History of Science and Technology in India

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History of Science and Technology - India

- The **history of science and technology in the Indian subcontinent** begins with

  - prehistoric human activity in the Indus Valley Civilization to early states and empires.

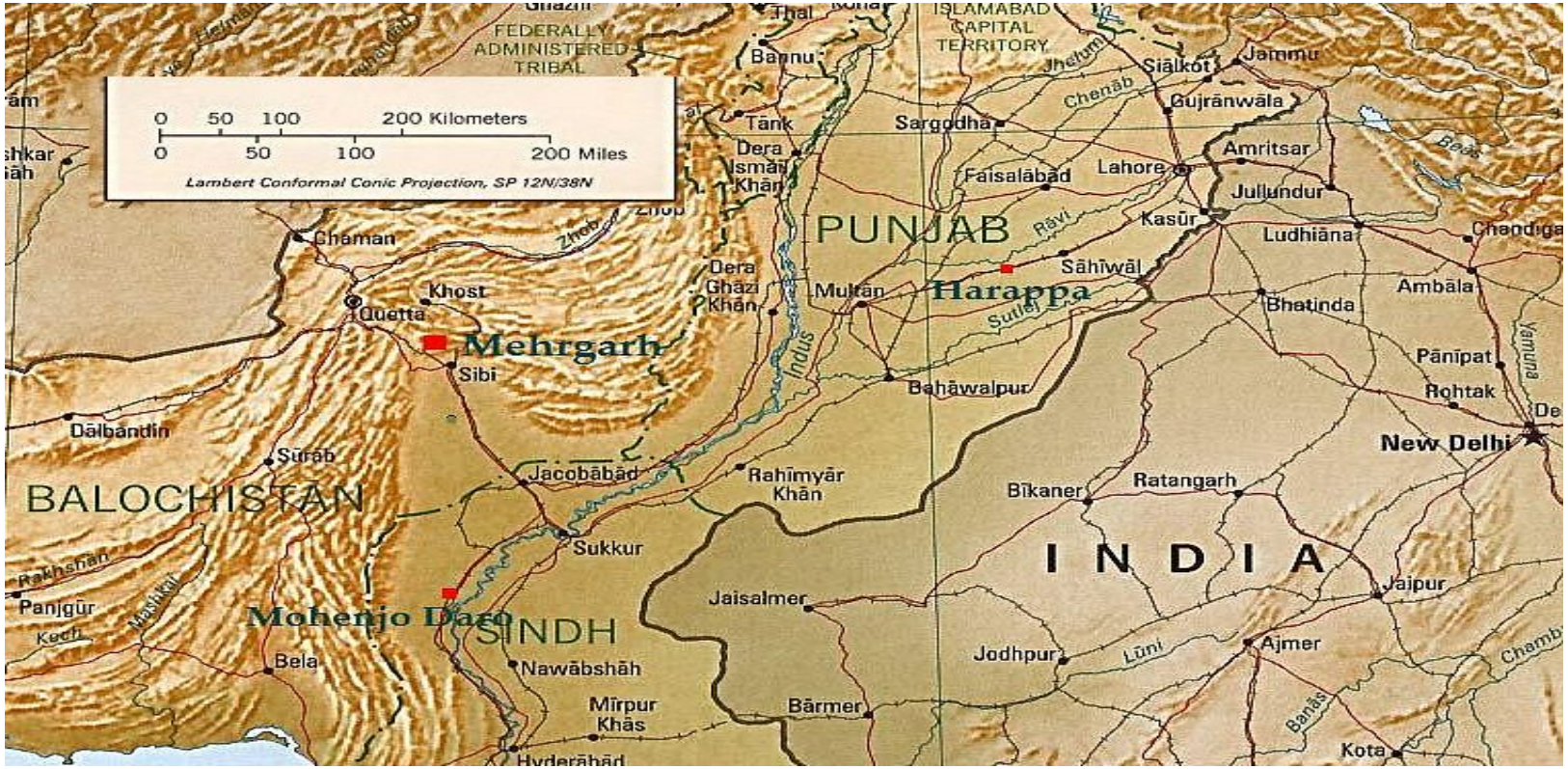
- Following independence science and technology in the Republic of India has included

- automobile engineering, information technology, communications as well as space, polar, and nuclear sciences.

