all atoms or ions of a given element in a particular quatum state, such as in the case of hydrogen in the $n = 2$ state, the Boltzmann and the Saha equations are combined. However, the calculation of the ionization temperature can be determined by Saha's equation alone. For instance, Figure 1 allows us to determine the temperature at which the total ionization occurs for Ca. Note that Saha's ionization equation predicts that the ionization rate is high at lower pressures.

Concluding Remarks

Saha was nominated for the Nobel Prize on several occasions for revolutionizing our understanding of stellar astrophysics. Arthur Compton, while nominating Saha for the Nobel Prize in Physis for the year 1940 wrote to the committee, "*M. N. Saha of the University of Calcutta, whom I recommended for the prize 2 years ago, because of his study of the ionization of stellar atmospheres. Not only has this work been fundamental to much of the recent development in Astrophysics, but it has also formed the basis of recent physical studies of the thermodynamics of high temperature ionization.*" [19,20]. Readers can glimpse further into Saha's life in Reference [21,22].

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Innovative assignment for continuous assessment – Doubt Cycling

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As a teaching-experiment, I introduced the "Doubt Cycling" technique with the objectives;

- To encourage the questioning skills of students
- To facilitate the habit of referring
- To identify a student's area of research interest at undergraduate level

In the continuous assessment system, I have observed that most colleges have a component called assignment. With two assignments per semester, this component has the general format of submitting a written document on a given topic. Moreover, this set-up has not changed for long and it is time for an update. The way it works is mundane as few students prepare the document by merely copying the content from sources like books or websites. It not only normalizes plagiarism but also inhibits questioning and referring skills. Irrespective of copied contents, all pupil receive equal marks.

Hence, I recommend Doubt Cycling as an effort to modernize this component yet not to over burden the students. I have been executing this technique since the year 2012 and found it very effective in enhancing multiple scientific skills. Figure1 depicts the approach of doubt cycling. Firstly, the most students are hesitant to raise a doubt in class and dump it within. Therefore, it becomes convenient for them to write it down. Meanwhile, receiving a doubt from a fellow student makes them more receptive to doubts as well. This step taps their research as well as teaching skills.

Following this, the course teachers review the questions to avoid repetition and provide clarity in the questions. In a matter of few minutes, the teacher can review and shuffle between students the questions in any order. Preferably, it is advisable to allot well performing students with a challenging question.This not only feeds the curiosity of the toppers, but also be better understood by the asker.

Later, the students may be given a period of 7 to 10 days to look up for the answer to their concerned questions. At the final stage, a maximum of one hour can be allotted for a class of 25 students to present their answers to their classmates. This can be done at the end of a semester after syllabus completion.

Step A Student X and Y each submit a doubt from the assigne Unit.

Step B Teacher receives and reviews the doubts. Doubts of students X and Y are interchanged

Step C Both look up for the answers to the assigned doubts

Step D Both students clarify the doubts of each other by answering in a seminar format.

Fig 1. Schematic of the doubt cycling technique

While presenting, the students also include their source of reference. This enables their habit of citation. Overall, the technique is a combination of many research and teaching ethics

incorporated in one. At the end of this assignment, students are habituated to the research and teaching ethics shown in figure 2.

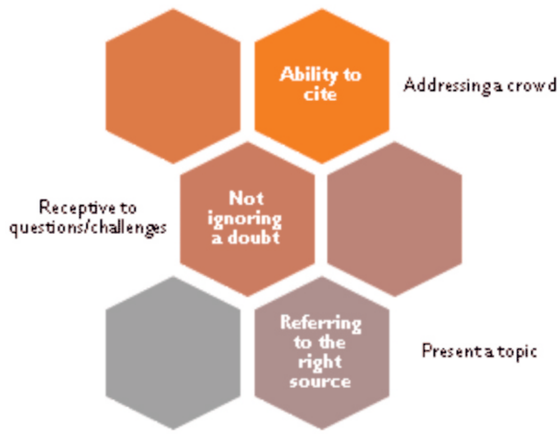

Fig 2. Expected outcomes of doubt cycling

REPORT (RC-07)

State Level Final CPEx-2023

IAPT RC – 07 provides a unique opportunity, to demonstrate innovative experiments, to both the teachers and the students, from secondary to the university level, through an event called CPEx (Competition of Physics Experiments). Participation in National Competitions, such as NCIEP and NCICP is encouraged through such an event.

