ज्ञान-विज्ञान विमुक्तये
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Secretary

सत्यमेव जयते

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University Grants Commission
(शिक्षा मंत्रालय, भारत सरकार)
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Public Notice

Subject:- Indian Knowledge System (IKS)

The National Education Policy 2020 lays emphasis on the promotion of Indian Languages, Arts and Culture, and tries to remove this discontinuity in the flow of Indian Knowledge System by integrating IKS into curriculums at all levels of education. In order to facilitate a seamless integration of Indian traditional knowledge with modern subjects, UGC has come up with'Guidelines for Training of Faculty on IKS'. These guidelines will inspire the faculty in higher education institutions of the country to generate a positive attitude, explore, and undertake quality research on IKS, and herald a new era in higher education ecosystem of the country in the light of NEP 2020. The IKS guidelines will be a part of the training modules under "Malviya Mission" and will be considered under CAS scheme as per the UGC regulations.

The guidelines are available on the UGC website. All the Higher Education Institutions are requested to take necessary steps to follow the guidelines to facilitate seamless integration of Indian traditional knowledge with modern subjects.

(Manish Joshi)

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Guidelines for

Training/Orientation of Faculty on Indian Knowledge System

University Grants Commission
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सत्यमेव जयते
Goverment Of India

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GUIDELINES FOR TRAINING/ORIENTATION OF FACULTY ON INDIAN KNOWLEDGE SYSTEMS

Preamble

National Education Policy (NEP) 2020 aims for a complete metamorphosis of the higher education landscape of the country in all its structural, content-related, and pedagogical dimensions. The rich heritage of ancient and eternal Indian knowledge and thought has been a guiding light for NEP-2020. The NEP 2020 has stressed upon the promotion of Indian Languages, Arts and Culture, and has recommended for the integration of IKS into curriculums at all levels of education. Indian Knowledge Systems (IKS) (Bhāratīya-Jñāna-Parampara) encompasses the treasure of knowledge in various disciplines that emerged systematically from the ancient times in India over generations.

Integrating IKS in curriculum for capacity building in faculty and educating the students as envisaged by NEP 2020 requires strengthening the role of the faculty and evolving them into energized, motivated, and capable faculty. The success of NEP 2020 and its special component on Indian Knowledge System relies heavily on the shoulder of the faculty of Higher Education Institutions. Most of the faculty in Higher Education Institutions (HEIs) across the country, although experts in their respective fields, may require additional familiarization efforts for the Indian Knowledge Systems. Teacher training/orientation in the UGC recognized institutions is typically conducted by various agencies such as HRDCs and Pandit Madan Mohan Malviya National Mission on Teachers Training (PMMMNMTT). The faculty are required to attend a mandatory induction program and periodic refresher courses for their continued professional advancement.

The purpose of these guidelines for teacher training during the induction program and refresher courses is to provide a roadmap to familiarize and enthuse faculty about the Indian Knowledge Systems (IKS) and identify strategies to incorporate IKS into their specific classroom teachings. Teachers and Learners will acquire the concept of the Indian Knowledge System and apply it in real life for the advancement and creation of knowledge

1 Background

Integration of IKS in the curriculum at various levels involves an introduction to IKS, it's Scope & History, and amalgamation of fundamental IKS concepts into modern textbooks, leading to developing Indian Thought Models based on available IKS literature, and their application into various contemporary problems solving methods. Understanding that teacher training is important to the success of NEP 2020, UGC constituted a committee of experts to recommend strategies by formulating guidelines for effective teacher training/orientation in IKS. Teacher training/orientation is typically conducted by various agencies such as HRDC, and PMMMNMTT (Malviya Mission). The faculty in the UGC- recognized institutions are required to attend a mandatory induction program (175 hours) and periodically attend the refresher courses which may include subject-specific courses. The refresher courses are required for the continued professional advancement of the faculty in UGC-recognized academic institutions.

2 Guidelines

The needs of faculty coming into the induction program are slightly different from the ones coming for the refresher courses. Faculty coming into the induction program are experts in their topics but may not have deep knowledge about the IKS. The freshly inducted faculty members attending this program may not have the experience of teaching large classes. Therefore, the guidelines are specified separately for the induction/orientation program and the refresher courses. The major purpose of all such training programs shall be to generate a positive attitude towards IKS and promote interest in knowing and exploring more, rather than covering a lot of content related to IKS.

2.1 Induction program

1. Because of the innate nature of IKS, the induction program should not be limited to the faculty's discipline. The content should be broad-based and cover introductory material on all aspects. It would enable teachers to explore the most fundamental ideas that have shaped IKS over the centuries.
2. The IKS Induction programme should ideally be of 30 hours in a 10-10-10 format. The induction module should be divided broadly into three parts:
    - <u>Overview of IKS</u>: philosophy, cross-disciplinarity, main approaches and methods, the place of Indian civilization among other classical civilizations and inter-civilizational exchanges, sources of authentic material

- Case studies: to illustrate a few remarkable accomplishments in diverse fields
- Pedagogy related to IKS: Innovative methods to teach IKS including innovative methods propounded by NEP, avoidance of bookish teaching, the use of audiovisual material, possible field studies, some exposure to a few primary sources, possible activities, and micro-research projects, innovative ways to evaluate learning in IKS, avoidance of common pitfalls such as exaggeration or glorification.

3. The IKS-related content should be allocated a minimum of 10% of the total time spent during the induction program. This will translate to about 17.5-20 hours for a typical induction program.
4. All faculty must be exposed to common underlying philosophical foundations across disciplines in the IKS.
5. At least one to two lectures on the fundamental vocabulary of IKS must be conducted to familiarize faculty with the common terms used in IKS.
6. Faculty must be exposed to the primary texts (Sutra Text) of IKS which is required for understanding the sources and origin of IKS. It would help teachers to understand the primary purpose of the text along with the objective, layout, concise and precise way (*sutras*) of presenting ideas, content, etc.
7. Common pedagogical template should be used for designing IKS subjects for every discipline to maintain consistency and quality in the instruction.
8. For each module, ready access to a wide range of primary and secondary resources must be provided to enable teachers to understand the continuous and vibrant tradition of IKS. These materials may be developed by a team of subject experts and provided to teachers so that there is consistency in the source material used for instruction. Extreme care must be taken to ensure the authenticity and scholarly nature of the content that may be developed for the orientation/induction and refresher courses. Unverified or unverifiable contents must not be used in any case.
9. A database of authentic books, papers, articles, videos should be created. Faculty should be invited to contribute to the database, with a mechanism for peer review to assess the quality of the submitted material.
10. A list of IKS content available in regional languages must be compiled and made available for the benefit of non-English medium teachers.

11. A field visit to nearby IKS related prominent places such as Temples, Gurukuls, Historical sites, Arts & Crafts communities, Ayurvedic Healing Centers, Astronomical Observatories (Jantar Mantar) would enable teachers to appreciate the various manifestations of IKS should be organized.
12. Sharing the life and work of contemporary original thinkers who have made seminal contributions in their field, using IKS framework, would motivate teachers to explore various dimensions of IKS.
13. The faculty must be informed about the opportunities to conduct original research in the IKS domain.
14. Courses must be developed in a range of subjects across natural sciences, social sciences, humanities, engineering, medicine, agriculture, community knowledge systems, fine and performing arts, vocational skills etc, which have IKS content. The courses must have a clear mapping of the traditional subjects in IKS with the modern subjects such a chemistry, mathematics, physics, agriculture, etc.
15. For orienting prospective teachers towards IKS, initiatives should be made to revise UGC syllabus (General Paper) so as to pay sufficient weightage to the IKS content in respective subjects. This would enable prospective teachers preparing for UGC NET examination to get familiarized with IKS. The same should be done in CSIR NET, GATE exams etc.