Mehrgarh is a large Neolithic and Chalcolithic site located at the foot of the Bolan pass on the Kachi plain of Baluchistan (also spelled Balochistan), in modern day Pakistan.

Neolithic settlement (7,000 BC) in Mehrgarh

Mehrgarh Civilization



Prehistory

- By 5500 BCE a number of sites similar to Mehrgarh had appeared, forming the basis of later chalcolithic cultures. The inhabitants of these sites maintained trading relations with Near East and Central Asia.
- Irrigation was developed in the Indus Valley Civilization by around 4500 BCE.
- The size and prosperity of the Indus civilization grew as a result of this innovation, which eventually led to more planned settlements making use of drainage and sewerage.

*Mehrgarh is one of the earliest known sites which show evidence of farming and herding in South Asia.

*The term "Chalcolithic" has also been used in the context of the South Asian Stone Age. A period in the 4th and 3rd millennia BC, chiefly in the Near East and south-eastern Europe, during which some weapons and tools were made of copper.

IVC

- The Indus Valley Civilisation (IVC), also known as the Indus Civilisation, was **a Bronze Age civilisation in the northwestern regions of South Asia, lasting from 3300 BCE to 1300 BCE, and in its mature form from 2600 BCE to 1900 BCE.**
- Together with ancient Egypt and Mesopotamia, it was one of three early civilisations of the Near East and South Asia, and of the three, the most widespread, its sites spanning an area stretching from today's northeast Afghanistan, through much of Pakistan, and into western and northwestern India.
- It flourished in the basins of the Indus River, which flows through the length of Pakistan, and along a system of perennial, mostly monsoon-fed, rivers that once coursed in the vicinity of the seasonal Ghaggar-Hakra river in northwest India and eastern Pakistan.

* BCE-Before Common Era

BC and AD, BCE and CE: What's the Difference?

- The Gregorian calendar is the global standard for the measurement of dates.
- Despite originating in the Western Christian tradition, its use has spread throughout the world and now transcends religious, cultural and linguistic boundaries.
- As most people are aware, the **Gregorian calendar** is based on the **supposed birth date of Jesus Christ.**
- **Subsequent years** count up from this event and are accompanied by either **AD or CE**, while **preceding years** count down from it and are accompanied by either **BC or BCE**.

But what is the difference between AD and CE, or BC and BCE? Do they mean the same thing, and, if so, which should we use?

- The **idea to count years from the birth of Jesus Christ** was first proposed in the year 525 by **Dionysius Exiguus**, a Christian monk.
- **Standardized** under the **Julian and Gregorian calendars**, the system spread throughout Europe and the Christian world during the centuries that followed.
- **AD** stands for ***Anno Domini***, Latin for “in the year of the Lord.”
- While **BC** stands for “before Christ”.

BCE and CE

- **CE** stands for “**common (or current) era**”, while BCE stands for “before the common (or current) era”.
- These abbreviations have a shorter history than BC and AD, although they still date from at least the early 1700s.
- They have been in **frequent use by Jewish academics for more than 100 years**, but became more **widespread in the later part of the 20th century**, **replacing BC/AD** in a number of fields, notably science and academia.

Why Have Some People Adopted BCE/CE?

An important **reason for adopting BCE/CE is religious neutrality.** Since the Gregorian calendar has superseded other calendars to become the international standard, members of non-Christian groups may **object to the explicitly Christian origins of BC and AD.** Particularly problematic is **AD ("in the year of the Lord")**, and its unavoidable implication that the Lord in question is Jesus Christ. **Religious neutrality was the main rationale behind Jewish academics' adoption of BCE/CE over a century ago, and continues to be its most widely cited justification.**

The movement towards **BCE/CE has not been universally accepted**, and BC/AD is still more widely used, **even though BCE/CE has been in the mainstream since the 1980s.** There have been **backlashes to the adoption of the new system in defence of BC/AD**, notably in 2002 when the UK National Curriculum made the transition. In 2011, education authorities in Australia were forced to deny that such a change had been planned for national school textbooks amid a similar controversy triggered by media reports.

IVC (contd.)

- The **civilisation's cities** were noted for their:

- urban planning, baked brick houses, elaborate drainage systems, water supply systems, clusters of large non-residential buildings, and new techniques in handicraft (carnelian products, seal carving) and metallurgy (copper, bronze, lead, and tin).