CPEx – 2024 was held in five categories:

1) For students studying in standard 11 and 12 (Science Stream)
2) For Undergraduate (UG) students
3) For Postgraduate (PG) students
4) For Research Scholars
5) For Teachers

Initially, the competition is held at the Cluster Level and then there is a State Level Final. The RC – 07 is divided into 10 clusters for this competition. This year, 9 out of the 10 clusters organized the Cluster Level Competition during January / February, 2024. Top two entries from each category from all the clusters get qualified for the State Level Final.

The State Level Final of CPEx-2024 was hosted for the second successive year by The Department of Physical Sciences, P. D. Patel Institute of Applied Sciences, Charotar University of Science and Technology, CHARUSAT Campus, Changa, Gujarat, on March 14 2024 in collaboration with the IAPT RC – 07. 32 participants from various regions of Gujarat reported at the venue on the day of the Final.

In the Inaugural session, Prof. P. N. Gajjar (President of GSA, Department of Physics, Gujarat University, Ahmedabad), Prof. R. V. Upadhyay (Provost, CHARUSAT), Dr. Abhishek Dadhania (Principal, PDPIAS), Prof. K. N. Joshipura (Former General Secretary, IAPT), Prof. P. C. Vinodkumar (President, IAPT RC-07), Dr. C. K. Sumesh (Local Coordinator of CPEx-2024 and Head, Department of Physical Sciences, PDPIAS), Prof. V. H.

Thakkar (Coordinator of CPEx – State level), distinguished guests, Coordinators/Mentors from different schools and colleges, PDPIAS faculty members and students were present. Prof. K. N. Joshipura encouraged the faculty and students to participate in these events by outlining the various activities of IAPT at various levels. Prof. P.N. Gajjar explained to the participants, various inventive ways to present novel ideas. Prof. R. V. Upadhyay, in his presidential address, encouraged the participants to become more excited about creating new experiments. Prof. V. H. Thakkar gave a detailed account of how the State Level Final of CPEx-2024 was planned and executed.

Then the competition was started. Parallel sessions for the postgraduate/teacher's category and school/undergraduate student's category were held for the presentation and assessment of the experiments. It was successfully carried out by two panels of judges, comprising of Prof. G. K. Solanki, Dr. Brijesh Amin, Dr. Sanni Kapatel, Dr. Pratik Pataniya, Dr. Shweta Dabhi and Dr. Vanaraj Solanki from different Institutes of RC – 07. After evaluating the experiments, the judges offered the students' tips on how and what to improve in their experiment for the national level contests.

Category wise winners in the State Level Final are listed below:

Category	Prize	Name of The Participant	Title of the Experiment	Name of the School/Institute
School student (working model)	1	Henil Sanjiv kumar Soni	Long board	R. C. Technical Institute, Ahmedabad
		Kruti Janardanbhai Dave		R. C. Technical Institute, Ahmedabad
	2	Param Hiteshbhai Mandaliya	Train Turbine	B. M. Commerce High School, Bhavnagar.
		Rudra Pravinbhai Bariya		B. M. Commerce High School, Bhavnagar.
UG (working model)	1	Nirmal Smruti Bharat kumar	Marangoni effect	Government Science College, Sector 15, Gandhinagar
		Joshi Mahi Harshadbhai		Government Science College, Sector 15, Gandhinagar
	2	Harsh Dipakbhai Pandya	IoT based Home automation	Sir P.T. Sarvajanik College of Science, Surat
		Pati Sanskruti Raghunath		Sir P.T. Sarvajanik College of Science, Surat
PG (working model)	1	Detroja Dhruv Dineshbhai	Digitized Simple Pendulum	P. D. Patel Institute of Applied Sciences
	2	Joshi Vivek Bhupendrabhai	Smart Parking System	Department of Physics, MKBU
		Pandit Kruti Samir		Department of Physics, MKBU

Each participant and the winner received a participation certificate and a memento. Special cash prizes were awarded to the students who stood first overall in the School, UG and PG categories.