2.2 Refresher courses

- All faculty must be exposed to a common underlying philosophical foundation across disciplines in the IKS.
- At least one to two lectures on the fundamental vocabulary of IKS must be conducted to familiarize faculty with the common terms used in IKS.
- A strong emphasis must be placed on providing exposure to the primary texts (Sutra Text) of IKS which is required for deeper understanding.
- The refresher courses must focus on the development of courses under the following categories:
    a. ***Multidisciplinary courses:*** These courses should serve faculty from at least two disciplines that are closely related. The courses should provide a greater depth and allow the faculty to explore the interdisciplinary aspects of the IKS and to appreciate

the cross-disciplinary connections. The primary aim of these courses is to sensitize teachers about the possible interdisciplinary education which is a key aspect of the NEP 2020. As an example, a course on mathematics and astronomy could be conducted and discuss the simultaneous development of mathematical tools and astronomy models in India. This course could serve the needs of faculty in mathematics and astronomy disciplines. A second example course could be a course on civil engineering, architectural engineering and town planning serving the disciplines of civil engineering, architecture and town planning.

b. ***Discipline-specific courses:*** The discipline specific courses must be focused on a particular subject. These courses are designed to provide a comprehensive understanding of the discipline in the IKS. The course should be usually designed using multiple source texts as the reference material. For example, a course on chemistry could use Rasaratnakara, Rasaratnasamucchaya, Sarveshwararasayana etc. The ayurvedic concepts of Dravyaguna shastra with the underlying philosophy from the Vaisheshika-Darshana can be taught together with their correlations to biochemistry, biophysics, and process engineering. A course for chemistry students can focus on the aspects related to the herbo-metal and mineral substances from a Dravyaguna perspective while a course for Physics students can focus more on the classification of materials as per the Vaisheshika-Darshana. Designing the course content is a challenge that needs to be carefully thought out by a team of experts in both traditional shastras and modern subjects as most of the IKS subjects do not map cleanly to their modern counterparts. For example, a chemistry-related book such as Rasaratnakara will have a discussion on laboratory construction and furnace construction in addition to discussing purely the chemistry aspects.

c. ***Specialized courses:*** Specialized courses are to be designed for providing in-depth and comprehensive knowledge of a particular text. These courses should be open to those faculty who would like to develop specific expertise in a subject on a particular text and must be taught preferably in person by the experts. The courses must be designed to convey the primary purpose of the text along with objective, layout, concise and precise way (*sutraic*) of presenting ideas, content, etc. It may be envisioned that these courses may only be taught at particular centers where experts are available, and these courses could become the 'USP' of a particular center.

- Courses must be developed in a range of subjects across natural sciences, social sciences, humanities, engineering, medicine, agriculture, community knowledge systems, fine and performing arts, vocational skills, etc, which have IKS content. The courses must have a clear mapping of the traditional subjects in IKS with the modern subjects such as chemistry, mathematics, physics, agriculture, etc.

2.3 Suggestions for effective implementation

3 To connect with the oral tradition of IKS, one practical session on the ancient technique of memorization, with a few examples from primary texts, would be helpful.

4 A few immersive sessions on Yoga, Meditation, Ayurveda, Classical Music should be arranged to give teachers some grounding in the experiential aspects of IKS.

5 One session on Ayurveda with reference to self-exploration (Ayurvedic Personality Test) will be very helpful at a personal level.

6 The higher education institutions with the help of the MoE-IKS cell and all scholars may build a database of authentic books, papers, articles, videos. Faculty members may be invited to contribute to the database, with a mechanism for peer review to assess the quality of the submitted material.

7 Master trainer program could be implemented under Malviya Mission. This would be more cost effective and will bring efficiency in implementation of IKS in right spirit as proposed in these guidelines.

8 Malviya mission centres could be designated as the nodal agencies for preparing reading materials and recorded lectures for training of faculty on the various subjects mentioned in the document for FIP & Refresher Courses and Short term programs.

9 A suggested roadmap of effective implementation is shown below.

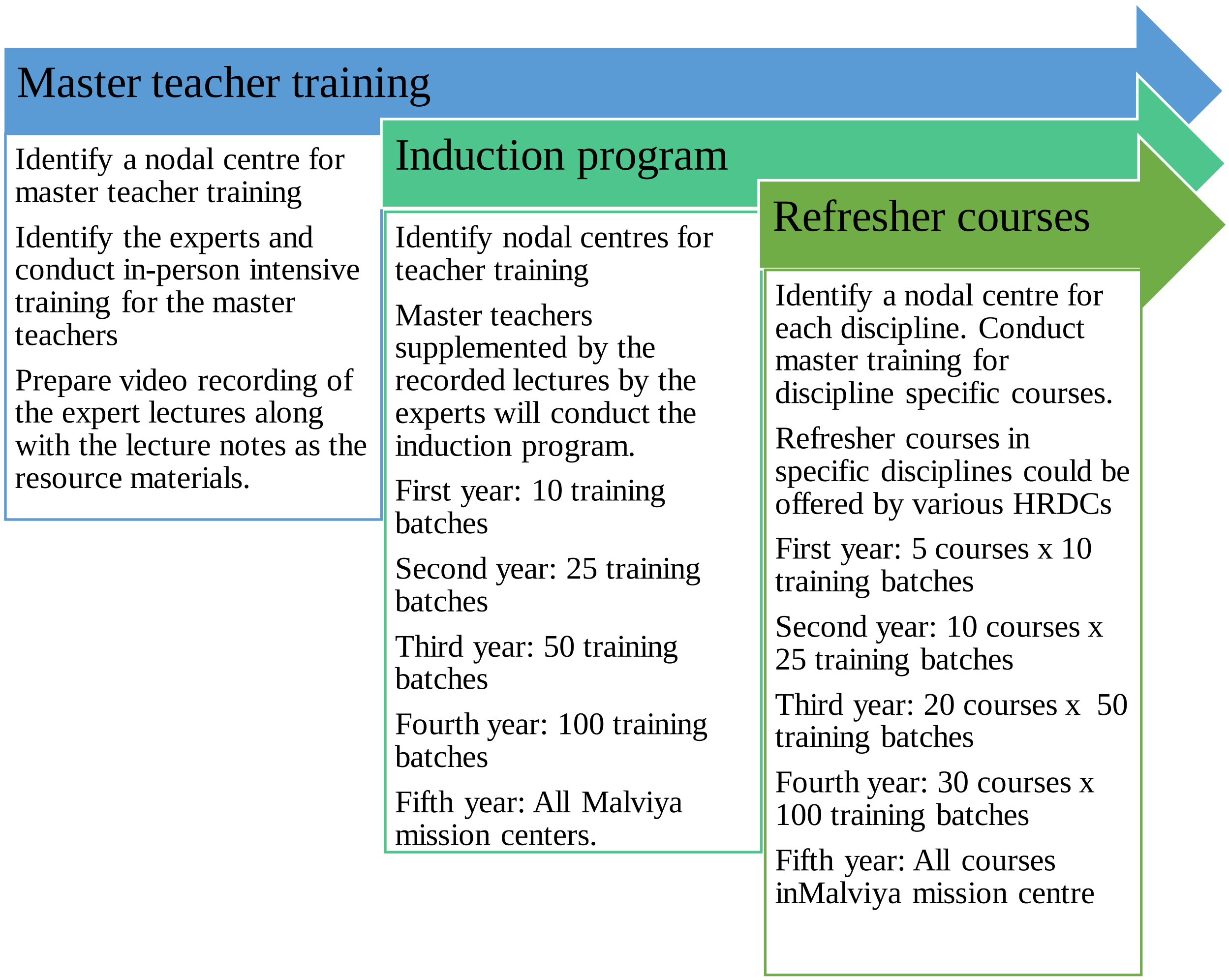

Figure 1. A roadmap for effective implementation of the teacher training in IKS

Annexure 1

Model Syllabi for the teacher training guidelines. The following syllabi have been prepared by the committee to help guide the creation of such courses for teacher training. These course outlines are not prescriptive and are intended to help the instructors in the preparation of course syllabi as per the needs of the learners.

