Unit-I
History of Physics in India

I. Physics in Vedas:

- **Atomic Theory from Bhagavad-Gita**

Which Indian invented atomic theory?

Acharya Kanad

However, the atomic theory was formulated 2500 years before Dalton which was given by an Indian sage and philosopher. - The Indian sage who gave the atomic theory was Acharya Kanad.

Who is the real father of atomic theory?

John Dalton, (born September 5 or 6, 1766, Eaglesfield, Cumberland, England—died July 27, 1844, Manchester), English meteorologist and chemist, a pioneer in the development of modern atomic theory

From the 19th century to the 21st century everyone knows John Dalton who is credited with the development of atomic theory.

But today in this era a very few people know that the atomic theory was originated about 2,600 years ago by an Indian sage and philosopher. It is believed that the sage lived between the 6th century to 2nd century BCE.

It was ***Rishi Kanada***, an Indian philosopher who drafted the ideas about the atom in a systematic manner. His real name was to be known as "**Kashyap**". Since his childhood, even small things tempted his attention. He is being been called as *the father of the atomism*, who propounded the *parmanu* (atoms), an approach to physics and philosophy in the approach to physics and philosophy in the Sanskrit text "***Vaisesika Sutra***".

Ideas about the atomic theory: -

Kanada's statements about physics are central that is knowable which is based on motion. His imputation to physics is the understanding of the universe which follows from his invariance principles.

Observations and theories: -

His primary area of study was *Rasavadam*, which is known to be a type of alchemy. He said that he presumed that all livings beings are composed of 5 elements: water, fire, earth, air, and ether. He proposed that ***Gurutva*** (Hindi/Sanskrit for gravity) was responsible for the earth, rising of fire and heat upwards, the growth of grass, the natural rainfall, and thunderstorm. He then attempted to apply his observations with his theories on atoms, molecules, and their interaction. This atom between the 5th and 3rd centuries BC, the atom is mentioned in the Bhagavad Gita (chapter 8).

The concept of anu(atom):-

Kanada propounded that parmanu (atom) is an indestructible particle of matter. The atom is indivisible because it is a state at which no measurement can be assigned. It is also believed that Kanada who also founded the school of philosophy considered the atom to be indestructible and hence eternal.

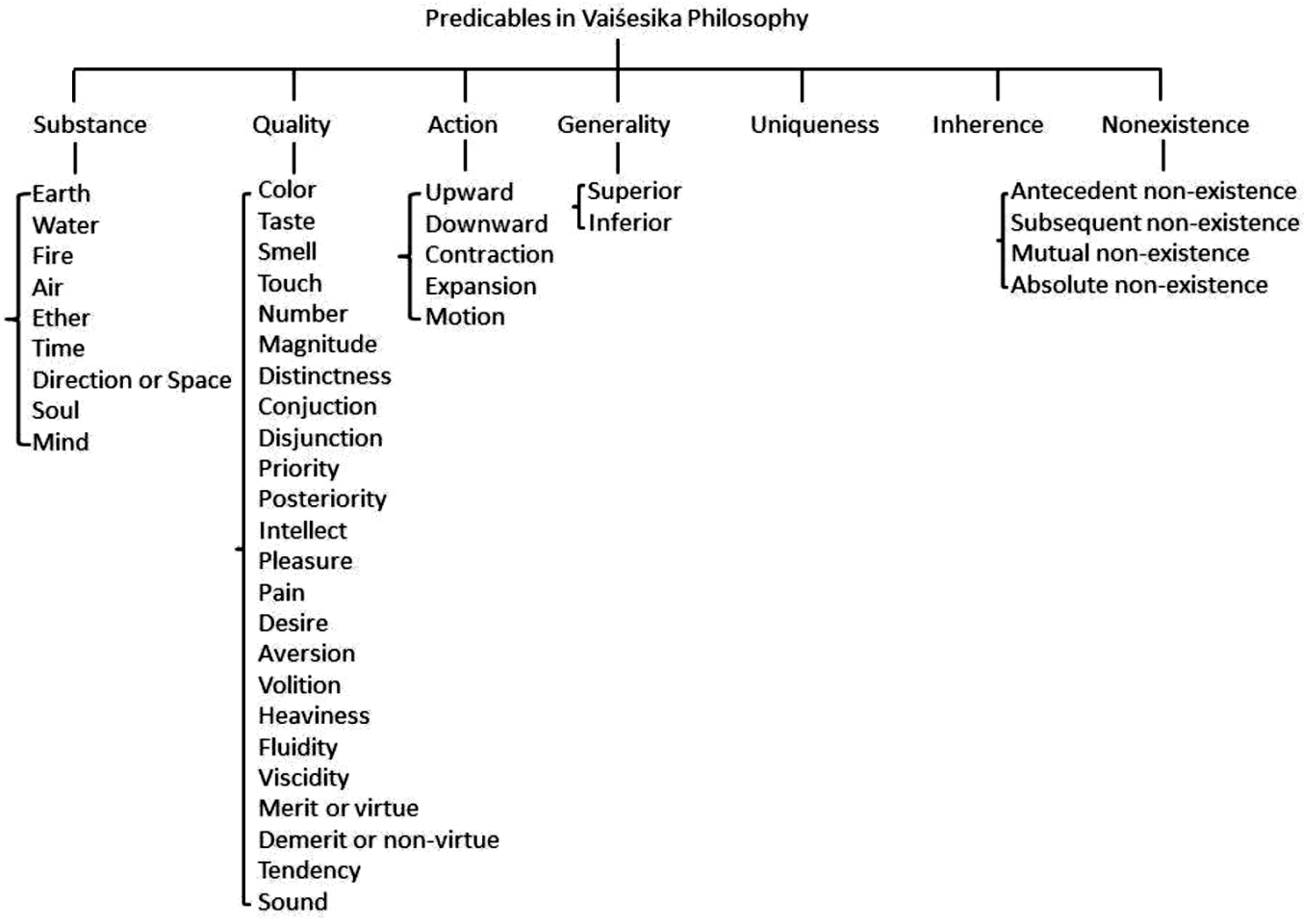
They observed that atoms which are very minute objects are invisible to the human being's naked eyes which come into being and vanish in an instant.

Vaiseshikas further claimed that atoms of the same substance combined with each other create ***dvyanuka***(diatomic molecules) and ***tryanuka***(triatomic molecules).

Kanada also further put forward that the idea of atoms could be combined in various ways to produce chemical changes in the presence of other factors such as heat.
He gave an example of the blackening of earthen pot and ripening of fruit for this phenomenon. *Kanada's* perception about the atom was likely independent from the similar concept among the ancient Greeks, because of the differences between the theories. For example, *Kanada* recommended that atoms as buildings blocks differ both qualitatively and quantitatively; while Greeks suggested the atoms differed only quantitatively but not qualitatively.

Physics is related to matter in the Indian **Nyaya-Vaisheshika** school, which will subsequently be called "Indian physics". **Kanada**, the originator of **Vaisheshika**, begins by claiming that "classification of things" is the primary task in his system. The purpose of this classification is to define material things. The understanding is to be arrived at using 'tattva-jnana', or ascertainment of attributes of reality by categorizing everything in to one or the other among six predicable padartha, logical categories. Indian physics considers both the objective universe, which is taken to be atomic, and the subjective universe of the experimenter or the observer, which is taken to be non-atomic. In other words, it presents a dualistic view where that the observed matter is atomic whereas the observing mind and time and space in which the universe exists is continuous.

We begin by noting that the concept of 'tattva-jnana' or 'ascertainment of reality' is the principle that there is no thought (or conceptual framework) that cannot be expressed. Everything that can be stated belongs to the highest class of knowledge called padartha, or "predicable", which is describable and hence nameable. Such nameables, classified to six categories, form the basis of physics.



Teachings of Vaisesika

Kanada then began his treatise with,

अथातो धर्म्म व्याख्यास्याम: (athato dharma vyaksyanam)

meaning, now (atha) we shall explain (vyaksa) Dharma or religion. Why did he want to explain Dharma? Because, Dharma is that from which results the supreme good. Here, the supreme good is nothing but the liberation of soul.

Fundamental teaching of Viasesika is;

तत्व ज्ञानात्नि: श्रेयशम् (tattva-jnanat-nihshreyasam)

meaning unsurpassed good comes from the knowledge of soul. According to Kanada, soul can be known by means of not-soul. In Vaisesika, the soul and not-soul make up reality. Realities are entities that have an existence antecedent to, and independent of our thought. He called them 'padharthas or predictable; as they are knowable and nameable. Kanada, by a subtle process of analysis, categorized the infinitely diverse universe into six predicables. They are;

(i) Dravya or substances,
(ii) Guna or quality,
(iii) Karma or action,
(iv) Sāmānya or generality,
(v) Viśesa or uniqueness or particularity,
(vi) Samavāya or inherence.

Knowledge of essence of these six predicable, according to Kanada, releases oneself from the coil of sufferings and mortality. He then elaborated on these predicables. He did not indulge in intellectual speculations about origin of things, rather tried to explain rationally the true nature of things.

Around 10th century, Vedic scholars included another predicable,

(vii) Abhāva or non-existence.

- **History of Electricity: From Ancient Times to the Modern Times**

Electricity is an essential part of our daily lives, powering everything from our smartphones to the appliances in our homes and the machines in our workplaces. However, the history of electric charges goes back several centuries, beginning with the ancient Greeks, who discovered the phenomenon of static electricity. Over time, scientists and inventors made significant contributions to the development of electrical technology, paving the way for the modern era of electricity.

Electricity has become an important part of our life. It is quite impossible to imagine life without electricity now a days. Electricity from thunder and lightning has also fascinated us since primitive ages. We are still working on how to safely store and use the enormous electric energy discharged from thunder and lightning. We have ample evidence which proves the use of electricity and battery way back around 10000 – 8000 BCE.

People in ancient times were well aware about electricity. Electricity has been cited in the 5th Mandal of Ṛigveda. Example: Oh people! The day and night can be spent in comfort, if electricity and fire, just like the Sun God are used tactically.