- The large cities of Mohenjo-Daro and Harappa very likely grew to contain:

- between 30,000 and 60,000 individuals, and the civilisation itself during its florescence may have contained between one and five million individuals.

- Gradual drying of the region's soil during the 3rd millennium BCE may have been:

- the initial spur for the urbanisation associated with the civilisation

-but eventually weaker monsoons and reduced water supply caused the civilisation's demise, and to scatter its population eastward and southward.

- The Indus civilisation is also known as the Harappan Civilisation, after its type site, Harappa, the first of its sites to be excavated early in the 20th century in what was then the Punjab province of British India and now is Pakistan.
- The discovery of Harappa and soon afterwards Mohenjo-Daro was the culmination of work beginning in 1861 with the founding of the Archaeological Survey of India during the British Raj.

- Sophisticated irrigation and water storage systems were developed by the Indus Valley Civilization, including artificial reservoirs at Girnar dated to 3000 BCE, and an early canal irrigation system from c. 2600 BCE.
- Cotton was cultivated in the region by the 5th–4th millennia BCE. Sugarcane was originally from tropical South and Southeast Asia. Different species likely originated in different locations with *S. barberi* originating in India, and *S. edule* and *S. officinarum* coming from New Guinea.

*Saccharum barberi is a strong-growing species of grass in the genus Saccharum, the sugarcanes.

*Saccharum edule is a species of sugarcane, that is a grass in the genus Saccharum with a fibrous stalk that is rich in sugar. It is cultivated in tropical climates in southeastern Asia. It has many common names which include duruka, tebu telor, Fiji asparagus, dule (Fiji), pitpit (Melanesia) and naviso.

*Saccharum officinarum is a large, strong-growing species of grass in the genus Saccharum. Its stout stalks are rich in sucrose, a simple sugar which accumulates in the stalk internodes. It originated in New Guinea, and is now cultivated in tropical and subtropical countries worldwide for the production of sugar, ethanol and other products.

- The inhabitants of the Indus valley developed a system of standardization

-using weights and measures, evident by the excavations made at the Indus valley sites.

- This technical standardization enabled gauging devices to be effectively used in angular measurement and measurement for construction.

- Calibration was also found in measuring devices along with multiple subdivisions in case of some devices.

- One of the earliest known docks is at Lothal (2400 BCE), located away from the main current to avoid deposition of silt.

- Modern oceanographers have observed that the Harappans must have possessed knowledge relating to tides

- in order to build such a dock on the ever-shifting course of the Sabarmati, as well as exemplary hydrography and maritime engineering.

- Excavations at Balakot (c. 2500–1900 BCE), present day Pakistan, have yielded evidence of an early furnace.
- The furnace was most likely used for the manufacturing of ceramic objects. Ovens, dating back to the civilization's mature phase (c. 2500–1900 BCE), were also excavated at Balakot.
- The Kalibangan archeological site further yields evidence of pot shaped hearths, which at one site have been found both on ground and underground. Kilns with fire and kiln chambers have also been found at the Kalibangan site.

Kalibangan is a town located at 29.47°N 74.13°E on the left or southern banks of the Ghaggar (Ghaggar-Hakra River) in Tehsil Pilibangan, between Suratgarh and Hanumangarh in Hanumangar District, Rajasthan, India 205 km. from Bikaner. It is also identified as being established in the triangle of land at the confluence of Drishadvati and Sarasvati Rivers. The prehistoric and pre-Mauryan character of Indus Valley Civilization was first identified by Luigi Tessitori at this site. Kalibangan's excavation report was published in its entirety in 2003 by the Archaeological Survey of India, 34 years after the completion of excavations. The report concluded that Kalibangan was a major provincial capital of the Indus Valley Civilization. Kalibangan is distinguished by its unique fire altars and "world's earliest attested ploughed field".It is around 2900 BC that the region of Kalibangan developed into what can be considered a planned city.

- Based on archaeological and textual evidence:

---Joseph E. Schwartzberg (2008)—a University of Minnesota professor emeritus of geography

---races the origins of Indian cartography (*the study and practice of making and using maps*) to the Indus Valley Civilization (c. 2500–1900 BCE).

- The use of large scale constructional plans, cosmological drawings, and cartographic material was known in India with some regularity since the Vedic period (2nd – 1st millennium BCE).