Annexure 1A: Model syllabi for IKS modules in the Induction Program

Course 1: IKS Induction Program in IKS

1 **Overview of IKS**

- Survey of IKS Domains: A broad overview of disciplines included in the IKS, and historical developments.
- Sources of IKS knowledge, classification of IKS texts, a survey of available primary texts, translated primary texts, and secondary resource materials. Differences between a sutra, bhashya, karika, and vartika texts. Fourteen/eighteen vidyasthanas, tantra yukti
- Vocabulary of IKS: Introduction to Pancha maha bhutas, concept of a sutra, introduction to the concepts of non-translatables (Ex. dharma, punya, aatma, karma, yagna, shakti, varna, jaati, moksha,loka, daana, itihaasa, puraana etc.) and importance of using the proper terminology. Terms such as praja, janata, loktantra, prajatantra, gana tantra, swarjya, surajya, rashtra, desh,
- Philosophical foundations of IKS: Introduction to Samkhya, vaisheshika and Nyaya
- Methods in IKS: Introduction to the concept of building and testing hypothesis using the methods of tantrayukti. Introduction to pramanas and their validity, upapatti; Standards of argumentation in the vada traditions (introduction to concepts of vaada, samvaada, vivaada, jalpa, vitanda). Concept of poorva paksha, uttara paksha.

2 **Case Studies (Few of these may be selected as appropriate)**

- Mathematics of Madhava, Nilakantha somayaji
- Astronomical models of Aryabhata
- Wootz steel, Aranumula Mirrors and lost wax process for bronze castings
- Foundational aspects of Ayurveda
- Foundational aspects of Ashtanga yoga
- Foundational aspects of sangeeta and natya Shastra
- Foundational aspects of Bhartiya jurisprudence
- Indian methods of pedagogy

3 **India and the World: Influence of IKS on the world, knowledge exchanges with other classical civilizations, and inter-civilizational exchanges.**

Course 2: IKS Induction Program Module for Chemistry and Metallurgy (6 lectures)

Lecture 1: Introduction to IKS in general; introduction to a few terms along with the IAST transliteration scheme with diacritic marks.

Lecture 2: Outline of the contributions of ancient and medieval Indians in the area of chemistry and metallurgy as gleaned from archaeological artefacts, temple icons and other such tangible objects like the Delhi Iron Pillar that have survived the test of time.

Lecture 2: Specific use, processing, and finishing of 6 metals since the vedic times and how the knowledge constantly evolved to incorporate other metals like mercury and zinc at later periods

Lecture 3: Chemistry of dyes, pigments, and other coloring materials used in paintings, fabrics, beads, and other day-to-day utilities since ancient times and their constant evolution through different periods of time

Lecture 4: Chemistry in Ayurvedic texts as well as in Ayurveda practice. A few case studies pertaining to the preparation, quality control, and delivery of herbo-mineral drug formulations.

Lecture 5: Introduction to select original texts pertaining to chemistry and metallurgy like the *Rasārṇava* and *Rasaratnasamuccaya*; dwelling on the style of writing a technical subject as well as on the content that are in vogue in contemporary chemistry.

Annexure 1B: Model Syllabi for Refresher Courses in IKS

Course 1: Course Name: Course on Indian Science and Technology

1. **Fundamentals**
    - An overview of Indian contributions to technology
    - Technological Innovations
2. **Metallurgy, Textile and Chemistry**
    - Copper/Bronze/Zinc: Important Mines (*Zawar*, *Khetri* mines)
    - Iron and Wootz Steel Technology
    - Textile and Dyeing- Indian Specialities (Kutchi Embroidery, Cotton Textile etc.)
    - Chemistry
3. **Pyro technology**
    - Ceramic Technology
    - Stone (Lapidary)
    - Shell, Ivory, Faience & Glass Technology
4. **Water Management**
    - Overview
    - Harappan and Traditional Water Management System of Gujarat
    - Historical Sites- Sringeverpur, South Indian Water Management System, Western Ghats Cave- Kanheri etc.
    - Medieval Period
    - Communities Involved in Water Management
5. **Mathematics**
    - An overview of the Development of Mathematics in India
    - Mathematics contained in the *Sulbasutra*
    - Weaving Mathematics into Beautiful Poetry- *Bhaskaracarya*.
    - The Evolution of Sine Function in India
    - The Discovery of Calculus by Astronomers
    - Concept of proof in Indian mathematics
6. **Astronomy**
    - Vedanga Jyotish
    - Measuring Time & Calendar
7. **Medical Science and Technology**
    - Medical science and its evolution
    - Basic concepts of Ayurveda
    - Ayurveda ethics and code of conduct rules
8. **Ecology and Environment**
    - *Nakshatrara Gyaan* and Agriculture
    - Indigenous Architecture
    - Forest Management and Urban Planning
    - Agroforestry
    - Tank, Lakes, and Stepwells
9. **Transportation**
    - Modes of Transportations and Reforms

- Grand Trunk Road (*Uttarapath & Dakshinapath*)
- Development of Trading Techniques
- Boat & Ship Building

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Text Books:

1. R.M. Pujari, Pradeep Kolhe, N. R. Kumar, 'Pride of India: A Glimpse into India's Scientific Heritage', Samskrita Bharati Publication.
2. 'Indian Contribution to science', compiled by Vijnana Bharati.
3. 'Knowledge traditions and practices of India',Kapil Kapoor, Michel Danino, CBSE, India.

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1. Dr. Subhash Kak , Computation in Ancient India,Mount, Meru Publishing (2016)
2. **Dharampal**, *Indian Science and Technology in the Eighteenth Century*, Academy of Gandhian Studies, Hyderabad, 1971, republ. Other India Bookstore, Goa, 2000
3. Robert **Kanigel**, *The Man Who Knew Infinity: A Life of the Genius Ramanujan*, Abacus, London, 1999
4. Alok **Kumar**, *Sciences of the Ancient Hindus: Unlocking Nature in the Pursuit of Salvation*, CreateSpace Independent Publishing, 2014
5. B.V. **Subbarayappa**, *Science in India: A Historical Perspective*, Rupa, New Delhi, 2013
6. S. **Balachandra Rao**, *Indian Mathematics and Astronomy: Some Landmarks*, Jnana Deep Publications, Bangalore, 3rd edn, 2004
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8. Bibhutibhushan **Datta**, *Ancient Hindu Geometry: The Science of the Śulba*, 1932, repr. Cosmo Publications, New Delhi, 1993
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10. George Gheverghese **Joseph**, *The Crest of the Peacock*, Penguin Books, London & New Delhi, 2000
11. J. **McKim Malville** & Lalit M. **Gujral**, *Ancient Cities, Sacred Skies: Cosmic Geometries and City Planning in Ancient India*, IGNCA & Aryan Books International, New Delhi, 2000).
12. Clemency **Montelle**, *Chasing Shadows: Mathematics, Astronomy and the Early History of Eclipse Reckoning*, Johns Hopkins University Press, 2011
13. Anisha Shekhar **Mukherji**, *Jantar Mantar: Maharaja Sawai Jai Singh's Observatory in Delhi*, AMBI Knowledge Resources, New Delhi, 2010
14. Thanu **Padmanabhan**, (ed.), *Astronomy in India: A Historical Perspective*, Indian National Science Academy, New Delhi & Springer (India), 2010
15. Acharya Prafulla Chandra **Ray**, *A History of Hindu Chemistry*, 1902, republ., Shaibya Prakashan Bibhag, centenary edition, Kolkata, 2002
16. R. **Balasubramaniam**, *Delhi Iron Pillar: New Insights*, Indian Institute of Advance Study, Shimla & Aryan Books International, New Delhi, 2002
17. R. **Balasubramaniam**, *Marvels of Indian Iron through the Ages*, Rupa & Infinity Foundation, New Delhi, 2008