सुपेशसं माव सृजन्त्यस्तं गवां सहस्रै रुशमासो अग्ने ।

तीव्रा इन्द्रममन्दुः सुतासोऽक्तौर्व्युष्टौ परितक्म्यायाः ॥

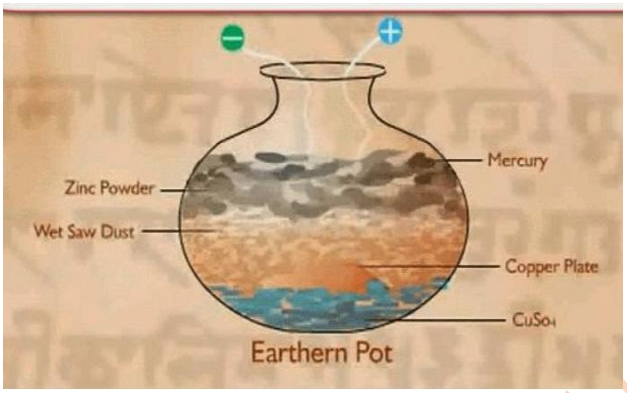
ऋग्वेद – ष्.३०.१३

The three main sources of Light and Energy mentioned in the Ṛigveda are:

1. The Sun
2. Electricity
3. Fire inside the Earth

त्री रोचना वरूण त्रीँरूत द्युन्त्रीणि मित्र धारयथो रजांसि ।
वावृधानावयतिं क्षत्रियस्थानु व्रतम् रक्षमाणावजुर्यम् ॥
ऋग्वेद ५.६९.१

Henceforth, it can be assumed from the above verse, that use of Sunlight during day time and Electricity at night was used during the Vedic age. The great Sage Agastya mentioned the process of making Battery in his composition Agastya Saṃhitā (around 8000 BCE).



संस्थाप्य मृण्मये पात्रे ताम्रपत्रं सुसंस्कृतम् ।
छादयेच्छिखिग्रीवेन चार्दाभिः काष्ठपांसुभिः ॥
दस्तालोष्टो निधातव्यः पारदाच्छादितस्ततः ।
संयोगाज्जायते तेजो मित्रावरुणसंज्ञितम् ॥
(दूसरा सन्दर्भ, परा. हि. शि. शा. सा , आगस्त्य षंहिता पृष्ठ १३६)

Different kinds of electricity

- *TAḌITA* (तडित) – Generated by rubbing silk cloths
- *SAUDĀMINĪ* (सौदामिनी) – Generated by rubbing two gems
- *VIDYUT* (विद्युत) – Generated from thunder
- *ŚATAKUMBHĪ* (शतकुंभी) – Generated by hundred cells of pillars (Kumbha's)
- *HṚDANI* (हृदनी) – Stored electricity with portable properties
- *AŚANI* (अशनी) – Generated from magnetic rods (P. P. Hole –Machines in Samskrit Literature)

Electricity is also described in Mahābhārata composed by Vedavyāsa. The great sage Vedavyāsa described the method of generating electricity from the atmosphere. According to Aṣṭāvakropākhyān, during a debate, King Janaka asked the sage Aṣṭāvakra, 'Who amongst the deities holds the womb of those which are attached like two horses and which falls suddenly like a hawk? And which womb is created by these two?' Aṣṭāvakra answered, 'Oh King! May these two don't fall on the roof of your enemy's home. The deity of (as!) clouds is the holder of the womb of those two whose charioteer is Vāyu or wind. And these two are the creators of womb like clouds.

वड्वे इव संयुक्ते श्येनपाते दिवौकसाम् ।
कस्तयोर्गर्भमाधत्ते गर्भं सुषुवतुश्च कम् ॥
मा स्म ते ते गृहे राजच्छात्रवाणामपि ध्रुवम् ।
वातसारथिरागन्ता गर्भं सुषुवतुश्च तम् ॥
महाभारत वनपर्व १३३.२६.७

The two technical terms 'Rayi' and 'Prāṇa' are used to mean 'Positive' and 'Negative' charges in ancient language. These are always in compound state together naturally. The compound state of these two are collectively called Electricity. This **negative and positive charge** is carried by the clouds like a womb. Friction between clouds generate electricity and thunder comes down because of the gravitation like a hawk. It is prayed that it may not be strike the roof of even our enemy because it burns everything in ashes at a glance.

Thus, is can be assumed that Aṣṭāvakra was familiar with the scientific process of how electricity was created in the atmosphere. William Wall, an eminent scientist from Britain, said in 1708 that the spark in the clouds is caused by a highest scientific process. According to which if the electricity is discharged by taking an electrified thing near a driver, it creates a spark between those two. Fifty years after this, a scientist named Benjamin Franklin from America proved the process of creation of spark in the clouds through an experiment. It is available in the Junior Science Encyclopedia, Volume IV, Page 188. The process of spark generation in the clouds, which has now been established by modern scientists, was already mentioned in Mahābhārata around 6th century BCE.

There is a lot of proof to conclude that the scholars and sages were well aware about the generation, classification and use of electricity in ancient times. People were encouraged to generate and use electricity for a comfortable life. Our scientists can explore, learn and rediscover newer horizons of inventions, if they can take inspiration and knowledge from our glorious past.

- **Laws of Motion:**

Invention of laws of motion There are two great scientists behind the invention of law of motion: (1) Rishi Kanada and (2) Sir Isaac Newton (1643-1727). We, all are familiar with Newton's Laws of Motion that Sir Isaac Newton, the physicist who formulated the laws of motion first. He published these laws in his book, "Philosophica Naturalis Principia Mathematica" on July 5, 1687.

But before Newton, the laws were discovered by Indian scientist and philosopher Rishi Kanada who had given Vaisheshika Sutra in 600 BCE which describes the relation between force and motion. We first discuss the Newton's three laws of motion.

The Rishi Kanada's Vaisheshika Sutra [5, 6, 11]

Mahrshi Kanada mentioned karma is related to motion, and there five types of motion:

1) Upward Motion
2) Downward Motion
3) Motion due to release of tensile stress
4) Shearing stress
5) General motion

First Sutra

वेगः निमित्तववशेषात किमणो जायते| [Vegah Nimitta Visheshat Karmano Jayate].

Translation: Change of motion is due to impressed force. (The law states that an object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.)

Second Sutra वेगः निमित्तापेा़ात किमणो जायते नियतदिक क्रियाप्रबन्धहेतु | [Vegah Nimitta Pekshat Karmano Jayate Niyatdik Kriya Prabandha Hetu].

Translation: Change of motion is proportional to the impressed force and is in the direction of the force.

Third Sutra वेगः संयोगववशेषववरोधी | [Vegah Sanyog Vishesh Virodhi.]

Translation: Action and reaction are equal and opposite.

First law Newton's, states that every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force. Newton's first law of motion refers to as the law of inertia. Newton's first law of motion is often stated as: an object at rest stays at rest and an object in motion stays in motion with the same speed and in the same direction unless acted upon by an unbalanced force. That is in an inertial frame of reference; an object either remains at rest or continues to move at a constant velocity, unless acted upon by a force.

Second law Newton's, second law states that the rate of change of momentum of a body is directly proportional to the force applied, and this change in momentum takes place in the direction of the applied force. In an inertial frame of reference, the vector sum of the forces P on an object is equal to the mass m of that object multiplied by the acceleration f of the object: P=mf (where mass m is constant). Newton's second law of motion pertains to the behavior of objects for which all existing forces are not balanced. The second law states that the acceleration of an object is dependent upon two variables: the net force acting upon the object and the mass of the object.

Third law, To every action there is always equal but opposed reaction or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

Comparison between the laws of motion of Sir Isaac Newton and the Sutra of Rishi Kanada			
Indicator	**Newton's Law**		**Rishi Kanada's Sutra**
Time of Invention	1687 AD		600 BCE
First Law	Every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force.		"Vegah Nimitta Visheshat Karmano Jayate". It means "Change of motion is due to impressed force".
Comparison	There is no intrinsically difference between the Newton's law of motion and the Kanada' Sutra.		
Second Law	Newton's second law states that the rate of change of momentum of a body is directly proportional to the force applied, and this change in momentum takes place in the direction of the applied force.		"Vegah Nimitta Pekshat Karmano Jayate Niyatdik Kriya Prabandha Hetu". It means that Change of motion is proportional to the impressed force and is in the direction of the force.
Comparison	Both the laws are bearing same meaning.		
Third Law	To every action there is always equal but opposed reaction.		" Vegah Sanyog Vishesh Virodhi." It means that action and reaction are equal and opposite.
Comparison	Both the laws are same and identical.		
Overall Explanations	Sir Isaac Newton published these laws in his book 'Philosophica Naturalis Principia Mathematica' on July 5, 1687 while the exact time of Rishi Kanada' Sutra is not known. From the ancient religious book/epics it is known to us that the time period of Rishi Kanada is 600 BCE. The invention of the Sutra by Rishi Kanada was before the time of innovation from "ZERO (invented by Aryabhatta)" to "INFINITY (invented by Bhaskaracharya)". So far as I understand, on account of scarcity of digits Rishi Kanada could not formulate his Sutra. On the contrary, the time period of Sir Isaac Newton was so far modern and at this time many things were either invented or discovered. As a result he could formulate his laws very easily in scientific way. Now question arises how the Newton's law and Sutra of Rishi Kanada are more or less same.		

	The people of the rest of the world knew that India was a home of Knowledge and Wealth on account of which many warriors attacked India so many times in search of wealth and many wise men came to India in search of knowledge. It is proved that ancient books of India were the root of many inventions/discoveries in the world. Sir Isaac Newton might search this knowledge from India and formulated in scientific way or he could invent independently. The actual fact remains mysterious. But all credits and respects go to Sir Isaac Newton and nothing to Rishi Kanada, though Rishi Kanada invented the entire laws before 2000 years of Sir Isaac Newton. This is very painful to every Indian. Last of all, I would say that Sir Isaac Newton formulated the laws of motion in more scientific way with the help of digits and letters qualitatively as well as quantitatively while Rishi Kanada had stated the laws qualitatively.

Matter States:

On an interesting note, the above-mentioned value of Paramaanu corresponds to the organic molecular size as estimated by the modern western scientists.