- Climatic conditions were responsible for the destruction of most of the evidence.

- However, a number of excavated surveying instruments and measuring rods have yielded convincing evidence of early cartographic activity.

- Schwartzberg (2008)—on the subject of surviving maps—further holds that-

'Though not numerous, a number of map-like graffiti appear among the thousands of Stone Age Indian cave paintings; and at least one complex Mesolithic diagram is believed to be a representation of the cosmos.'

- Archeological evidence of an animal-drawn plough dates back to 2500 BCE in the Indus Valley Civilization.
- The earliest available swords of copper discovered from the Harappan sites date back to 2300 BCE.
- Swords have been recovered in archaeological findings throughout the Ganges–Jamuna Doab region of India, consisting of bronze but more commonly copper.

Early Kingdoms

- The religious texts of the Vedic Period provide evidence for the use of large numbers.
- By the time of the last Veda, the Yajurveda Samhita (1200–900 BCE), numbers as high as -10 to the power 12- were being included in the texts.
- For example, the mantra (sacrificial formula) at the end of the annahoma ("food-oblation rite") performed during the Ashvamedha ("an allegory for a horse sacrifice"), and uttered just before-, during-, and just after sunrise, invokes powers of ten from a hundred to a trillion.
- The Satapatha Brahmana (9th century BCE) contains rules for ritual geometric constructions that are similar to the Sulba Sutras.

- Baudhayana (c. 8th century BCE) composed the Baudhayana Sulba Sutra, which contains examples of simple Pythagorean triples, such as:

-(3,4,5), (5,12,13),(8,15,17), (7,24,25), and (12,35,37)

- As well as a statement of the Pythagorean theorem for the sides of a square:

"The rope which is stretched across the diagonal of a square produces an area double the size of the original square."

- It also contains the general statement of the Pythagorean theorem (for the sides of a rectangle): "The rope stretched along the length of the diagonal of a rectangle makes an area which the vertical and horizontal sides make together.“

- Baudhayana gives a formula for the square root of two. Mesopotamian influence at this stage is considered likely.

- The earliest Indian astronomical text:

—named Vedānga Jyotiṣa and attributed to Lagadha—is considered one of the oldest astronomical texts, dating from 1400–1200 BCE.

- It details several astronomical attributes generally applied for timing social and religious events.

- It also details astronomical calculations, calendrical studies, and establishes rules for empirical observation.

- Since the **Vedānga Jyotiṣa** is a religious text, it has connections with Indian astrology and details several important aspects of the **time and seasons**, including lunar months, solar months, and their adjustment by a lunar leap month of Adhikamāsa. Ritus and Yugas are also described.

- Tripathi (2008) holds that "Twenty-seven constellations, eclipses, seven planets, and twelve signs of the zodiac were also known at that time."

- The **Egyptian Papyrus of Kahun** (1900 BCE) and **literature of the Vedic period in India** offer early records **of veterinary medicine**.
- Kearns & Nash (2008) state that mention **of leprosy** is described in the **medical treatise Sushruta Samhita** (6th century BCE).
- The **Sushruta Samhita an Ayurvedic text** contains 184 chapters and description of 1120 illnesses, 700 medicinal plants, a detailed study on Anatomy, 64 preparations from mineral sources and 57 preparations based on animal sources.
- However, The Oxford Illustrated Companion to Medicine holds that the mention of leprosy, as well as ritualistic cures for it, were described in the Hindu religious book Atharva Veda, written in 1500–1200 BCE.

- **Cataract surgery** was known to the physician Sushruta (6th century BCE).
- Traditional cataract surgery was performed with a **special tool called the *Jabamukhi Salaka***, a curved needle used to loosen the lens and push the cataract out of the field of vision.
- The eye would later be soaked with warm butter and then bandaged.
- Though this method was successful, Susruta cautioned that it should only be used when necessary.
- The removal of cataract by surgery was also introduced into India from China.

- During the 5th century BCE, the **scholar Panini** had made several discoveries in the fields of phonetics, phonology, and morphology.
- Panini's morphological analysis remained more advanced than any equivalent Western theory until the mid-20th century.
- **Metal currency was minted in India** before the 5th century BCE, with coinage (400 BCE–100 CE) being made of silver and copper, bearing animal and plant symbols on them.
- **Zinc mines of Zawar, near Udaipur, Rajasthan**, were active during 400 BCE.