18. Anil **Agarwal** & Sunita **Narain**, (eds), *Dying Wisdom: Rise, Fall and Potential of India's Traditional Water-Harvesting Systems*, Centre for Science and Environment, New Delhi, 1997
19. Fredrick W. **Bunce**: *The Iconography of Water: Well and Tank Forms of the Indian Subcontinent*, DK Printworld, New Delhi, 2013

Course 2: Refresher Courses on IKS based Chemistry and Metallurgy

1 **Theoretical framework for the practice of science in ancient India (12 lectures):**
- *Sāṅkhya-Pātañjala* system: (*Prakṛti* – The original constituents and their interactions; conservation of energy and transformation of energy; the doctrine of causation; principle of collocation, storing and liberation of energy; dissipation of energy and mass and their dissolution into formless *prakṛti*, the evolution of matter; the evolution of infra atomic unit; chemical analysis and synthesis; elements and compounds).
- Evolution of different forms of matter (*Pañcīkaraṇa*) from the *Vedāntic* view.
- The atomic theory of the Buddhists and Jains.
- *Nyāya-Vaiseśika* chemical theory: theory of atomic combinations; chemical combinations, mono and hetero bhautika compounds, theory of dynamic contact (Viśṭambha), chemical action and heat, three axes of *Vācaspati* (graphical representation of the constitution of a bi-*bhautika* compound), conception of molecular motion (*parispanda*)

2 Chemistry in practice as gleaned from the medical schools of ancient India (4 lectures):
- Physical characteristics of the *Bhūtas*, The *Mahābhūtās*, mechanical mixtures.

3 Qualities of compounds; formation of molecular properties in chemical compounds. (5 lectures)

4 Chemistry of colors, measures of weight and capacity, size of the minimum visible. (2 lectures)

5 Ideas of chemistry as in bṛhatsaṁhitā: making of *vajrālepa*/*vajrasamghāta*; *gaṁdhayukti*. (2 lectures)

6 Metallurgical heritage (12 lectures):
- *Arthaśāstra* as the earliest text describing gold, silver and other metals;
- Processing of gold, silver, copper, iron, tin, mercury and lead as mentioned in the Indian texts in the ancient and Medieval period
- Bhasma; A nano-medicine of ancient India

7 Zinc distillation as mentioned in *Rasārṇava* and *Rasaratnasamukāyā*. (4 lectures)

8 Concepts of acid and bases in Indian chemistry from organic fruit, vegetable based. Acids, plant-ash based bases to mineral acids of the medieval period. (4 lectures)

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1 The Positive Sciences of the Ancient Hindus; Brijendra Nath Seal; 4th Edition; 2016

2 Fine Arts & Technical Sciences in Ancient India with special reference to Someśvara's Mānasollāsa; Dr. Shiv Shekhar Mishra, Krishnadas Academy, Varanasi 1982

3 Mints and Minting in India; Upendra Thakur; Chowkhanba Publication; 1972

4 A Concise History of Science in India, ed. D M Bose, S N Sen and B V Subbarayappa; INSA; 2009

5 Science and Technology in Medieval India - A Bibliography of Source Materials in Sanskrit, Arabic and Persian by A Rahman, M A Alvi, S A Khan Ghori and K V Samba Murthy; 1982.

6 Science and Technological Exchanges between India and Soviet Central Asia (Medieval Period), ed B V Subbarayappa;1985

7 Scientific and Technical Education in India, 1781-1900 by S N Sen; 1991

8 History of Technology in India , Vol. I, ed. A K Bag (1997); Vol III, ed. K V Mital (2001); Vol-II by Harbans Mukhia (2012).

Course 3: Course on Indian Economics and Business Model

1. **History of Indian Economy Thoughts**
    - History of Indian Economy Thoughts: Context from *Dharmashastras, Shukraniti, Mahabharata, and Arthashastra*.
    - Kautiya's Economic thoughts in specific. India and Global GDP: Ancient India
2. **New Indian Economic Model**
    - Beyond Capitalism and Communalism, Dharmic, Caste as Social Capital, Black Money, and Tax Heaven.
3. **Sectorial Contribution Past vs Present**
    - Agriculture: Ancient India, Manufacturing: Ancient India, Education in India, Wealth in India, Governance and Business in India, Where India Stands Globally.
4. **Indian Business Model: Based on 10-point formula:**
    - Family Base
    - High Level of Savings
    - Self-Employment
    - Highly Entrepreneurial Nature
    - Non-corporate Sector as the Core of the Economy
    - Community Orientation and Higher Social Capital
    - Faith and Relationship in Economic Affairs
    - A Society-driven Economy
    - Driven by Norms and Values
5. **Project Report: Indian Models of Economy, Business and Management — 1**

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- Economic Sutras by Prof. Satish Y. Deodhar, IIMA Books series
- Black Money Tax Heaven by R Vaidyanathan, Westland ltd. Publication.

Web resources:

- Goswami, Anandajit, Economic Modeling, Analysis, and Policy for Sustainability, IGI Global, Latest Edition.
- GangulyAnirban, Redefining Governance, published by Prabhat Prakashan, Latest Edition.
- VaidyanathanR., India Unincorporated, ICFAI Books, Latest Edition.

Course 4: Course on Ancient Indian Art and Architecture

1. **Fundamentals of Indian**
2. **Art and Architecture**
    - Geography of *Bharatvarsh* and Civilizational Journey

- Origin of *Sthapatyaveda*
- Concept of Space and Time
- Vedic *Yajna*: Recreating the microcosmos
- *Vastu* Purusha
- Six Limbs of Indian Art and Architecture

3. **Exploring the Traditional and Historical Town Planning**
    - Harappan Town Planning
    - Early Historical Cities and Early Text (*Arthshastra*)
    - Mud Forts of Chattisgarh
    - Site Visit to Harappan Cities
4. **Ancient Indian Art & Architecture**
    - Concept of Sacred and Profane
    - Symbolism of *purusha* in Temple Architecture: *shastriya parampara*
    - *Tala-Maan Garana*: Physical Manifestation of Temple Architecture
    - Techno-Typological Evolution & Regional Variations in Temple Architecture
        - Rock Cut Architecture
        - Structural Temple Architecture
    - *Tirthkshetra- Kashi, Dwaraka, Kanchi, Avantika, Ayodhya, Prabhas-kshetra* etc**.**
    - Continuity of Traditional Town Planning: Jaipur, Madurai, Srirangam etc.
    - Functional Aspects of Temples
        - Temple as a living tradition
        - Temple as Cosmopolitan Space: Socio-Economic Entanglement.
5. **Sacred Ecology**
    - Sacred Forest (*Naimisaranya, Panchvati, Dandkaranya* etc.)
    - Sacred Groves (*Aaramika, Devkunj etc*.)
    - Rainwater Harvesting System: *Vav, Kund, Talav* etc.
    - Sacred Hills and Mountains (*Kailash, Vindhyachal, Sahyadri, Satrunjay, Goverdhan*)
    - *Kumbha*: assimilation of ritual, myth, symbology, and cosmology.
6. **Modern Contribution to Indian Architecture**
    - Anand K. Coomaraswamy
    - Patrick Geddess
    - Alice Boner
    - Kapila Vatsayayan
    - Stella Kramrisch
    - Adam Hardy

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- Sathapati, V. Ganapati. 2001. Indian Sculpture and Iconography-Forms and Measurements, Auropublications.