As mentioned in the *Upanishads*, the five elements of the nature are -

- Earth
- Water
- Air
- Fire and
- Akasa

However, the concept of Akasa was missing amongst the ancient Greek or Roman philosophers. It was quite easy to deduce the role of the remaining four elements as –

- The Earth represents the solid state
- The Water constitutes the liquid state
- The Air forms the gaseous state and
- The Fire constitutes of the plasma as the fourth state of matter.

The western scholars, though, failed to recognize and include nuclear state as part of a state of matter. Akasa is a nuclear state in which few nuclear parts are stable. Maharshi Gauthama, in his Sanskrit text *Anu Sidhdhantam*, has explained the three major models of microscopes under which the atoms and electrons can be clearly seen, observed and examined.

Laws of Motion and Theory of Gravitation:

We, all are familiar with Newton‟s Laws of Motion that Sir Isaac Newton, the physicist who formulated the laws of motion first in 1687. But before Newton, the laws were discovered by Indian scientist Rishi Kanada who had given Vaisheshika Sutra in 600 BCE which describes the relationship between force and motion. The world believes that Newton was the first to discover the gravitational concepts. You will be surprised to know that the theory of gravitation was created 1200 years before Newton by an Indian Mathematician Bhaskaracharya. He explained that gravity is a universal force that allows the mass of a body to attract other masses of bodies. The bigger a mass of a body, the higher will be the force of gravity. Objects stay on earth because of the gravitational pull. Every single body in the universe is affected by gravitational forces which also include the earth, sun, and the moon. Tidal waves are created by the gravitational pull of the moon. Sun‟s gravitational pull keeps all the planets in the orbit. Earth‟s gravity allows it to revolve around the sun. Bhaskaracharya was one of the most prominent astronomers and mathematicians of the 12th century. He is also considered as the greatest mathematician from the medieval era. He is known amongst the theorist for discovering principles on astronomy and calculus. He wrote “Siddhānta Śiromaṇī” at the age of 36 in 1150 AD. He also contributed to “Surya Siddhanta” that was originally written by Aryabhatta. The first principle of gravity was stated by Bhaskaracharya and not Newton. Bhaskaracharya stated the laws of gravity in the book Surya Siddhanta in 11th century. Thus, the law actually existed even before the birth of Sir Isaac Newton (Newton was born in the 16th century). Here there are some of the shlokas from Surya Siddhanta that mentions how gravitation works:

“मध्ये समन्तन्दस्य भुगोलो व्योमनि तिस्थति बिभ्रानः परमम्

सक्तिं ब्राह्मणो धरणात्मिकम्” २.

[सूर्यसिद्धान्त १२ अध्याय ३२ श्लोक]

Translation: The spherical earth stands at its centre in space due to the dharanatmikam sakti which prevents earth from falling away and helps it to stand firm.

"अक्रस्त सक्तिश्च महि ताय यत् स्वस्थं गुरु स्वाभिमुखं स्वसक्त्य अक्रस्यते तत्पततीव भाति समान समन्तत् क्व पातवियम् खे"

[सिद्धान्त शिरोमणि, भुवनकोस, ६ श्लोक] ।

Translation: Every object falls on the ground due to earth‟s force of attraction. This force allows the sun, earth, moon and constellations to stay in the orbit. Bhaskaracharya wrote a treatise „Lilavati', he explained that earth has gravitational force (gurutvakarshan shakti). There is a mutual attraction between the planets and this allows them to hold themselves firmly in space. He also mentioned the shape of the earth that "what we see is not the reality, Earth may appear flat but it is spherical in reality‟. He further explained this theory by stating: "if you draw a very big circle and look at one fourth of its circumference, you see it as a straight line. But in true sense it is a circle. Similarly, earth is spherical in shape." These historical mentions were the proofs that law of gravity was first discovered in India by Bhaskaracharya. His law predated the law of Newton. Everybody knows about Newton‟s law of Gravity but we do not have any idea about "Bhaskaracharya‟s Law of Gravity".

Light:

The concept of light has been an important part of Hindu shastras, and is associated with various philosophical, spiritual, and scientific ideas. These include Jyotish (Vedic Astrology), Prakasha (Illumination), Jnana (Knowledge), Surya (Sun), and Tejas (Radiance). The symbol of light has been used in Hindu texts to describe the transformative power of knowledge and spiritual practice, and as a symbol of enlightenment, inner strength, and energy.

Jyotish (Vedic Astrology): The word "jyotish" itself means "light" or "illumination", and refers to the idea that the study of astrology sheds light on the mysteries of the universe and our place within it. Jyotish uses the positions of celestial bodies and other astronomical phenomena to understand and interpret human affairs and natural phenomena.

Prakasha (Illumination): In Hindu philosophy, the concept of prakasha refers to the illuminating aspect of consciousness. Prakasha is the light that illuminates our thoughts, feelings, and experiences, and allows us to know and understand the world around us.

Jnana (Knowledge): Jnana, or spiritual knowledge, is often associated with the concept of light in Hindu philosophy. Just as light illuminates the darkness, jnana illuminates our ignorance and reveals the truth of our nature and the nature of the universe.

Surya (Sun): The sun, or surya, is an important symbol of light and illumination in Hinduism. The sun is often associated with knowledge, enlightenment, and the power of consciousness to dispel darkness and ignorance. Many Hindu rituals and practices are performed at sunrise and sunset, when the light of the sun is believed to be most potent.

Tejas (Radiance): Tejas is a Sanskrit word that refers to radiance or brilliance. In Hindu philosophy, tejas is associated with the concept of agni, or fire, and is considered to be a form of energy that fills the universe. It is often associated with the concept of tapas, or spiritual discipline, and is believed to be the source of inner strength, energy, and illumination.

Hymn (chant) 1.50 of the Rigveda is a hymn that is dedicated to the sun, which is viewed as a source of light and life. The hymn praises the sun as a deity who brings light and vitality to all living beings, and it reflects the ancient Vedic understanding of the sun as a powerful and benevolent force in the universe.

आदि त्य वर्णः तमसः परस्ता त् | यत् आदि त्यस्तन्मस्तु वि द्या त् |
तपसो रजस्तमसो मयि ज्यो ति रुत्तरं | धा रा आपो अपा मृतमद्भुतं हव्यमर्च |
आदि त्यस्य भा नो देवो जा तो वनस्पति षु | वि श्वेदेवाः सवि तुर्यजमा नो यज्ञमा दधा त ||[1]

Translation: "Let us invoke today the effulgent powers of the radiant rising of the sun, that they may guide us on the path of goodness, and that we may see the light that leads to the highest goal. May the sun, who is the source of all life and energy, Fill us with vitality and strength, And may his light shine upon our path of righteousness."

Hymn 10.85 of the Rigveda is a hymn dedicated to the sun, which is viewed as a symbol of knowledge and enlightenment. The hymn praises the sun as a deity who brings understanding and wisdom to human beings and reflects the ancient Vedic understanding of the sun as a powerful force in the universe.

उषस्सुपर्णा रो चते वि श्ववा रा | अभि जा यते जगतः प्रति ष्ठा मेति |
सुवर्णरश्मि रस्मा कं भा स्करो दि वि जा गृवति | वि श्वेदेवा अयं जा तो जगतो बभूव ||
तच्छ्रेयो रश्मि भि र्यजते सप्त सख्ये | वि श्वेदेवाः सवि तुर्यजमा नो यज्ञमा दधा त ||[2]

Translation: "The dawns have brought the light to us, And the brilliant sun has risen, Dispelling the darkness of the night. May he guide us on the path of truth, and may his light shine upon our hearts and minds, Illuminating the way to wisdom and understanding. May we receive the blessings of the sun, and may he bestow upon us his knowledge and enlightenment."

In Rig Veda, light is explained as a source of energy or source of our life. Nature of light as a wave or as a particle was not come into picture till late into the modern age, but in Rig Veda it is clearly mentioned that **"Seven horses draw the chariot of the sun, tied by snakes". (Rig-Veda 5. 45. 9)**

Above poetic verse speaks about the nature of light as being composed of 7 rays and the snake symbolizes it's curved path. Now, these colors are actually described as red, orange, yellow, green, blue, Indigo and violet in the yoga sutras and the Vedic Upanishads.

In Rigveda, following sloka's state about the speed of light which is nearly about of modern value of 186,282.397 miles / seconds:

"योजनानं द्वे द्वे शाते द्वे च योजना एकें निमिषर्धेन क्रम्मना नमोस्तुते"

(Rig-Veda I,50-4) In the verse Sun light speed is measured with the help of units called Yojan & Nimesha. This verse explain that sunlight moves 2202 Yojans in Half Nimish.

तारानिर् विश्वदर्शतो ज्योतिष्क्रदसि सूर्य |
विश्वमा भासिरोचनं ||

Meaning: Oh Sun! (You) overwhelm all in speed, visible to all, source of light (You) shine pervading the Universe.

In the Vedas, Yojana is a unit of distance and Nimisha is a unit of time. Distance travelled=2202 Yojanas
1 Yojana=9 miles, 110 Yards=21,144.705 miles (Approx.)
Time taken 1/2 Nimisha=0.114286 seconds (Approx.)
Speed of light=185,016.169 miles / seconds.
Modern Value=186,282.397 miles / seconds.
Modern science claims the speed of light to be approximately 186,282.397 miles / seconds.

Sound in Vedic Science:
Sound plays a major role in various aspects of life. The field of acoustics deals with generation, transmission and reception of sound. Sound in modern scientific terms refers to the pressure waves in air received by human beings in the audible range of generally 20 cycles/sec to 20000 cycles/sec. However, the infra- and ultra-sound refers to the frequencies below and above the audible range respectively. Acoustics has also received a very high importance in Vedas and Vedic literature. The classical literature of Hinduism or Sanatana Dharma is rooted in Vedas. It is known that the Vedas are collection of mantras. In Vedas and Vedic literature several terms such as Nāda and Shabda are used. These terms cannot be translated directly as sound as they refer to vibrations including both physical and spiritual aspects. However, the Nāda and Shabda include the human auditory range sound. The Vedic four-fold model for generation of speech is discussed with applications general sound. The acoustical aspects of speech, music, language, literature and spirituality are discussed. Also, the paper includes discussions of Vedic view in relation to views of modern acoustics.