The feedback and reflections were received from the esteemed guests and student participants. The function came to an end with a vote of gratitude from Dr. C. K. Sumesh. The program's overall success was partly attributed to the students' extremely enthusiastic engagement.

C. K. Sumesh
(P. D. Patel Institute of Applied Sciences, Changa)

Viresh Kumar Thakkar
(Sir P. T. Sarvajanik College of Science, Surat)

REPORT (RC-08)

National Photo Essay Competition in Physics

The National Photo Essay Competition in Physics, organized by Bajaj College of Science in collaboration with Sub RC- 08E Vidarbha region provided a platform for students from 16 universities to showcase their creativity and scientific knowledge through captivating photo essays. Out of 50 submissions, 37 participants were selected for evaluation.

The virtual event on 24th March 2024 unveiled the top 10 photo essays and announced the winners. The event was hosted by the event coordinator Dr.Govinda Lakhotiya, and was graced by the presence of esteemed individuals such as Dr. S.W. Anwane, President of RC08E; Dr. PV Tekade, Principal of Bajaj College of Science; Prof. PK Ahluwalia, President, IAPT; and guest of honour Dr. Raka Dhabade, among others. Prof. Ahluwalia encouraged the winners to engage in national-level activities and invited them to the upcoming National Convention. Dr. Sanjay Bagade proposed the vote of thanks.

The winners of the competition were announced as follows:

- Ms. Romachita Choudhary from Pandu College (Guwahati University) secured the first prize of Rs. 6000 for her captivating work on "Supernova: The Grand Finale of a Dying Star."

Ms. Malvika Naik from Xavier's College, Mumbai, claimed the second prize of Rs. 4000 for her engaging photo essay on "Black Hole Soft Hairs."

- Aastha Shende from Bajaj Engineering College, Wardha, received the third prize of Rs. 2000 for her insightful essay on "NEBULA: Life of a Star."

- The remaining seven participants were each awarded a consolation prize of Rs. 1000.

The competition successfully celebrated the fusion of art and science, providing recognition to talented students in the field of physics.

Govinda Lakhotia

REPORT (RC-15)

Special Lecture on 'Einstein & E = Mc^2

A special lecture on the topic, EINSTEIN & E=mc^2 was organized on Wednesday, the 20th March. 2024 under the joint aegis of the Dept. of Physics, Prabhat Kumar College, Contai, East Midnapore, West Bengal and the IAPT, RC- 15. Prof Ajoy K Ghatak delivered the lecture. He is a former Emeritus Professor of IIT, Delhi, the Meghnad Saha Professor of the National Academy of Sciences, India of which he is a former President. He is a Fellow of the Optical Society of America, from where he has won the Beller Award in 2003.

The programme was held effectively in a hybrid mode, with the speaker making his presentation online from New Delhi.

Dr. Pijus Kanti Samanta of the Dept of Physics of the College introduced the topic and compeered the Programme. Prof Amit Kr De, the Principal of the College delivered the Welcome Address. Prof. C. K. Ghosh, Former Director, NCIDE, presented a brief introduction of the speaker. Prof P.K. Ahluwalia, President, IAPT, joined from Shimla, made the Presidential and Concluding Remarks. Expression of Gratitude for the Speakers and the entire audience was made by Dr Pradipta Panchadhayee of Dept. of Physics of the College and also the Secretary, RC-15.