Course 5: Mathematics in India: from Vedic period to modern times

1. **Introductory Overview**
   - Mahāvīrācārya on the all-pervasiveness of Gaṇita. The algorithmic approach of Indian Mathematics. Overview of development of Mathematics in India during the ancient and early classical Period (till 500 CE), later classical period (500-1250) medieval period (1250-1750) and the modern periods (1750- present). Proofs in Indian Mathematics. The genius of Srinivasa Ramanujan (1887-1920).Lessons from History.
2. **Mathematics in the Vedas and Śulva Sūtras**
   - Mathematical references in Vedas. The extant Śulbasūtra texts & their commentaries. The meaning of the word Śulbasūtra. Qualities of a Śulbakāra. Finding the cardinal directions. Methods for obtaining perpendicular bisector. Bodhāyana's method of constructing a square. The Bodhāyana Theorem (so called Pythagoras Theorem)
   - Applications of Bodhāyana Theorem. Constructing a square that is the difference of two squares. Transforming a rectangle into a square. To construct a square that is *n* times a given square. Transforming a square into a circle (approximately measure preserving). Rational approximation for $\sqrt{2}$. Construction of Citis. Details of fabrication of bricks, etc.
3. **Pāṇini's *Aṣṭādhyāyī***
   - Development of Vyākaraṇa or Śabadaśāstra. Pāṇini and Euclid. Method of Pāṇini's *Aṣṭādhyāyī*. Śiva-sūtras and Pratyāhāras. Context-sensitive rules and other techniques of *Aṣṭādhyāyī*. Pāṇini and zero. Patañjali on the method of *Aṣṭādhyāyī*. *Vākyapadīya* on *Aṣṭādhyāyī* as an upāya.
4. **Piṅgala's *Chandaḥśāstra***
   - Development of Prosody or Chandaḥśāstra. Long (guru) and short (laghu) syllables. Scanning of Varṇavṛtta and the eight Gaṇas. Pratyayas in Piṅgala's *Chandaḥśāstra*. Prastāra or enumeration in the form of an array. Saṅkhyā or the total number of metrical forms of *n* syllables. Naṣṭa and Uddiṣṭa (the association between a metrical form and the row-number in the prastāra through binary expansion). Lagakriyā or the number of metrical forms in the prastāra with a given number of Laghus. Varṇameru and the so called "Pascal Triangle".
5. **Mathematics in the Jaina Texts**
   - Place of Mathematics in Jaina literature. Important Jaina mathematical works. Jaina geometry. Circumference of a circle. Area of a circle. Relation between chord, śara (arrow) and diameter, etc. Approximation for the value of π. Notion of different types of infinity. The law of indices. Permutations and Combinations.
6. **Development of Place Value System**
   - Earliest evidence of the use of place value system. Numerals found in the inscriptions (Brāhmi & Kharosṭhi). Use of Zero as a symbol in Piṅgala's *Chandaḥśāstra*. References to use of decimal place value system in the commentary *Vyāsabhāṣya* on *Yogasūtra* and in Southeast Asian Inscriptions. Different systems of numeration employing place value system. Bhūtasaṅkhyā system. Āryabhaṭan system. Kaṭapayādi system. Algorithms for arithmetical operations based on decimal place value system.
7. ***Āryabhaṭīya* of Āryabhaṭa**
   - Āryabhaṭa, his period and his work *Āryabhaṭīya*. Names of the notational places. Square and Squaring. Algorithm for finding the square root. Cube and cubing. Algorithm for

finding the cube root. Formula for the area of a triangle. Bhāskara I on altitude and area of a triangle. Numerical examples

- Area of a circle, trapezium and other planar figures. Approximate value of π. Computation of tabular Rsines (geometric and difference equation methods). Approximate formula for Rsine (as given by Bhāskara I). Problems related to gnomonic shadow. Bhujā-koṭi-karṇa-nyāya, jyā-śara-nyāya and their applications. Arithmetic progressions. Finding sum of natural numbers, sum of sums, and so on.
- Some algebraic identities. Rule of three. Problems on interest calculation. Ekavarṇa-samikaraṇa and anekavarṇa-samikaraṇa. The Kuṭṭaka problem (sāgra and niragra-kuṭṭaka). Illustrative examples.

8. *Brāhmasphuṭasiddhānta* of Brahmagupta

- Introduction. Twenty logistics. Cube root. Rule of Three, Five Seven, etc. Mixtures. Interest calculations, etc. Progressions: Arithmetic and Geometric. Plane figures. Triangles, right triangles and quadrilaterals.
- Diagonals of a Cyclic quadrilateral. Rational triangles and quadrilaterals. Chords of a circle. Volumes with uniform and tapering cross-sections. Pyramids and frustum. Shadow problems.
- Mathematical operations with plus, minus and zero. Rules in handling surds (karaṇī) Operations with unknowns (avyakta-ṣaḍvidha). Equations with single unknowns (ekavarṇa-samīkaraṇa). Equations with multiple unknowns (anekavarṇa-samīkaraṇa). Equations with products of unknowns (bhāvita). Brahmagupta on kuṭṭaka. The Second order indeterminate equation (Vargaprakṛti). Bhāvanā principle and its applications.

9. Bakṣālī Manuscript

- The discovery of Bakṣālī Manuscript. Its antiquity and uniqueness. Use of symbols. Symbol for negative sign (kṣaya). Symbol for denoting unknown quantities (yāvatāvat). Solution of indeterminate equations. Formula for approximate value of surds. Some interesting problems involving simultaneous equations.

10. *Gaṇitasārasaṅgraha* of Mahāvīra

- Introduction. Arithmetical operations, operations with zero. Squares, cubes, square roots, cube roots. Arithmetical and Geometric progressions, Citi (summation). Manipulations with fractions and solutions of equations. Mixed problems including interest calculations.
- Vallīkāra-kuṭṭākara – linear indeterminate equations. Two and more simultaneous indeterminate equations. Other indeterminate equations. Vicitra-kuṭṭākara – Truthful and untruthful statements. Sums of progressions of various types. Variable velocity problem
- Plane figures**:** Circle**,** Dīrghavṛtta, Annulus. Ratio of circumference and diameter. Segment of a circle. Janya operations: rational triangles, quadrilaterals. Excavations: Uniform and tapering cross-sections, volume of a sphere. Time to fill a cistern. Shadow problems.

11. Development of Combinatorics

- Combinatorics in Āyurveda. Gandhayukti of Varāhamihira Mātrā-vṛttas or moric metres. Prastāra or enumeration of metres of *n*-mātrās in the form of an array. Saṅkhyā or the total number of metrical forms of given number of mātrās. The Virahāṅka sequence (so called Fibonacci sequence. Naṣṭa and Uddiṣṭa processes for finding the metrical form given the row-number and vice versa in a prastāra. Mātrā-meru to determine the number of metrical forms with a given number of gurus. Representation of any number as a sum of Virahāṅka numbers.

- *Saṅgīta-ratnākara* of Śārṅgadeva (c.1225). Tāna-Prastāra or enumeration of permutations or tānas of svaras. Prastāra, the rule of enumeration of permutations in the form of an array. Khaṇḍameru and the processes of naṣṭa and uddiṣṭa. Factorial representation of Śārṅgadeva. Tāla-Prastāra: Enumeration of tāla forms. The tālāṅgas: Druta, Laghu, Guru and Pluta and their values. Prastāra: Rule of enumeration of all tāla-forms of a given value. Saṅkhyā and the Śārṅgadeva-sequence of numbers. The processes of naṣṭa and uddiṣṭa. Representation of natural numbers as sums of Śārṅgadeva-numbers. Laghu-Meru. The general relation between prastāra and representation of numbers.