Veda refers to the body of knowledge that deals with physical, psychological and spiritual aspects of life and cosmos. The word Veda etymologically relate to the verbal root 'Vid' meaning 'to know'. However, it is interesting to note that the Vedas also refers to 'mantras', which means 'chants that convey knowledge'. The Vedic chants have acoustical characteristics such as phonetics, tonal quality, length measure, effort etc. Thus, acoustics of human speech is very important. Also, it is well known that the faculty of speech is revered as Goddess of Speech (Vagdevi). The mantra from the Yajurveda says:

"देवीं वचनजन्यन्त देवास्ता विश्वरूपः पशवो वदन्ति । सा नो मन्द्रेषमूर्ज दुहाना धेनुर्वाग स्मानुप सुष्टुतैतु ॥

The meaning of this mantra could be summarized as "Creator Lord Brahma and other devata brought forth Vagdevi (Goddess of Speech) to manifest communication. All beings use their abilities to communicate through Vagdevi. May Vagdevi like an all-desire fulfilling cow bless us with food, strength and faculty of speech?"

It is quite difficult to precisely define and describe the origin of language and human speech. However, it is known that Vedic chants and music in India has existed from very ancient times. Sir C.V. Raman in his article titled "The acoustical knowledge of ancient Hindus", says that: "It would form a fascinating chapter of history to try and trace the gradual development of musical

instruments and musical knowledge, from the rhythmic chanting of the Rig-Veda in the ancient home of the Aryan race to the Indian music of the present day".

Importance of Acoustics:

In modern times the importance of acoustics is very well known. The field of acoustics deals with generation, propagation and reception of sound. The importance of acoustics in arts, life sciences, earth sciences and engineering play vital role. It is interesting to note that acoustics has high importance in Vedas and Vedic literature, which are the classical source literature for Sanatana Dharma also popularly known as Hinduism. The Vedas and Vedic literature, which deals with all aspects of life including sciences and arts.

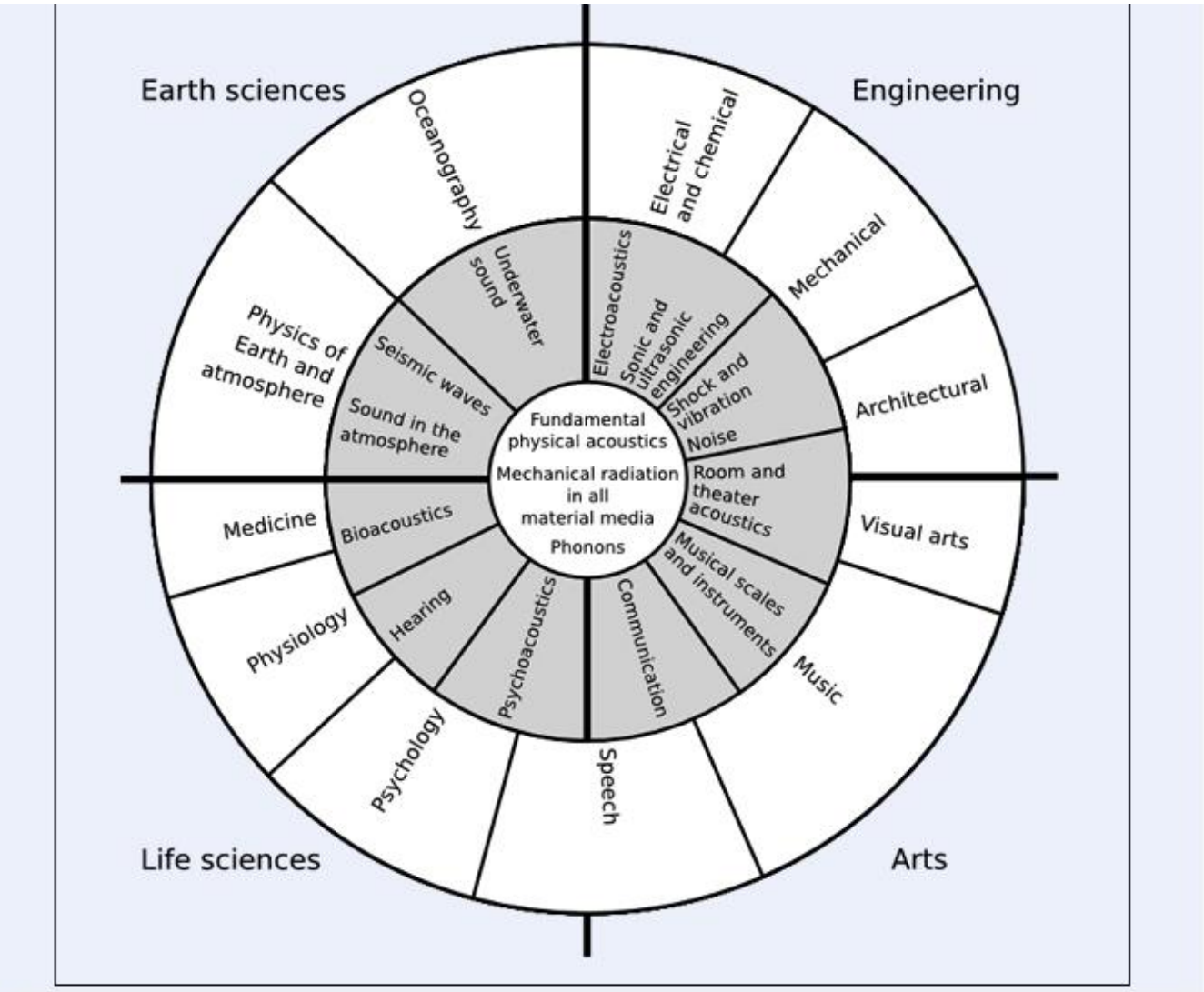


Figure 1: Lindsay's Wheel of Acoustics showing the presence of acoustics in various fields.

In reference to figure 2, Gandharva Veda deals with music and fine arts and Chandas deals with science of prosody and its knowledge aids in melodious pronunciation of mantras. It is well known that that the four main Vedas (Rik, Yajus, Sama and Atharva) are collections of mantras, which have been orally transmitted through the ages. The proper recitation of mantras requires proper knowledge of acoustics for their recitation.

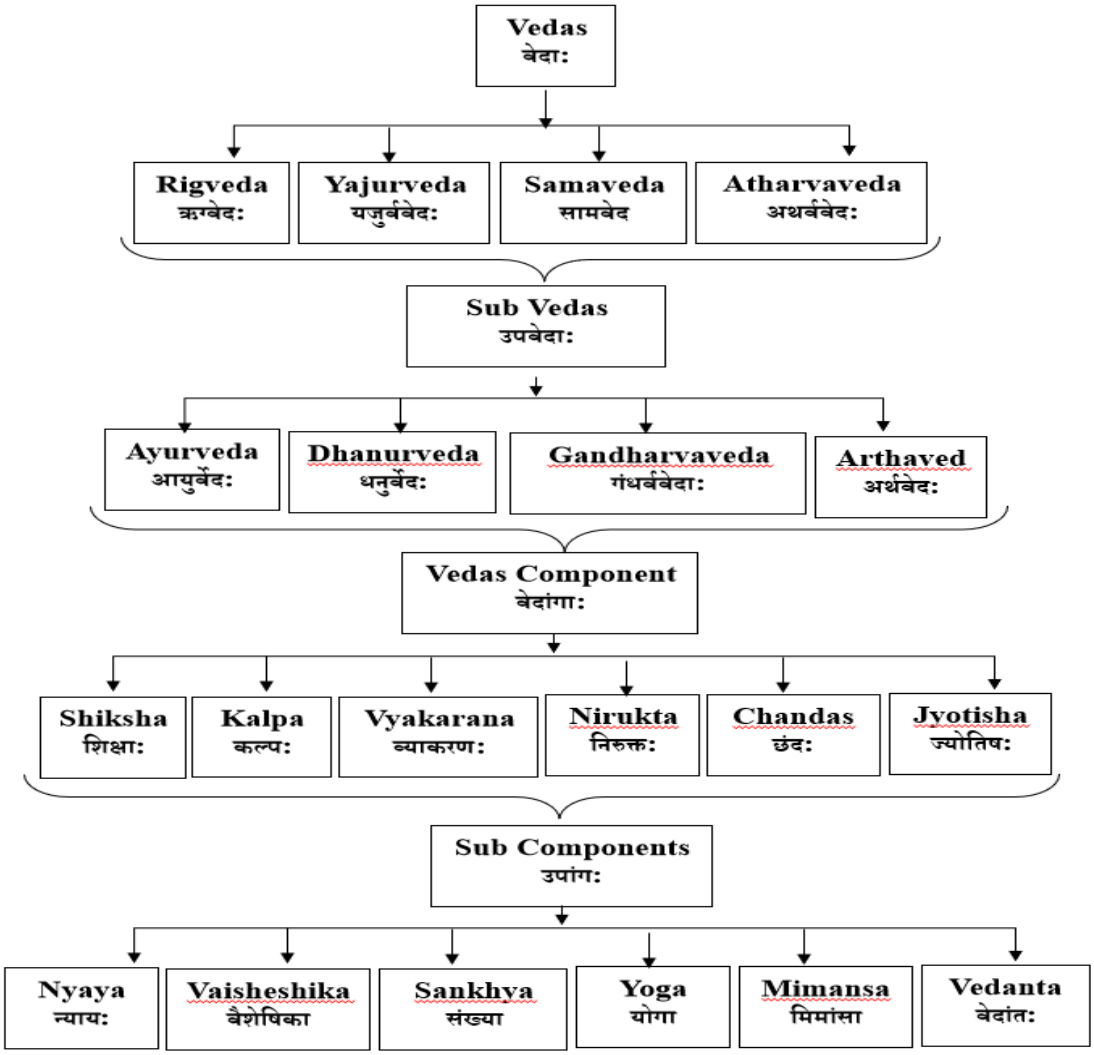


Figure 2: Integrated Vedic Knowledge &science represented as a tree

The six acoustical factors involved in precise Vedic chanting as per taittirīya upaniśat are pronunciation of letters (Varnaha), their pitch (Svarha), the timing or duration (matrā), the force (balam), melodious articulation (sāma) and combined sound effects (santānaha).