Prof Ghatak made the beginning in his characteristic style by making reference to Einstein's birthday (14th March), which when written in MM.DD Style, becomes 3.14, which is an approximate value of ?, and is hence, his birthday is called Pi Day.

He mentioned about the year 1905, which is referred to as the Miracle Year in the life of Einstein, when he was barely 26 years old, and as an obscure clerk at the Bern Patent Office, he published five phenomenal papers which changed the face of physics and revolutionized our thought process. Einstein had trodden the path almost alone, and the speaker explained the importance of isolation in the pursuit for excellence, which, he said, also applies to the year 1665 for Sir Isaac Newton when he remained confined to his native village, Woolsthorpe due to the spread of plague in London.

The speaker made brief references to the Photoelectric Equation of Einstein, his insightful work on Molecular Dimensions, his theory of Specific Heat, his iconic Special Theory of Relativity and last but not the least the famous equation, $E=mc^2$, with which his name has almost become synonymous.

The speaker took up the discussions on $E=mc^2$ in detail. He inter alia cited the example of mass defect occurring when two small bar magnets stand attracted to each other end-to-end with opposite polarities, then went over to multiple illustrations of mass-energy equivalence from the domain of atomic and nuclear physics, where the examples of binding energy of a nucleus, the energy released during nuclear fusion and fission, the chain reaction and so on stood out. The most striking feature of Prof Ghatak's presentation was his art of providing clarity using figures; for example, the total energy emitted by the sun per second is 4×10^{20} joule, which amounts to an approximate loss of mass of the sun by 4×10^{9} kg per second. Likewise, he substantiated every example with numerical calculations, which at no point of time appeared to be intimidating, rather those were highly facilitating in terms of comprehensibility of apparently difficult concepts.

The most crucial conceptual input happened to be a proof of the equation, $E=mc^2$ by using a very simple application of Doppler Effect on the frequency of a photon. Prof Ghatak made a special mention about the sentence: "Light carries mass with it…", which Einstein wrote in a letter to his friend Conrad Habicht after he arrived at his famous equation.

Chinmoy Kumar Ghosh

REPORT (RC-18)

World Quantum Day-24 Celebration

Physics Department, ICFAI University

Since 2022, the date 14th April is celebrated across the World as World Quantum Day. This is the 2nd time World Quantum Day was celebrated in hybrid mode, on 10th and 12th April, in the Department of Physics, ICFAI University Tripura, in collaboration with IAPT RC-18.

The program began with the smokeless lamp-lighting (lamps glow as they are placed in water without consuming extra electricity), which is standardized by the department to cut pollution.

The new issue of the 'Reflections', the newsletter that showcases the quality, achievements and talents of the students and the faculty members of the department, was opened for all by Prof.(Dr.)

A Ranganath, the Registrar, ICFAI University Tripura and President, IAPT RC-18. He informed the gathering regarding the revolutionary impact of Quantum Science, Prof.(Dr.) Priyangshu Rana Borthakur informed the budding Physicists of the Quantum Mission of India and the endeavours and approaches of ICFAI University Tripura to take part in it. Dr. Camelia Das proposed the vote of thanks for the session.

The opening talk was delivered in online mode by Prof. Usha Devi A R, Professor of the Department of Physics, Bangalore University on 'A Tale of Quantum Computation' that took the audience from basics to the depth of the theory of Quantum Computation. She just took the audience in a very nice flow to enrich the knowledge. The celebration continued with a Public Quiz on Quantum Mechanics and corresponding things. The audience enjoyed it a lot with quiz-master Dr. Arunabha Saha.

Post-lunch sessions were divided into two parts: Oral and Poster Presentations by M.Sc. students. The students presented their research works. Eight oral and 25 posters were presented. Later the posters were highly praised by the invited guests and faculty members of different departments.