12. *Līlāvatī* of Bhāskarācārya

- Introduction. Importance of *Līlāvatī*. Arithmetical operations: Inversion method, rule of supposition. Solution of quadratic equations. Mixtures. Combinations, progressions.
- Plane figures**:** Right triangles, applications. Sūcī problems. Construction of a quadrilateral: Discussion on earlier confusions. To find the second diagonal, given the four sides and a diagonal of a quadrilateral. Cyclic quadrilaterals. Value of π, area of a circle, surface area of a sphere, volume of a sphere
- Regular polygons inscribed in a circle. Expression for a chord in a circle. Excavations and contents of solids. Shadow problems (advanced problems). Importance of rule of proportions. Combinations (advanced problems).

13. *Bījagaṇita* of Bhāskarācārya

- Development of Bījagaṇita or Avyaktagaṇita (Algebra) and Bhāskara's treatise on it. Understanding of negative quantities. Development of algebraic notation. The Vargaprakṛti equation $X^2 - D Y^2 = K$, and Brahmagupta's bhāvanā process. The Cakravāla method of solution of Jayadeva and Bhāskara.
- Bhāskara's examples $X^2 – 61Y^2 = 1$, $X^2 – 67Y^2 = 1$. The equation $X^2 - D Y^2 = -1$. Solution of general quadratic indeterminate equations. Bhāskara's solution of a bi-quadratic equation.
- Review of the Cakravāla method. Analysis of the Cakravāla method by Krishnaswami Ayyangar. History of the solution of the "Pell's Equation" $X^2 - D Y^2 = 1$. Solution of "Pell's equation" by expansion of $\sqrt{D}$ into a simple continued fraction. Bhāskara semi-regular continued fraction expansion of $\sqrt{D}$. Optimality of the Cakravāla method.

14. ***Gaṇitakaumudī* of Nārāyaṇa Paṇḍita**

- Importance of *Gaṇitakaumudī*. Solutions of quadratic equations. Double equations of second and higher degree – rational solutions. Determinations pertaining to the mixture of things. Interest calculations – payment in installments
- Meeting of travelers. Progressions. Vārasaṅkalita: Sum of sums. The kth sum. The kth sum of a series in A.P. The Cow problem. Diagonals of a cyclic quadrilateral – Third diagonal, area of a cyclic quadrilateral. Construction of rational triangles with rational sides, perpendiculars, and segments whose sides differ by unity. Generalisation of binomial coefficients and generalized Fibonacci numbers.
- Vargaprakṛti. Nārāyaṇa's variant of Cakravāla algorithm. Solutions of Vargaprakṛti and approximation of square roots. Bhāgadāna: Nārāyaṇa's method of factorisation of numbers. Aṅkapāśa (Combinatorics). Enumeration (prastāra) of generalised mātrā-vṛttas (moric metres with more syllabic units in addition to Laghu and Guru). Some sequences

(paṅkti) and tabular figures (meru) used in combinatorics. Enumeration (prastāra) of permutations with repetitions. Enumeration (prastāra) of combinations.

15. Magic Squares

- The earliest textual references and references in inscriptions. The sarvatobhadra square of Varāhamihira. Nārāyaṇa's classification of magic squares into samagarbha (doubly-even numbers of the form 4m), viṣamagarbha (singly-even or numbersof the form 4m + 2) and viṣama (odd). Use of Kuṭṭaka to find the arithmetic sequences to be used in magic squares. 4x4 Pandiagonal magic squares of Nārāyaṇa.
- Ancient method for the construction of odd magic squares and doubly even squares. The folding method (sampuṭīkaraṇa) of Nārāyaṇa for samagarbha squares. The folding method for Viṣama squares. Illustrative examples.

16. **Kerala School of Astronomy and Development of Calculus**

- Background to the Development of Calculus (c.500-1350). The notions of zero and infinity. Irrationals and iterative approximations. Second order differences and interpolation in computation of Rsines. Summation of infinite geometric series. Instantaneous velocity (tātkālika-gati). Surface area and volume of a sphere. Summations and Repeated summations (saṅkalita and vārasaṅkalita). The Kerala School of Astronomy and the Development of Calculus. Mādhava (c. 1340-1420) and his successors to Acyuta Piśārați (c. 1550-1621). Nīlakaṇṭha (c.1450-1550) on the irrationality of π. Nīlakaṇṭha and the notion of the sum of infinite geometric series. Binomial series expansion. Estimating the sum $1^k + 2^k + ... n^k$ for large n.
- Mādhava Series for π. End-correction terms and Mādhava continued fraction. Transformed series for π which are rapidly convergent. History of Approximations to π. Nīlakaṇṭha's derivation of the Āryabhaṭa relation for second-order Rsine differences. Mādhava series for Rsine and Rcosine. Nīlakaṇṭha and Acyuta formulae for instantaneous velocity.
- Āryabhaṭa's sine table (makhi, bhaki, phaki…). Āryabhaṭa 's recursion relation and the approximation involved in it. Attempts to improve the sine values by Lalla, Govindasvāmi, Vaṭeśvara, etc. Bhāskara's formula for $\sin(A + B)$ and its application. The refined recursion relation in *Tantrasangraha* and its commentary. Mādhava's sine series and the use of mnemonics vidvān, tunnabala etc. Mādhava's sine table. Comparison of sine-tables of Āryabhaṭa, Govindasvāmi, Vaṭeśvara and Mādhava.

17. Trigonometry and Spherical Trigonometry

- Crucial role of trigonometry in astronomy problems. Indian sines, cosines : Bhujājyā, Koṭijyā, sine tables. Interpolation formulae. Determination of the exact values of 24 sines. Bhāskara's Jyotpatti sin (18º), sin (36º).
- Sine of difference of two angles. Sines at the interval of 3º, 1.5º. Jīve-paraspara-nyāya. Sines at the interval of 1º. Trigonometry in later texts such as *Siddhāntatattvaviveka* of Kamalākara
- Spherical trigonometry in astronomy: Tripraśna problems. Applications to specific diurnal problems: Duration of day (carajyā), Time from shadow. Systematic treatment of spherical trigonometry problems in Nīlakaṇṭha's *Tantrasaṅgraha*. Proofs of *Tantrasaṅgraha* results in *Yuktibhāṣā.*

18. **Proofs in Indian Mathematics**

- Upapattis or proofs in Indian mathematical tradition. Early European scholars of Indian Mathematics were aware of upapattis. Some important commentaries which present upapattis. Bhāskarācārya II on the nature and purpose of upapatti. Upapatti of bhujā-koṭi-karṇa-nyāya (Baudhayana-Pythagoras theorem). Upapatti of kuṭṭaka process. Restricted use of tarka (proof by contradiction) in Indian Mathematics. The Contents of *Gaṇita-yukti-bhāṣā*. *Yukti-bhāṣā* demonstration of bhujā-koṭi-karṇa-nyāya. Estimating the circumference by successive doubling of circumscribing polygon.
- Expression for abādhās, area and circum-radius of a triangle. Theorem on the sum of the product of chords (jyāsaṃvarga-nyāya). Theorem on the difference of the squares of the chords (jyāvargāntara-nyāya). From jyāsaṃvarga-nyāya to jyotipatti (generation of tabular sines). The cyclic quadrilateral. Expression for the diagonals in terms of the sides. Expression for the area in terms of the diagonals. Expression for the area and circum-radius in terms of the sides.
- *Yuktibhāṣā* estimate of the samaghāta saṅkalita $1^k + 2^k + ... n^k$ for large *n*. *Yuktibhāṣā* estimate of Vārasaṅkalita. *Yuktibhāṣā* derivation of Mādhava Series for π. *Yuktibhāṣā* derivation of end-correction terms. *Yuktibhāṣā* derivation of Mādhava Rsine and Rcosine Series. Upapatti and "Proof". Lessons from history.