Although sound is generated by varieties of sources in nature, the sound produced by human beings is of chief importance because of its role in communication. In Vedas and Vedic literature, the term nāda and śabda are referred to indicate both audible and inaudible sounds. This can be referred as ***Sound Field***. The production of sound from human beings as speech and music are part of the nāda and śabda. However, it is important to remember that the Vedic terms nāda and śabda cannot be translated as sound in the audible range (of 20 Hz to 20000 Hz). The various manifestations of sound in the world thatare generated and propagated become part of the sound filed. The sound field as nāda and śabda has received utmost importance in Vedic literature. ṣāranga deva, the author of sangīta ratnākara, a treatise on classical Indian music says:

नादेन व्यज्यते वर्णाह पदं वर्णात् पदवचहा

वचसा व्यवहरोयं नादधिनामतो जगत्

which means "the alphabets have established from the naada (sound field). The words are made up from alphabets and from the words speech come out. Worldly transactions are carried out through the speech, and thus, the world is dependent on nāda".

In a similar way, in the words of a yogī-seer **Śriranga Sadguru**, "Just as from seed comes naturally sprout, branch, leaf, flower, unripe fruit and full fruit likewise starting from spiritual light as seed, the nāda, the svara and aksharas have developed into the various aspects of knowledge".

द्वे ब्राह्मणी वेदितव्याए शब्द ब्रह्म परमचायात्,
शब्द ब्रह्मणि निश्रातह परं ब्रह्माधि गच्छति||

This means, "Two Brahmas to realize namely: śabda and Param Brahma. One who has realized and is well versed in śabda Brahman will realize Param Brahman". Thus, it is seen that the knowledge of sound field as śabda and nāda is a precondition to the spiritual fulfillment of realization of Param Brahma. Also, the sound field as the revered nāda Brahman in addition to its being all-pervasive (सर्व-व्यापक) in the world is also source of happiness.

Sāranga deva gives it highest importance in Vedic literature. Sāranga deva, the author of sangīta ratnākara says:

चैतन्यं सर्व भूतनं विवृतं जगदात्मनः,
नाद ब्रह्म तदनन्दम अद्वितियम्पास्महे||

Which means "we worship the nāda Brahman second to none which is wonderful and is in all beings as consciousness has established itself as universe."

The scriptures also refer to two types of nāda namely **anāhata** (Anāhata (अनाहत) or Anāhatadhvani refers to the "unstruck sound" symbolizing the energy of transcendental consciousness) **and āhata** (Striking a neighbouring note and coming back is known as struck (*āhata*). The anāhata refers to self-existing sound field without any vibratory cause and is experienced only in spiritually focused deepest states of yoga. The āhata refers to the sound field produced vibratory cause. The discussion in this paper deals with produced sound field namely āhata naada.

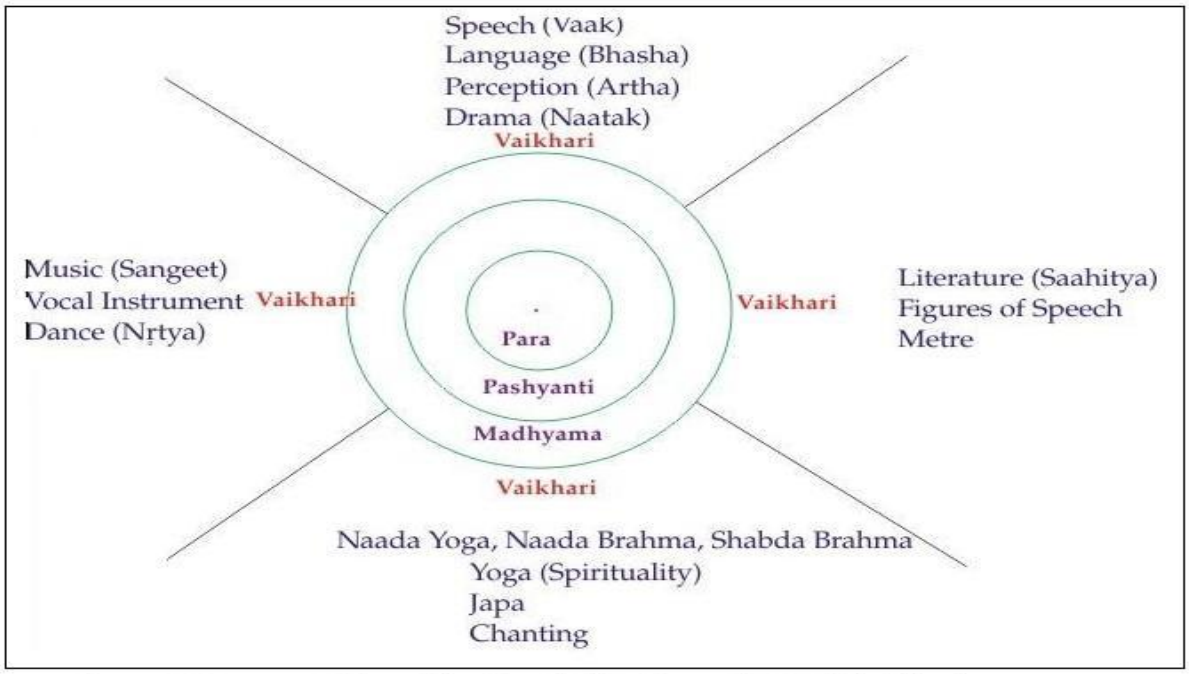


Figure 3: Representation of the four fields of sound at Vaikhari level

In Vedic literature, major emphasis is given for the human speech. The production of speech is seen as a four-fold process of sound generation namely para, pashyanti, madhyama and vaikhari. After a brief discussion of modern view of speech production.

There is a verse from a classical Hindu text, which specifically gives the locations in terms of cakras to the four-fold level of speech in physiological terms in the human body similar to that as the previous verse. The verse says:

परा वङ्गमूलचक्रस्था पशयन्ती नभिसंस्थिता
हृद्गा तु मध्यमा ज्ञेया वैखारी कण्ठदेशगा ||

Which means "In the four–fold speech, the parā level speech manifests at the mūladhāra cakra (coccygeal triangle), the paśyantī at the manipūraka cakra (navel region), madhyamā at the anāhata cakra (cardiac or heart region) and the vaikharī at the viśuddhi cakra (at the cavity of the throat)". It is seen that similar description is given in the bhāgavata purana in the verse 11-12-17. The various chakras that are referred in the above verse are shown in figure 4.

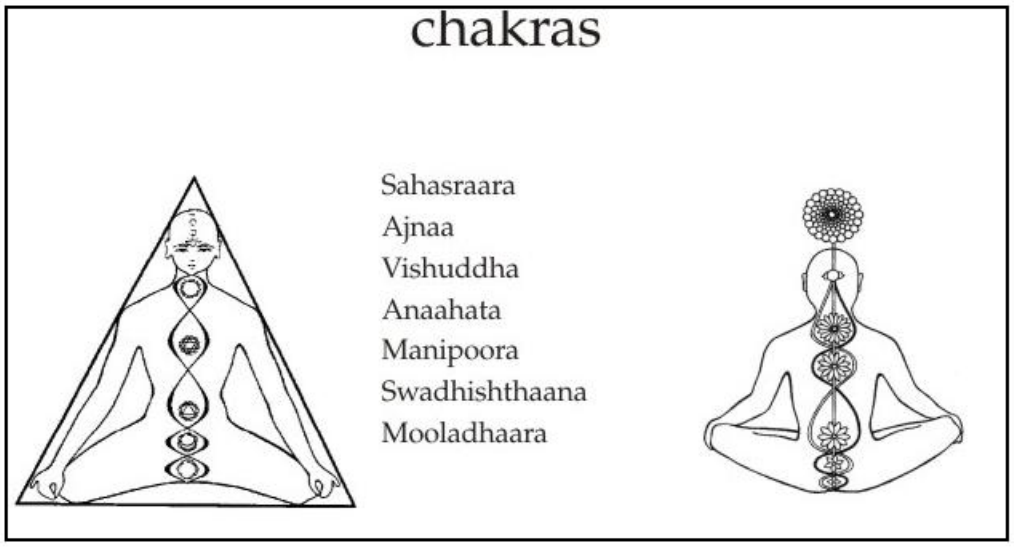


Figure 4: Representation of the seven yogic chakras in a human being.

The **svaras** in music refer to the basic **seven notes** found in the **seven sounds produced from animals in nature.** They are **Sa from a peacock, Ri from a bull, Ga from a goat, Ma from a curlew, Pa from a cuckoo, Dha from a horse and Ni from an elephant**. A raaga is an acoustic presentation using various svaras to depict an emotion or a mood. The various moods are broadly classified in to nine moods namely Shringaara (amorous), Veera (heroic), Karuna (pathetic), Haasya (comic), Adbhua (marvelous), Raudra (ferocious), Bhayanaka (frightening), Bheebhatsa (odious), and Shaanta (peace). **The essential effect of the various moods produced by musicians on the listeners is called rasa.**

The two types of music are essentially vocal and instrumental. As vocal music comes powerfully through a melodious voice, the instrumental music produced through a well-designed and tuned instrument can also be very powerful. Substantial scientific and engineering knowledge and skills are required to build a good instrument. In Indian instrumental music there are hundreds

of instruments from ancient times. It is well known that the instruments namely veena (a string instrument) is held by Goddess Saraswati and bamboo flute is held by Lord Krishna.

The divine energy within a human being, which energizes human speech and music, is Goddess Saraswati in the form of deity. She is also referred as Vagdevi or Goddess of speech. The instrument veena she is holding is a string instrument, which has 24 frets. The number 24 also refers to the 24 syllables of the celebrated Gayatri Mantra. In addition, the instrument veena also is a representation of the human spinal cord, which also has 24 cartilages. This representation is shown in figure 5.