The 2nd day of the WQD celebration was 12th April, 2024. The day started with an online talk by Dr. Antariksha Das from ICFO, Bercelona, Spain on 'Distributing Entanglement: From Lab to the Field'. How the world can advance with corresponding experiments – a glimpse of it enthralled the entire fraternity present there.

The final talk of the Program was delivered by Dr. Satadal Bhattacharyya of the Scottish Church College on Correspondence Principle which also marked the celebration of the centenary of Correspondence Principle. The eminent speaker took the stage to showcase how the Correspondence Principle is applied from classroom to advanced application.

Dr. Swapan Majumder, Secretary of IAPT RC-18 praise the organization for such a program in the concluding session.

Winners of the oral and poster competitions were awarded. Department of Physics also awarded the previous semester's toppers of all five batches of B.Sc. and M.Sc. The program ended with thanks from the convener Dr. Sovan Ghosh, Head, Department of Physics, ICFAI University Tripura.

Swapan Majumdar
Secretary

1st ANNOUNCEMENT

38th IAPT National Annual Convention - 2024

October 16 - 18, 2024

Co-host

- **Central University of Himachal Pradesh, Dharamshala - H. P.**
- **Rainbow International School, Dharamshala, H.P.**

Participating Institutes

- IAPT REGIONAL COUNCIL CHANDIGARH AND HIMACHAL PRADESH.
- C.U.H.P. DHARAMSHALA H.P.
- GOVT. COLLEGE DHARAMSHALA
- GOVT.COLLEGE NAGROTA BANGWAN
- RAINBOW INTL. SCHOOL DHARAMSHALA
- S.C.E.R.T. SOLAN, H.P.

Themes:

- **QUANTUM COMPUTING & TECHNOLOGY**
- PHYSICS EDUCATION RESEARCH (PER)
- ASTRONOMY EDUCATION
- WORKSHOPS ON HANDS ON ACTIVITIES
- INDIAN KNOWLEDGE SYSTEM (IKS)

Paper Submission Deadline: June 15, 2024

Registration Fees : Rs. 5000
https://saivyasa.in/iapt/registration/

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Active w. e. f. 10.05.2024

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Prof. C.N. Kumar
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Prof. O.S.K.S. Sastri
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MORE DETAILS IN THE NEXT ANNOUNCEMENT

COMETS COMMENTORY

We were/are Omens-Disaster for people

We were/are Messengers-of-God for people

We were/are Super-Sky -Shows for people

We were/are Scientific-Challenge for people

We were born 4.5 billion years ago with SUN.

We are from Homeland Oorts-disc and Oorts - cloud.

We are from Outer most Coldest part of Solar-System

We are Dirty -Icy- Snow Balls

We Run with Speed 20-70 km per second around SUN.

We have Size 1km—20 km Wide.

We have Mass around 10 billion tones.

We Contain Water Methane Ethene CO HCN etc.

We travel randomly or periodically around SUN

We are totally Trillion in Number

We are 5000 in Number So for Recorded on Earth

We have short period 200years Long Million years.

We can survive for 20000 years.

We Bring Super-Sky-Show on Earth

We Carry Secrets of Solar-System and near Stars

We may get Credit for bringing Water and Life on Earth

We are seen in Sky enjoyed since so many Centuries.

One of us seen by Telescope first-time in1680

One of us followed by Space-Probe in 1978

One of us touched by Rossetti-probe in 2014.

One of us blasted by D I Probe in 2022

One of us Shown everywhere through Virtual-Telescope in 2024

One of us was seen in 1680 by Kirch.

One of us was seen through Telescope by Newton

One of us was Correctly Predicted by Halley

One of us s dashing on Jupiter predicted by Levy-Shoemaker

On of us visiting Sun and Earth in 2024 was predicted by Pon-

Brook

We are…..We are …..We are…..

Comets…..Comets …..Comets….

We are …..We are….. We are…..

Solar-mates….Solar-mates…..Solar-mates

We are ….. We are ….. We are ……

Icy-dusty-Sockets…..Icy-dust-Sockets….