19. Mathematics in Modern India

- Continuing tradition of Indian Astronomy and Mathematics (1770-1870). Surveys of indigenous education in India (1825-1835). The Orientalist-Anglicist debate shaping the British policy on education (c.1835). Survival of indigenous education system till 1880. Modern Scholarship on Indian Mathematics and Astronomy (1700-1900). Rediscovering the Tradition (1850-1900). Development of Higher Education and Modern Mathematics in India (1850-1910). Srinivasa Ramanujan (1887-1920). Brief outline of the life and mathematical career of Ramanujan. Hardy's assessment of Ramanujan and his Mathematics (1922, 1940). Some highlights of the published work of Ramanujan and its impact. Selberg's assessment of Ramanujan's work (1988). The saga of Ramanujan's Notebooks. Ongoing work on Ramanujan's Notebooks. The enigma of Ramanujan's Mathematics. Ramanujan not a Newton but a Mādhava.
- Rediscovering the tradition (1900-1950). Rediscovering the tradition (1950-2010). Modern scholarship on Indian Mathematics (1900-2010). Development of modern mathematics in India (1910-1950). Development of modern mathematics in India (1950-2010). Development of higher education and scientific research in India (1900-1950). Development of higher education and scientific research in India (1950-2010). Comparison with global developments.

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2. C. N. Srinivasiengar, *History of Indian Mathematics*, The World Press, Calcutta 1967.
3. T. A. Saraswati Amma, *Geometry in Ancient and Medieval India*, Motilal Banarsidass,

Varanasi 1979.

4. S. Balachandra Rao, *Indian Mathematics and Astronomy: Some Landmarks*, 3rd Ed. Bhavan's Gandhi Centre, Bangalore 2004.
5. G. G. Emch, M. D. Srinivas and R. Sridharan, Eds., *Contributions to the History of Mathematics in India*, Hindustan Book Agency, Delhi, 2005.
6. C. S. Seshadri, Ed., *Studies in History of Indian Mathematics*, Hindustan Book Agency, Delhi 2010.
7. G. G. Joseph, *Indian Mathematics Engaging the World from Ancient to Modern Times*, World Scientific, London 2016.
8. P. P. Divakaran, *The Mathematics of India Concepts Methods Connections*, Hindustan Book Agency 2018. Rep Springer New York 2018.
9. *Gaṇitayuktibhāṣā* (c.1530) of Jyeṣṭhadeva (in Malayalam), Ed. with Tr. by K. V. Sarma with Explanatory Notes by K. Ramasubramanian, M. D. Srinivas and M. S. Sriram, 2 Volumes, Hindustan Book Agency, Delhi 2008.

Course 6: Basics of Indian Astronomy

1. Introduction

- The science of Astronomy. Astronomy as one of earliest sciences; observational astronomy in the Vedic corpus. Emergence of Jyotiḥśāstra encompassing the three skandhas of Gaṇita (Astronomy), Horā (Horoscopic Astrology and Saṃhitā (Omens and Natural Phenomena). The purpose of Astronomy—as stated in the texts. Contents of a typical Indian astronomical *Siddhānta* text. Broad classification of the texts in Indian astronomy. Names of some of the prominent astronomers and their important contributions. Highlight the continuity of the Indian astronomical tradition (1400 BCE – 19th cent CE).

2. The different units of time discussed in the texts

- Brief introduction to the concept of time (approach of physics and philosophy). Quote from Bhāskara I's commentary at the beginning of Kālakriyā; also quote the verse in the famous text *Sūryasiddhānta*. Recount the currently used units of time—duration of year, month, week, etc. in the Gregorian calendrical system—subtly point out that they do not have any astronomical basis whatsoever. Introduce the different shorter units of time discussed in Indian astronomical texts year, month, fortnight, *tithi*, etc. Introduce larger units or time like *yuga, mahāyuga, manvantara* and *kalpa*.

3. Systems employed for representing numbers

- Highlight the need for having different systems for representing numbers in those days. Explain the three systems adopted - *Bhūtasaṅkhyā, Kaṭapayādi and Āryabhaṭīyapaddhati*. With illustrative examples, bring out their beauty and ingenuity. Briefly discuss the advantages in each of these systems.

4. Spherical trigonometry

- Introduce the notion of shortest path on a non-Euclidean surface. Definition of great circle, small circle, spherical triangle, etc. Their illustration using the Earth as an example, which the students will be familiar with. Compare and contrast the properties of a spherical triangle with a planar triangle. Derive the cosine and sine formula from 'first' principles. Introduce the four-part formula. Work out a few illustrative problems (such as distance travelled by a flight along the great circle arc, small circle arc, etc) that would help visualise the circles on a sphere, as well as assimilate the application of the formulae. Demonstrate how to derive the sine formula simply using the planar triangles, and their projections inside the sphere.

5. Celestial Sphere

- The notion of celestial sphere and the need for its conception. The different coordinate systems (horizontal, equatorial and ecliptic) employed. The range of the coordinates in each of these systems. The advantages and disadvantages of one system over the other. Some illustrative examples for converting one set of coordinates into another. Indian names for the fundamental circles and the coordinates used in these systems.

6. What is *Pañcāṅga*?

- Division of the celestial sphere/ecliptic into 12 and 27 equal parts — *rāśi* and *nakṣatra* division. Explain their significance by pointing out their basis; that is, they are connected with the duration of 12 lunar months and the period of moon's revolution around the earth, and not introduced arbitrarily. Explain the five elements that constitute *Pañcāṅga* – and also bring out their astronomical significance. Also point out that they are essentially different units of time. Illustrate with numerical examples the computation of these elements in a *Pañcāṅga*. Explain how to compute the average period of a lunar month; Bring out the need for the introduction of an *adhikamāsa* in the calendrical system. Outline the broad categories into which different calendars that are followed can be put into— namely solar, lunar and luni-solar.

7. Key concepts pertaining to planetary computations

- The revolution numbers of various planets, nodes, apogees, etc.; The count of the number of civil days, *adhikamāsas*, etc. in a *mahāyuga*. Introduce the concept of Ahargaṇa, and its significance; The basis for choice of epoch. Calculation of *Ahargaṇa*; Illustration with a few numerical examples choosing contemporary dates – using *siddhāntic* text (to begin with). Explain the computation of mean motion of planets, and how its computation along with the *Ahargaṇa* can help in finding the mean position of planets.

8. Computation of the true longitudes of planets

- Provide an overview of the steps involved in the computation of the true longitudes. Explain *manda-saṃskāra* in detail using epicyclic model and eccentric model. Outline the nature of the resultant orbit, etc, and explain how this correction takes into account the eccentric nature of the planetary orbit. Emphasise and make the students appreciate the simplification achieved in computation by the 'constraint' $r/R = r_0/R$. Explain *śīghra-saṃskāra* in detail; Point out how this correction boils down to the transformation of the heliocentric coordinates to geocentric. Also indicate how this simple model takes care of the retrograde motion of the planets. Bring out the distinction between the inner and outer planets.

9. Precession of equinoxes – *sāyana* and *nirayaṇa* longitude

- Introduce the concept of precession of equinoxes. Explain solsticial and equinoctial points, and connect them to the concept of *uttarāyaṇa* and *dakṣiṇāyana* in the Indian calendrical system. Derive the formula for finding the declination of the sun on any day at any time, and also illustrate it with examples. Also highlight how crucial its accurate computation is for the computation of various other quantities precisely — including the problem of finding the direction and the latitude of the place — even if we choose to do them by experimental methods.

10. Finding the cardinal directions and the latitude of a place

- Introduce *śaṅku* (the gnomon), and explain how it has to be prepared as described in the texts. Describe the experimental set up that has to be made meticulously for conducting experiments with *śaṅku* and doing shadow measurements. Explain how with a very simple experiment the directions at a given place can be easily and precisely determined. Also point out that this experimental method is very old—described even in the *Śulbasūtras*. Also outline the theoretical basis for the formula that has been given for correcting the points marked in connection with determination of the direction using *śaṅku*. Bring out the versatility of this simple device *śaṅku* in determining a variety of physical quantities of interest including the latitude of the place. Explain the concept of parallax in general, and how it introduces an error – that is unavoidable in conducting this experiment for determining the latitude of the place. Outline the corrections that have been prescribed in the text that would take into account the above error, as well as the fact that sun is not a point source of light.