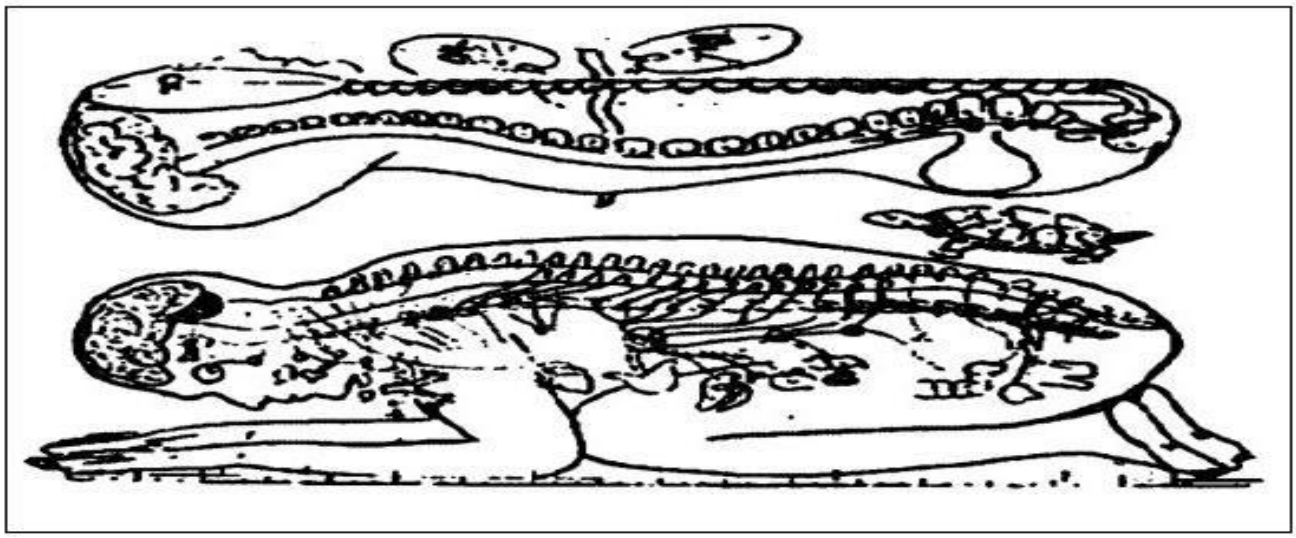
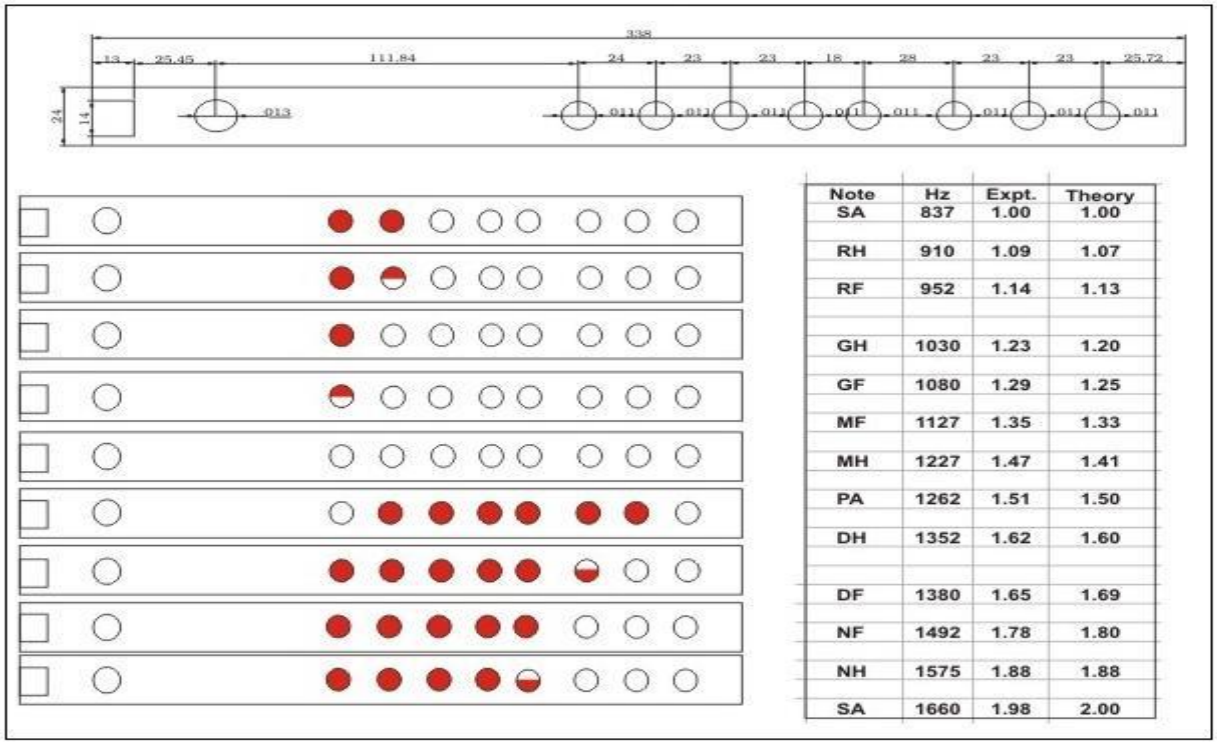


Figure 5 Representation of the musical instrument Veena (above) with spinal cord of a human being (below).

The flute, which is held by Lord Krishna, is known for ecstatic music and its spiritual impact on listeners. The epic Bhagavata describes in detail the impact of music played by Lord Krishna on



Note	Hz	Expt.	Theory
SA	837	1.00	1.00
RH	910	1.09	1.07
RF	952	1.14	1.13
GH	1030	1.23	1.20
GF	1080	1.29	1.25
MF	1127	1.35	1.33
MH	1227	1.47	1.41
PA	1262	1.51	1.50
DH	1352	1.62	1.60
DF	1380	1.65	1.69
NF	1492	1.78	1.80
NH	1575	1.88	1.88
SA	1660	1.98	2.00

the flute. In this context also the holes in the flute represent the location of the various chakras. The measurements of frequencies of various notes produced from a bamboo flute are shown in figure 6. Also, the experimental ratios obtained from a bamboo flute compares well with the well-known Pythagorean scale.

Indian Scientist in Physics:

Advancements in science and technology have been the major reason for the development of human civilization. India has been contributing to the fields of science and technology since ancient times. Even today, what we term as 'traditional knowledge' is actually based on scientific reasoning.

The history of scientific discoveries and development in India dates back to the Vedic era. Aryabhatta, the famous mathematician of the Vedic era, invented 'zero'. It is believed that ancient Indian scholars had developed geometric theorems before Pythagoras had made them popular. The concept of squares, rectangles, circles, triangles, fractions, and the ability to express number 10 to the 12th power, algebraic formulae, and astronomy have all had their origins in Vedic literature; some are stated to have been known as early as 1500 BCE. The decimal system was already in use during the Harappan Civilization. This is evident in their use of weights and measures. Moreover, the concepts of astronomy and metaphysics are all described in the Rig Veda, an ancient Hindu text of the Vedic era.

Bhaskaracharya (Bhaskara II):

Bhaskara II, also known as ***Bhaskaracharya***, was born in 1114 CE near Vijjaydavida or present-day Bijapur in the state of Karnataka. Born to a family of scholars, he learnt mathematics from his astrologer father Mahesvara. A leading mathematician of twelfth century, he wrote his first work on the systematic use of the decimal number system. He also headed the astronomical observatory at Ujjain, a leading mathematical centre of ancient India. His main work ***Siddhanta Shiromani*****,** which has four parts, namely, Lilavati, Bijaganita, Grahaganita and Goladhaya deals with arithmetic, algebra, mathematics of the planets and spheres, respectively. Bhaskara is particularly known for the discovery of the principles of differential calculus and its application to astronomical problems and computations.

While Newton and Leibniz have been credited with differential and integral calculus, there is strong evidence to suggest that Bhaskara was a pioneer in some of the principles of differential calculus. He was perhaps the first to conceive the theorems of differential coefficient and differential calculus. He conceived the modern mathematical finding that when a finite number is divided by zero, the result is infinity. He also accurately defined many astronomical quantities using models developed by seventh-century scholar Brahmagupta. For example, he calculated that the time that is required for the Earth to orbit the Sun is 365.2588 days. The modern accepted measurement is 365.2563 days, a difference of just 3.5 minutes. Bhaskara wrote *Karanakuthuhala*, a book on astronomical calculations, which is still referred in making precise calendars. Bhaskara II was also a noted astrologer, and it is said that he named his first work after his daughter Lilavati.

Aryabhatta:

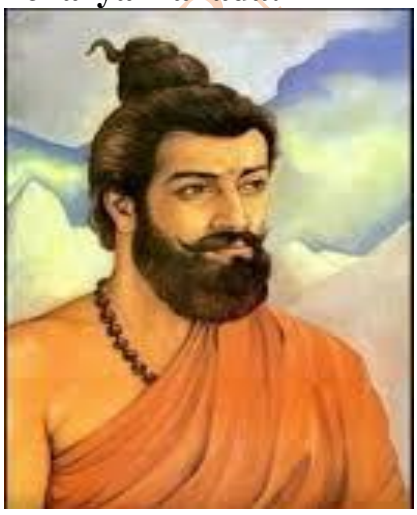
Aryabhatta is the earliest known mathematician and astronomer of India. The birth place of Aryabhatta, who lived between circa 476–550 CE, is still a mystery. While many believe that he was born in Pataliputra in Magadha, present-day Patna in the state of Bihar, others are of the view that he was born in Kerala and lived in Magadha at the time of the Gupta rulers. His works include the *Aryabhatiya* (499 CE, when he was 23) and the *Arya Siddhanta*.

His most famous work, **Aryabhatiya** is a detailed text on mathematics and astronomy. The mathematical part of the Aryabhatiya covers arithmetic, algebra and trigonometry. It also contains continued fractions, quadratic equations, sums of power series and a table of sines. Aryabhatta is believed to have written at least three texts on astronomy and wrote some free stanzas as well. Aryabhatta was a genius and all his theories continue to surprise many mathematicians of the present age. The Greeks and the Arabs developed some of his works to suit their demands.

His other work *Arya Siddhanta* deals with astronomical calculation and this is evident through the writings of Aryabhatta's contemporary, Varahamihira and later mathematicians and commentators, including Brahmagupta and Bhaskara I. It contains description of several astronomical instruments like gnomon (*shanku yantra*), a shadow instrument (*chhaya yantra*), possibly angle-measuring devices, semicircular and circular instrument (*dhanur yantra*/*chakra yantra*), a cylindrical stick *yasti yantra*, an umbrella-shaped device called the *chatra yantra* and water clocks of at least two types—bowshaped and cylindrical.