- Diverse **specimens of swords** have been discovered in **Fatehgarh**, where there are several varieties of hilt.
- These swords have been variously dated to periods between 1700–1400 BCE, but were probably used more extensively during the opening centuries of the 1st millennium BCE.
- **Archaeological sites in such as Malhar, Dadupur, Raja Nala Ka Tila and Lahuradewa** in present-day Uttar Pradesh show iron implements from the period between 1800 BCE and 1200 BCE.

- Early iron objects found in India can be dated to 1400 BCE by employing the method of radio carbon dating.
- Some scholars believe that by the early 13th century BCE iron smelting was practiced on a bigger scale in India, suggesting that the date of the technology's inception may be placed earlier.
- In Southern India (present day Mysore) iron appeared as early as 11th to 12th centuries BCE.
- These developments were too early for any significant close contact with the northwest of the country.

Middle Kingdoms (230 BCE – 1206 CE)

- **The Arthashastra of Kautilya mentions the construction of dams and bridges**. The use of suspension bridges using plaited bamboo and iron chain was visible by about the 4th century.
- **The stupa, the precursor of the pagoda and torii, was constructed by the 3rd century BCE.** Rock-cut step wells in the region date from 200–400 CE. Subsequently, the construction of wells at Dhank (550–625 CE) and stepped ponds at Bhinmal (850–950 CE) took place.
- During the 1st millennium BCE, the **Vaisheshika school of atomism** was founded.

- The most **important proponent of this school was Kanada**, an Indian philosopher who lived around 600 BCE.
- The school proposed that atoms are indivisible and eternal, can neither be created nor destroyed, and that each one possesses its own distinct viśeṣa (individuality).
- It was further elaborated on by the **Buddhist school of atomism, of which the philosophers Dharmakirti and Dignāga in the 7th century CE were the most important proponents.** They considered atoms to be point-sized, duration less, and made of energy.

* A torii is a traditional Japanese gate most commonly found at the entrance of or within a Shinto shrine, where it symbolically marks the transition from the mundane to the sacred.

Pagoda and Torii

- By the **beginning of the Common Era glass was being used for ornaments and casing in the region.**
- Contact with the Greco-Roman world added newer techniques, and local artisans learnt methods of **glass molding, decorating and coloring** by the early centuries of the Common Era.
- The **Satavahana period** further reveals short cylinders of composite glass, including those displaying a lemon yellow matrix covered with green glass.
- **Wootz originated in the region before the beginning of the common era**. Wootz was exported and traded throughout Europe, China, the Arab world, and became particularly famous in the Middle East, where it became known as **Damascus steel**. Archaeological evidence suggests that manufacturing process for Wootz was also in existence in South India before the Christian era.

*The **Satavahanas** were also referred to as the **Andhras** in the Puranas, they were an ancient Indian dynasty based in the Deccan region.

***Wootz steel** is a crucible steel characterized by a pattern of bands and high carbon content.

***Damascus steel** was the forged steel of the blades of swords smithed in the Near East from ingots (piece of relatively pure material) of Wootz steel either imported from Southern India or made in production centres in Sri Lanka or Khorasan, Iran.

- Evidence for using **bow-instruments for carding** comes from India (2nd century CE). The mining of diamonds and its early use as gemstones originated in India.
- **Golconda served as an important early center for diamond mining and processing**. Diamonds were then exported to other parts of the world. Early reference to diamonds comes from Sanskrit texts.
- **The *Arthashastra* also mentions diamond trade in the region**. The Iron pillar of Delhi was erected at the times of Chandragupta II Vikramaditya (375–413), which stood without rusting for around 2 millennium.
- **The Rasaratna Samuccaya**(800) explains the existence of two types **of ores for zinc metal**, one of which is ideal for metal extraction while the other is used for medicinal purpose.

*__Carding__ is a mechanical process that disentangles, cleans and intermixes fibres to produce a continuous web or sliver suitable for subsequent processing.

*__*Rasaratna Samuchchaya*__ is an alchemical work written in India, in the Sanskrit language, and datable to the thirteenth, fourteenth, or the sixteenth century.