11. Determination of the variation of the duration of the day at a given location

- Introduce the 6'o clock circle and its significance. Derive the formula for the hour angle at sunset, and explain how the latitude and the declination of the sun play a role in it.

Explain the concept of *cara* as outlined in the Indian astronomical texts that captures the variation in the duration of the day at a given location. Present the formula for determining the local time using shadow measurements. Also outline how *cara* plays a role in determining this local time. Bring out the distinction between this local time and the standard time that we are generally familiar with and generally keep track of.

12. *Lagna* and its computation

- Introduce the concept of *lagna*, and how non-trivial a problem it is to determine it precisely. Also point out how this is deeply connected with fixing times for various social and religious functions such as marriage, etc. Bring out the connection between its computation and the computation of declination, *cara* etc. that would have been discussed before. Explain how this can be determined 'reasonably' accurately using interpolation. Also outline more precise formulations that have been given by later astronomers by introducing the notion of *kālalagna*.

13. Eclipses and their computation

- Briefly explain the phenomenon of lunar and solar eclipses, and the crucial role played by the position of the lunar nodes in their computation. Also bring out how difficult it is to precisely determine the position of the nodes—as they are not physical objects available for observation. Explain how the latitude of the moon is computed, and then outline the procedure for the determination of the semi-diameters of the eclipsing and the eclipsed bodies. Derive the simple formula for determining the duration of eclipses as well as the obscuration. Also mention that iterative procedures are followed to improve accuracy. Point out the role of parallax in the determination of solar eclipses.

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2. S. Balachandra Rao, *Indian Astronomy An Introduction*, Universities Press, Hyderabad, 2000
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Course 7: Introduction to Indian Astronomy

SEMESTER I

1. **Preliminaries**
   - Sky viewed as the inside of a hemisphere. Cardinal directions, zenith, horizon, pole star at any location. Daily motion of celestial objects (Sun, Moon, planets, stars) and diurnal circles. Motion in the stellar background. Ecliptic. Basic time units: Day, Month and Year. Celestial coordinates and elementary spherical trigonometry. Cosine and Sine formulae. Horizontal (z,A), Equatorial (δ, α and H), and Ecliptic (λ, β) systems. $\cos z = \sin \varphi \sin \delta + \cos \varphi \cos\delta \cos H$, and other relations. Planetary positions.
2. **Developments from the Vedic period up to the *Siddhāntic* period**
   - *Vedic Astronomy:* Astronomical concepts in Vedic literature regarding Sun, Moon, Stars, Earth. Months, seasons, year. 27 *nakṣatras*. Ecliptic and *ayana*. Planets, Comets etc. Pole star in an earlier era. *Nakṣatra* division of the ecliptic and motion of the Sun along it in *Vedāṅga Jyotiṣa* (VJ) and other texts. VJ calendar. VJ computations. Duration of a day. Better value for an year in Vedic literature.
   - *Siddhāntic astronomy*: Earlier *Siddhāntas* and *Pañcasiddhāntikā*. Introduction of trigonometry, Indian *jyā*–astronomy. *Āryabhaṭīya* . *Mahāyuga*. (*Kalpa* etc., and also smaller units of time can be introduced at this stage). Revolution numbers of planets. *Ahargaṇa* and Mean longitudes, Examples. Obtaining the true longitudes by applying corrections to mean longitudes.
   - Epicycle models: *Manda* correction (Equation of centre) in detail. Its significance. Latitude of Moon.
   - *Śīghra* correction to planets and its significance: Essential features only with the aid of diagrams and final formulae. Latitudes of planets.

     Precession of equinoxes— *Nirayana* and *Sāyana* longitudes.
   - Nature and organisation of texts. *Sūtra* (algorithmic) format. *Siddhānta*, *Tantra*, *Karaṇa* and *Vākya* texts. *Sāraṇis* or Tables.
3. **Indian Calendar**
   - *Pañcāṅga*. *Adhikamāsas*. Solar and Luni-Solar systems.
4. **Solar and Lunar Eclipses**
   - Angular diameters of the Sun, Moon and Earth's shadow. Possibility of eclipses. Finding the middle of an eclipse by iteration. Amount of obscuration at any time.
5. **Tripraśna Topics (Diurnal problems)**
   - Description of the celestial spheres and various circles. Similarity to modern description. Determination of the East-West directions. Derivation of the expression for the declination in terms of the longitude. Shadow of a gnomon. Equinoctial day when the locus of the tip of the shadow is a straight line. Finding the latitude. Mid-day shadow. Finding the declination. Relation between the time and the shadow at an arbitrary instant (no derivation).

SEMESTER II

1. **Planetary longitudes and latitudes and Nīlakaṇṭha Somayājī's revised planetary model**
   - True longitudes of planets: *Manda* and *Śīghra* corrections in detail. Geometrical description. Comparison with Kepler's model. Latitudes of planets.
   - Nīlakaṇṭha Somayājī's revision of the planetary model: Nīlakaṇṭha's analysis of the motion of the interior planets (Mercury and Venus). His geometrical model which is geometrically similar to the Tycho Brahe model (planets moving around the Sun which itself orbits the Earth), but computationally approximates the Kepler model.
2. **Rates of motion of planets**
   - Idea of derivative in finding the *Mandagatiphala* (*manda*-correction to the mean rate of motion). The correct formula due to Nīlakaṇṭha. True rates of motion of planets: Correct expression due to Bhāskara. Application to calculate retrograde motion of planets.
3. ***Tripraśna* topics**
   - Latitudinal triangles (of Bhāskara) and applications. *Agrajyā* or the distance between rising-setting line and the east-west line. Correction to the east-west line due to change in Sun's declination. Zenith distance in terms of the declination, hour angle and latitude ($\cos z = \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos H$). Derivation of this formula as in S*iddhāntaśiromaṇi*. Relation among *Śaṅkutala* (*Śaṅkvagra*), *Bhujā*, *Agrajyā* and its applications.
4. **Rising times of *Rāśis* and finding *Lagna***
   - Relation between the right ascension and longitude and rising times of *rāśis* at the equator. Rising times at an arbitrary latitude. Finding the *Lagna* at any instant after Sunrise (approximate).
5. **Eclipse calculations**
   - Details of calculations of the middle of a lunar eclipse and half-durations iteratively, using the correct expression for the rate of motion of the Moon. Parallax and the calculation of the middle of a solar eclipse.
6. **The *Vākya* system**
   - Longitude of the Sun from the 'subtractive minutes' at any time ('*Bhūpajña* etc. *vākyas*). *Vākyas* for zodiacal transit times ('*Śrīrguṇamitra*' etc.). Longitude of the Moon using the *Candravākyas* ('*gīrnaśreyaḥ*' etc). More accurate values due to Mādhava.
7. **Astronomical Instruments**
   - Gnomon . *Cakra* and *Dhanur* yantras for measuring the zenith distance of the Sun. Approximate and exact times from a '*yaṣṭi*'. *Phalakayantra* to measure the hour angle. Equatorial sundial to measure time. Clepsydra for measuring time. Celestial globe and Armillary sphere for explaining celestial coordinates and various circles.
8. **Indian Astronomy in the 18th and 19th centiries**
   - Astronomical endeavours of Savai Jayasiṃha. *Samrat-yantra* and other instruments in the observatories of Jayasiṃha. European observers on the simplicity and accuracy of Indian eclipse computations. The work of Śaṅkaravarman and Candraśekhara Sāmanta. Efforts to update the Indian calendar.

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