Aryabhatta was aware that the earth rotates on its axis and that the earth rotates round the sun and the moon moves round the earth. He discovered the positions of the nine planets and related them to their rotation round the sun. He also knew about the eclipse of the sun, moon, day and night, earth contours and the 365 days as the exact length of the year. Aryabhatta also revealed that the circumference of the earth is 39,968km. According to modern-day scientific calculations it is 40,072 km. Solar and lunar eclipses were also scientifically explained by Aryabhatta. India's first satellite Aryabhatta was named in his honor.

Acharya Kanada:



Acharya Kanada, originally known by the name of Kashyap, is believed to have been born either around 600 BC or 800 BC in Prabhas Kshetra near Dwaraka in present day Gujarat, India. He was the son of a philosopher named Ulka.

Kashyap displayed a keen sense of detail since childhood and minute things attracted his attention. As a young boy, he once accompanied his father on a pilgrimage to Prayaga. He noticed that thousands of pilgrims in the town were littering its roads with flowers and grains of rice which they offered at the temples by the shore of river Ganges. Fascinated by the tiny particles, Kashyap began collecting the grains of rice from the ground while everyone else was busy offering prayers or bathing in the Ganges. Noticing this behaviour from a boy of a well-to-do

family, an inquisitive crowd gathered around him and started wondering why he was acting in such a strange manner. National Aeronautical Laboratory in Bangalore runs a ***science magazine*** in this great philosopher's name called ***Kanada.***

When questioned about why he was collecting grains of rice that even a beggar wouldn't touch, Kashyap replied that one grain in itself may seem worthless but a collection of some hundred grains make up a person's meal. The collection of many meals would feed an entire family and ultimately the entire mankind was made up of many families. And for this reason alone, a single grain of rice was as important as all the ***riches in the world.*** People started calling him Kanada after this incidence as 'kan' translates to the smallest particle in Sanskrit. It was Kanada who first realized the idea that "anu" (atom) was an ***indestructible particle*** of matter.

This theory occurred to him while he was walking with food in his hand. As he nibbled at the food in his hand, throwing away the small particles one by one until he was unable to break it down anymore and it left a smell on his hands. He realized that he could not divide the food into further parts and the realization of a ***matter which cannot be divided*** further came into existence. He called this indivisible matter, ***"anu"*** which literally means atom. He founded the Vaisheshika School of philosophy where he taught his ideas and the nature of the universe. He authored the text "Vaisesika Sutras" or Aphorisms, pioneering the ***atomic theory,*** describing dimension, motion and chemical reactions of atoms.

Acharya Kanada considered the atom minute objects invisible to the naked eye which come into being and vanished in an instant; they were indestructible and hence eternal. Adherents of this philosophy further held that atoms of same substance combined with each other to produce dvyanuka (bi-atomic molecules) and tryanuka (tri-atomic molecules). This devinuka has the properties similar to those of the two original paramanu. Kanada also put forward the idea that atoms could be combined in various ways to produce ***chemical changes*** in presence of other factors such as heat. He gave blackening of earthen pot and ripening of fruit as examples of this phenomenon. His primary area of study was Rasavādam, considered to be a type of alchemy. He is said to have believed that all living beings are composed of five elements: water, fire, earth, air, ether. Vegetables have only water, insects have water and fire, birds have water, fire, earth and air, and Humans, the top of the creation, have ether—the sense of discrimination (time, space, mind) are one. He theorized that ***Gurutva*** (Hindi/Sanskrit for Gravity) was responsible for the falling of objects on the Earth.

Accordingly, the universe is the interplay of seven aspects or states of material things, namely:

1. Dravyam (matter)
2. Guna (Quality)
3. Karma (Action)
4. Samanya (Generic species)
5. Vishesha (Unique trait)
6. Samavaya (Inherence or integrated part of the whole), and
7. Abhava (Non-existence)

Dravyam (matter) is again subdivided into nine aspects:

1. Prithvi (Earth)
2. Jala (Water)
3. Teja (Light)
4. Vaayu (Gas)
5. Aakaasa (Ether)
6. Dika (Direction / space dimension)
7. Kaala (Time)
8. Maanas (Mind)

9. Atma (Soul)

Kanada defined ***'life'*** as an organized form of atoms and molecules and ***'death'*** as an unorganized form of those atoms and molecules.

Sir C. V. Raman:

Chandrashekhara Venkata Raman was born on 7 November 1888 at Tiruchirappalli, Tamil Nadu. His father, Chandrashekhara Iyer, was a lecturer in physics, in a local college. His mother Parvathi was a homemaker. He passed his matriculation when he was 12. He joined Presidency College in Madras. He passed his Bachelors and Masters examinations in science with high distinction. He had a deep interest in physics. While doing his Masters, Raman wrote an article on physics and sent it to various scientific journals of England. On reading this article, many eminent scientists in London noted the talent of this young Indian. Raman wanted to compete for the ICS examination. But to write that examination, one had to go to London.

As he was poor and could not afford it, he took the Indian Financial Service examination conducted in India. He was selected and posted at Rangoon, Burma (now Myanmar), which was then a part of British India. Later, while working in Kolkata, he associated himself with an Institute called Indian Association for the Cultivation of Science, which was the only research institution in those days. While working there, his research work came to the notice of the Vice Chancellor of Calcutta University. The Vice Chancellor appointed him as Professor of Physics in Calcutta University. Sir Raman was in a good position in the Financial Service. He sacrificed his profession and joined the academic career.

When he was working as a professor, he got an invitation from England to attend a science conference. As the ship was sailing through the Mediterranean Sea, Raman had a doubt as to why the sea water was blue in colour. This doubt initiated his research on light. He found out by experiment that the sea looks blue because of the 'Scattering Effect of the Sunlight'. This discovery is called 'The Raman Effect'. A question that was puzzling many other scientists at the time was easily solved by him. His pioneering work helped him become a Member of Royal Society of London in 1924. He was awarded with Knighthood by the British Empire in 1929. This discovery also got Sir Raman the Nobel Prize for Physics for the year 1930. He became the first Indian scientist to receive the Nobel Prize. Raman discovered 'The Raman Effect' on 28 February 1928 and this day is observed as the 'National Science Day' in India. In 1933, he joined the Indian Institute of Science, Bangalore, as Director. Later he quit the post of Director and continued to work only in the Department of Physics. The University of Cambridge offered him a professor's job, which he declined stating that he is an Indian and wants to serve in his own country. Dr Homi Bhabha and Dr Vikram Sarabhai were his students. Sir C.V. Raman died on 21 November 1970.

Satyendra Nath Bose:

Satyendra Nath Bose came into the news in connection with the discovery of 'Higgs Boson' or popularly called the 'God Particle'. Satyendra Nath Bose was an outstanding Indian physicist. He is known for his work in Quantum Physics. He is famous for the 'Bose- Einstein Theory' and a kind of particle in atom has been named after him as Boson. Satyendra Nath Bose was born on 1 January 1894 in Kolkata. His father Surendra Nath Bose was

employed in the Engineering Department of the East India Railways. Satyendra Nath was the eldest of seven children. Satyendra did his schooling from Hindu High School in Kolkata. He was a brilliant student and did his college from the Presidency College, Kolkata with mathematics as his major. He topped the University in the Bachelors and Masters. In 1916, the University of Calcutta started MSc classes in modern mathematics and modern physics. S.N. Bose started his career in 1916 as a lecturer in physics in the University of Calcutta. He served there from 1916 to 1921.

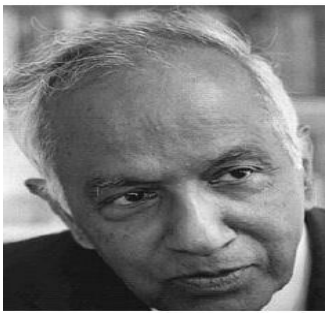
He joined the newly established Dhaka University in 1921 as a Reader in the Department of Physics. In 1924, Satyendra Nath Bose published an article titled 'Max Planck's Law and Light Quantum Hypothesis'. This article was sent to Albert Einstein, who appreciated it so much that he himself translated it into German and sent it for publication to a famous periodical in Germany—*Zeitschrift fur Physik*. The hypothesis received great attention and was highly appreciated by scientists who named it as the 'Bose-Einstein Theory'. In 1926, Satyendra Nath Bose became a professor of physics in Dhaka University. Though he had not completed his doctorate till then, he was appointed as professor on Einstein's recommendation. In 1929, Satyendra Nath Bose was elected as Chairman of the Physics Session of the Indian Science Congress and, in 1944, as Chairman of the Congress. In 1945, he was appointed as Khaira Professor of Physics in the University of Calcutta. He retired from Calcutta University in 1956. The University honoured him on his retirement by appointing him as Emeritus Professor. Later, he became the Vice Chancellor of the Visva-Bharati University. In 1958, he was made a Fellow of the Royal Society, London. Satyendra Nath Bose was honoured with Padma Bhushan by the Government of India in recognition of his outstanding achievements. He died in Kolkata on 4 February 1974.

Homi Jahangir Bhabha:

Homi Jehangir Bhabha, the main architect of Indian Atomic Energy programme, was born in a rich Parsi family on 30 October 1909 in Mumbai. He received his early education at Mumbai's Cathedral Grammar School and did his college in Elphinstone College. He went to Cambridge University, forced by his father and his uncle Dorabji Tata, who wanted him to get a degree in mechanical engineering so that on his return to India he can join the Tata Mills in Jamshedpur as a metallurgist. Bhabha's illustrious family background had a long tradition of learning and service to the country. The family, both on his father's and his mother's side was close to the house of Tatas, who had pioneered projects in the fields of metallurgy, power generation and science and engineering, in the early half of the twentieth century. The family imbibed a strong nationalistic spirit, under the influence of Mahatma Gandhi and the Nehru family. The family also had interests in fine arts, particularly Western classical music and painting, that aroused Bhabha's aesthetic sensibilities, and it remained a dominant influence in all the creative work he undertook during his life time. Bhabha, after completion of his engineering, switched over to physics. During the period 1930–39, Bhabha carried out outstanding original research relating to cosmic radiation. This earned him a Fellowship of the Royal Society in 1940, at the young age of 31. Bhabha returned to India in 1939, and had to stay back on account of the outbreak of the Second World War. He was selected to work at the Indian Institute of Science, Bangalore, where Sir C.V. Raman, India's first Nobel laureate in science, was at the time Head of the Department of Physics. Initially appointed as a Reader, Bhabha was soon designated as Professor of Cosmic Ray Research. Bhabha's leadership of the atomic energy programme spanned 22 years, from 1944 till

1966. The Tata Institute of Fundamental Research was formally inaugurated in December 1945 in 'Kenilworth' building, which was Bhabha's ancestral home. In January 1966, Bhabha died in a plane crash near Mont Blanc while heading to Vienna, Austria, to attend a meeting of the International Atomic Energy Agency.