- The **origins of the spinning wheel are unclear but India is one of the probable places of its origin.** The device certainly reached Europe from India by the 14th century.
- **The cotton gin was invented in India as a mechanical device known as *charkhi***, the "wooden-worm-worked roller". This mechanical device was, in some parts of the region, driven by water power.
- **The Ajanta Caves** yield evidence of a single roller cotton gin in use by the 5th century. This cotton gin was used until further innovations were made in form of foot powered gins.
- Chinese documents confirm at least two missions to India, initiated in 647, for obtaining technology for sugar-refining.

- **Pingala** (300–200 BCE) was a musical theorist who authored a Sanskrit treatise on prosody.
- There is evidence that in his work on the **enumeration of syllabic combinations**, Pingala stumbled upon both the Pascal Triangle and Binomial coefficients, although he did not have knowledge of the Binomial theorem itself.
- **A description of binary numbers is also found in the works of Pingala.** The Indians also developed the use of the law of signs in multiplication.
- Negative numbers and the subtrahend had been used in East Asia since the 2nd century BCE, and **Indian mathematicians were aware of negative numbers by the 7th century CE**, and their role in mathematical problems of debt was understood.

*Acharya **Pingala** was the ancient Indian author of the *Chandaḥśāstra* (also called *Pingala-sutras*), the earliest known treatise on Sanskrit prosody.

*In mathematics, **Pascal's triangle** is a triangular array of the binomial coefficients that arises in probability theory, combinatorics, and algebra.

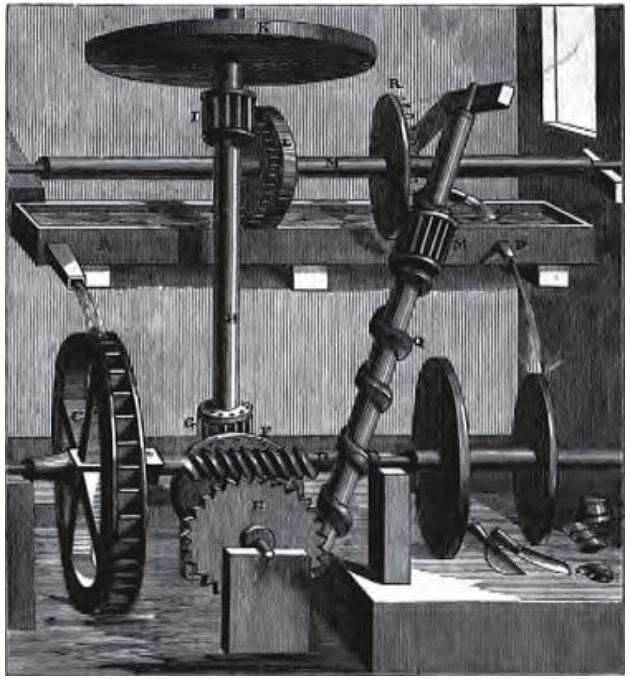
- A decimal number system using hieroglyphics dates back to 3000 BC in Egypt, and was later in use in ancient India.
- By the 9th century CE, the Hindu–Arabic numeral system was transmitted from the Middle East and to the rest of the world.
- The concept of 0 as a number, and not merely a symbol for separation is attributed to India.

* **hieroglyphic** writing- system that employs characters in the form of pictures.

- In India, practical calculations were carried out using zero, which was treated like any other number by the 9th century CE, even in case of division.
- Brahmagupta (598–668) was able to find (integral) solutions of Pell's equation.
- Conceptual design for a perpetual motion machine by Bhaskara II dates to 1150. He described a wheel that he claimed would run forever.
- The calculus theorem now known as "Rolle's theorem" was stated by mathematician, Bhaskara II, in the 12th century.