Icy-dusty-Sockets….

We are….. We are ….. We are ……

Icy-dirty-Pockets…..Icy-dirty-Pockets…

Icy-dirty-Pockets…..

We are Cool-mates…We are Icy-mates…

We are Dusty-mates….

We are COMETS… We are COMETS…

We are COMETS.

Shams

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Trends and Themes in Physics Education Research

Concept Inventories - Enabling a Scientific Approach to Teaching and Learning of Physics

A Concept Inventory (CI) is a carefully crafted set of multiple choice questions (MCQ) on a concept or a topic aimed at probing student alternative conceptions, and eliciting their ill-suited reasoning patterns. Currently there exist physics CIs on topics ranging from basic mechanics to quantum mechanics, developed from multiple countries including India (can be accessed @ https://www.physport.org/assessments/). CIs emerged in PER as a continuation of the studies on student alternative conceptions, which in turn have their roots in the work of psychologist Jean Piaget on genetic epistemology- the development of knowledge in human individuals. Though insightful, these studies arguably had limitations in gaining the traction of the physics teaching community, barring few exceptions. To address this, a theoretical physicist and physics education researcher - David Hestenes, came up with the idea of a concept inventory. As expected, the MCQ format and the associated potential for objective and quantitative data, rapid and easy evaluation, large scale application etc generated more appeal among physicists and physics teachers. The experience shared by Harvard physicist Eric Mazur in his talk `Confessions of a Converted Lecturer' , is illustrative of this point. For a detailed discussion of the history and reform potential of CIs on teaching and learning of physics, see:

Hake, R. (2011). The Impact of Concept Inventories On Physics Education and Its Relevance For Engineering Education. In Proceedings of the National Meeting on STEM Concept Inventories.

CI type questions should be distinguished from the MCQs that form a part of admission tests like the IIT JEE. Their role is to elicit, diagnose student alternative conceptions and ill-suited reasoning patterns. For example, consider the situation of a particle moving in a straight line with constant speed and the origin is taken to be away from the line of motion. Now ask students questions about the angular acceleration, angular momentum, torque etc. Many of them tend to think that all angular quantities are zero or cannot be defined for the particle since it is moving in a straight line. However the particle has an angular - velocity, acceleration and momentum. Interestingly the angular acceleration exists without a torque. In summary, a simple situation like this can provide a rich context to elicit recurring, interesting reasoning modes and patterns among students, like fixation to prototypes and indiscriminate use of equations. All one have to do is to carefully construct the different choices of an MCQ so that they incorporate student conceptions and reasoning patterns. Broadly a CI is a coherent set of such MCQs, subjected to different validity and reliability criteria.

Educational implications of CIs for our contexts:

1) CIs appeal better to the sensibilities of physicists and physics teachers than many other threads in PER. This aspect can be leveraged to create awareness and grow PER in our country. Concept inventories have played a facilitating role in convincing traditional instructors in a denial mode with regard to PER findings, to adopt research driven approaches to teaching. They can play a crucial role in enabling large scale science education reform initiatives as exemplified by the Carl Wieman Science Education Initiative.
2) Development of CI type questions provides a fertile context for teacher professional development. By virtue of a teacher's vast experience interacting with students, most of them will have an intuitive feeling about how students think, their difficulties and reasoning modes. This undervalued and untapped repertoire of experience is among the best resources for developing CI type questions. In fact one of the authors of FCI - the first and the most popular inventory was Malcom Wells, a high school teacher. Development of FCI is illustrative of the way in which PER informed community in our university departments can play a useful role in capacity building of teachers in schools and colleges.
3) CIs can be easily incorporated with the traditional lecture method, the widely prevailing pedagogy in our schools and colleges. CI type questions enable Peer Instruction, which again gels well with lectures.
4) Translating existing CIs to regional languages and adapting them to local idioms will help us take PER to classrooms in rural India. Such an initiative is currently ongoing under the aegis of IAPT.

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