Subrahmanyan Chandrasekhar:



Subrahmanyan Chandrasekhar was born on 19 October 1910 in Lahore. His father, Chandrasekhara Subrahmanya Iyer was an officer in Indian Audits and Accounts Department. His mother Sitalakshmi was a woman of high intellectual attainments. Sir C.V. Raman, the first Indian to get Nobel Prize in science, was his paternal uncle. Till the age of 12, Chandrasekhar was educated at home by his parents and private tutors. In 1922, at the age of 12, he attended the Hindu High School. He joined the Madras Presidency College in 1925. Chandrasekhar passed his Bachelors (hons) in physics in June 1930. In July 1930, he was awarded a Government of India scholarship for graduate studies in Cambridge, England. Subrahmanyan Chandrasekhar completed his PhD at Cambridge in the summer of 1933.

In October 1933, Chandrasekhar was elected to receive Prize Fellowship at Trinity College for the period 1933–37. In 1936, while on a short visit to Harvard University, Chandrasekhar was offered a position as a Research Associate at the University of Chicago and remained there ever since. In September 1936, Chandrashekhar married Lalitha Doraiswamy. She was his junior at the Presidency College in Madras. Subrahmanyan Chandrasekhar is best known for his discovery of Chandrasekhar Limit. He showed that there is a maximum mass which can be supported against gravity by pressure made up of electrons and atomic nuclei. The value of this limit is about 1.44 times a solar mass. The Chandrasekhar Limit plays a crucial role in understanding the stellar evolution. If the mass of a star exceeded this limit, the star would not become a white dwarf but it would continue to collapse under the extreme pressure of gravitational forces. The formulation of the Chandrasekhar Limit led to the discovery of neutron stars and black holes. Depending on the mass, there are three possible final stages of a star—white dwarf, neutron star and black hole. Apart from the discovery of the Chandrasekhar Limit, major works done by Subrahmanyan Chandrasekhar includes: stellar dynamics, including the theory of Brownian motion (1938–43); the theory of radiative transfer, including the theory of stellar atmospheres and the quantum theory of the negative ion of hydrogen and the theory of planetary atmospheres, which again comprised the theory of the illumination and the polarization of the sunlit sky (1943–50); hydrodynamic and hydro magnetic stability, including the theory of the Rayleigh- Bénard convection (1952–61); the equilibrium and the stability of ellipsoidal figures of equilibrium, partly in collaboration with Norman R. Lebovitz (1961–68); the general theory of relativity and relativistic astrophysics (1962–71); and the mathematical theory of black holes (1974–83). Subrahmanyan Chandrasekhar was awarded (jointly with the nuclear astrophysicist W.A. Fowler) the Nobel Prize in Physics in 1983. He died on 21 August 1995.

Vikram Ambalal Sarabhai:

The 'Father of the Indian space programme', Vikram Sarabhai was born in Ahmedabad on 12 August 1919 to an affluent family. It was his early years at a private school that shaped his scientific bend of mind. After studying at the Gujarat College in his hometown in 1937, he left for England to study physics at St. John's College, Cambridge.

There, Sarabhai earned an undergraduate tripods degree. That was the year 1940 and the world was facing the Second World War. So, Sarabhai returned to India and became a research scholar at the Indian Institute of Science, Bangalore, where he studied the effects of cosmic rays. It was at Bangalore, under the direct guidance of Nobel laureate, Dr C.V. Raman that he started setting up observatories in Bangalore, Pune and the Himalayas. Soon after the war was over, he returned to UK for a while. Sarabhai received a PhD from Cambridge University for his pathbreaking work. His real work began in 1947 along with meteorologist, K.R. Ramanathan, who helped him establish the Physical Research Laboratory, Ahmedabad. Initially, it consisted of rooms at the Science Institute of the Ahmedabad Education Society. Analys`ing and studying cosmic rays and atmospheric physics, the scientists set up two dedicated teams at the site. Sarabhai's team realized that evaluating the weather was not enough to comprehend variations in the cosmic rays; they had to relate it to variations in solar activity. He was the pioneer researcher in the field of solar physics. With such a big breakthrough in hand, Sarabhai soon received financial support from the Indian Council of Scientific and Industrial Research and the Department of Atomic Energy. And the support did not just end there. He was asked to organize the Indian programme for the International Geophysical Year of 1957. Around this time, the erstwhile Soviet Union launched Sputnik-1. India, not too far behind, decided to set up the Indian National Committee for Space Research chaired by Sarabhai.

The visionary scientist set up India's first rocket launching station, TERLS in Thumba on the coast of the Arabian Sea on 21 November 1963 with the support of Homi Bhabha from the Atomic Energy Commission. In 1966, Sarabhai was appointed as Chairman of the Indian Atomic Energy Commission following Bhabha's untimely demise. Sarabhai's greatest achievement was It was at Bangalore, under the direct guidance of Nobel laureate, Dr C.V. Raman that he started setting up observatories in Bangalore, Pune and the Himalayas. Soon after the war was over, he returned to UK for a while. Sarabhai received a PhD from Cambridge University for his pathbreaking work. His real work began in 1947 along with meteorologist, K.R. Ramanathan, who helped him establish the Physical Research Laboratory, Ahmedabad. Initially, it consisted of rooms at the Science Institute of the Ahmedabad Education Society. Analys`ing and studying cosmic rays and atmospheric physics, the scientists set up two dedicated teams at the site. Sarabhai's team realized that evaluating the weather was not enough to comprehend variations in the cosmic rays; they had to relate it to variations in solar activity. He was the pioneer researcher in the field of solar physics. With such a big breakthrough in hand, Sarabhai soon received financial support from the Indian Council of Scientific and Industrial Research and the Department of Atomic Energy. And the support did not just end there. He was asked to organize the Indian programme for the International Geophysical Year of 1957. Around this time, the erstwhile Soviet Union launched Sputnik-1. India, not too far behind, decided to set up the Indian National Committee for Space Research chaired by Sarabhai. The visionary scientist set up India's first rocket launching station, TERLS in Thumba on the coast of the Arabian Sea on 21 November 1963 with the support of Homi Bhabha from the Atomic Energy Commission. In 1966, Sarabhai was appointed as Chairman of the Indian Atomic Energy Commission following Bhabha's untimely demise. Sarabhai's greatest achievement was the establishment of the Indian Space Research Organization (ISRO). He died in his sleep at 52 on 31 December 1971. The pioneering work on space science and research done by Dr Vikram Sarabhai earned him Shanti Swarup Bhatnagar Medal in 1962 and Padma Bhushan in 1966.

Meghnad Saha:

Meghnad Saha was an astrophysicist, best known for his development of the Saha equation, used to describe chemical and physical conditions in stars. Meghnad Saha was born on the 6 October 1893 in a village near Dhaka in Bangladesh. His father Jagannath Saha had a grocery shop in the village. His family's financial condition was very bad. He studied in the village primary school while attending the family shop during free time. He got admitted into a middle school which was seven miles away from his village. He stayed in a doctor's house near the school and had to work in that house to meet the cost of living. He was ranked first in the Dhaka middle school test and got admitted into Dhaka Collegiate School. Saha graduated from Presidency College with major in mathematics and got the second rank in the University of Calcutta whereas the first one was bagged by Satyendra Nath Bose, another great scientist of India.

In 1915, both S.N. Bose and Meghnad ranked first in MSc examination, Meghnad in applied mathematics and Bose in pure mathematics. Meghnad decided to do research in physics and applied mathematics. While in college, he got involved with the freedom struggle and came in contact with great leaders of his time like Subhash Chandra Bose and Bagha Jatin. Meghnad Saha made remarkable contribution to the field of astrophysics. He went abroad and stayed for two years in London and Germany. In 1927, Meghnad Saha was elected as a Fellow of the London Royal Society. He joined the University of Allahabad in 1923 where he remained for the next 15 years. Over this period, he gained a lot of recognition for his work in astrophysics and was made president of the physics section of the Indian Science Congress Association in 1925. In 1938, he became a professor of physics at the University of Calcutta. He took several initiatives, such as, introducing nuclear physics in the MSc physics syllabus of the University of Calcutta, starting a post post-MSc course in nuclear science, and also took steps to build a cyclotron, the first of its kind in the country. Saha also invented an instrument to measure the weight and pressure of solar rays and helped to build several scientific institutions, such as the Department of Physics in Allahabad University and the Institute of Nuclear Physics in Calcutta.

He founded the journal *Science and Culture* and was its editor until his death. He was the leading spirit in organizing several scientific societies, such as the National Academy of Science (1930), the Indian Physical Society (1934), Indian Institute of Science (1935) and the Indian Association for the Cultivation of Science (1944). A lasting memorial to him is the Saha Institute of Nuclear Physics, founded in 1943 in Kolkata. In addition to being a great scientist, he was also an able institution builder. He founded the Indian Science News Association at Calcutta in 1935 and the Institute of Nuclear Physics in 1950. He is also credited with preparing the original plan for the Damodar Valley Project. Other than being a scientist, he was also elected as a Member of Parliament. Besides, Saha's work relating to the reformation of the Indian calendar was very significant. He was the Chairman of the Calendar Reform Committee appointed by the Government of India in 1952. It was Saha's efforts which led to the formation of the Committee. The task before the Committee was to prepare an accurate calendar based on scientific study, which could be adopted uniformly throughout India. It was a mammoth task, but he did it successfully. Saha died on 16 February 1956.