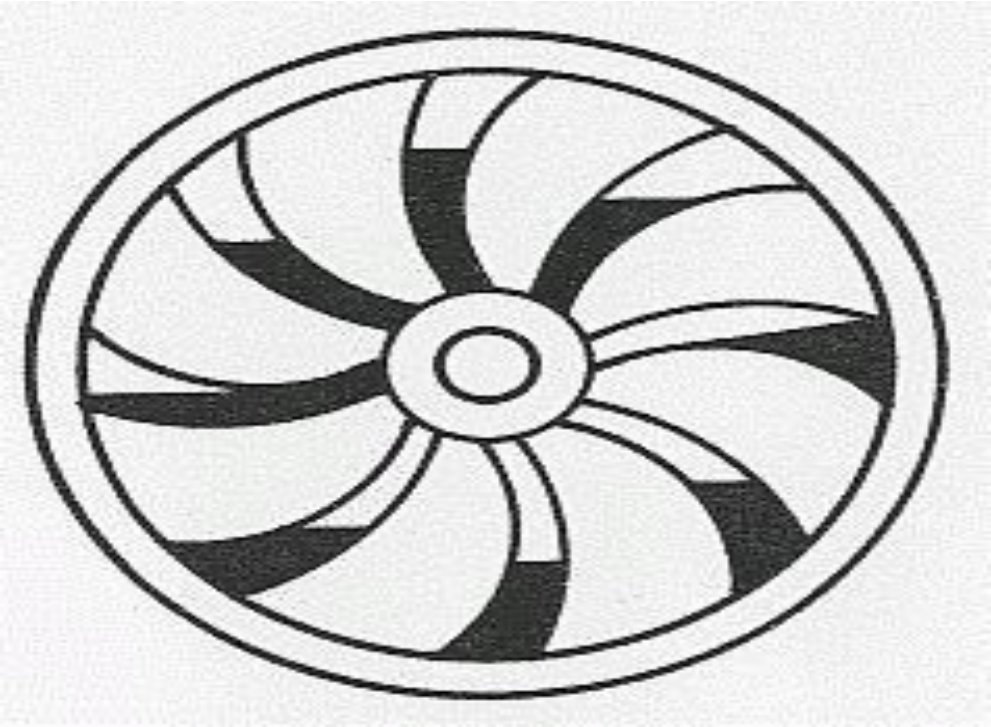
* Pell's equation is an important topic of algebraic number theory that involves quadratic forms and the structure of rings of integers in algebraic number fields. The history of this equation is long and circuitous, and involved a number of different approaches before a definitive theory was found. There were partial patterns and quite effective methods of finding solutions, but a complete theory did not emerge until the end of the eighteenth century.

A **perpetual motion machine** is a hypothetical machine that can do work infinitely without an external energy source. This kind of machine is impossible, as it would violate either the first or second law of thermodynamics or both.



Robert Fludd's 1618 "water screw" perpetual motion machine from a 1660 wood engraving. It is widely credited as the first attempt to describe such a device .

Bhaskara Wheel with Curved Spokes

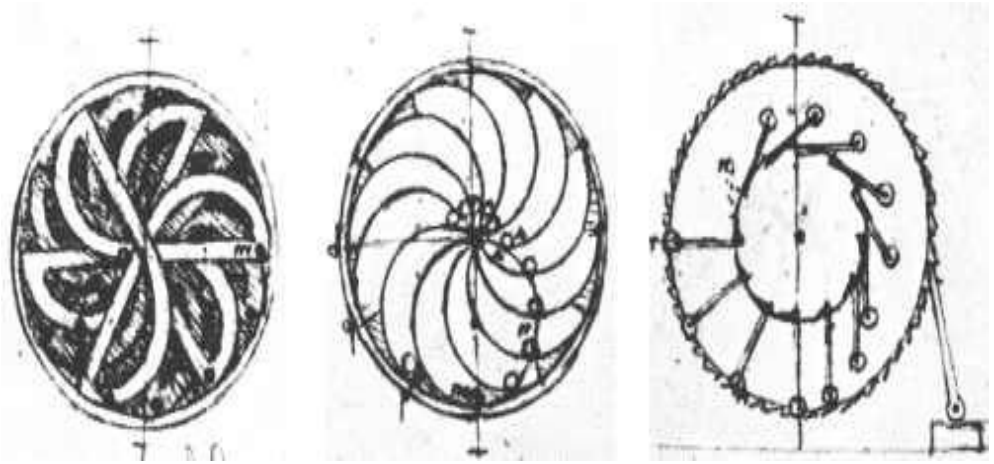


Bhaskara's Wheels

- The first documented perpetual motion machines were described by the Indian author Bhaskara (c. 1159).
- One was a wheel with containers of mercury around its rim.
- As the wheel turned, the mercury was supposed to move within the containers in such a way that the wheel would always be heavier on one side of the axle.
- Perhaps this was not so much a practical proposal as an illustration of Indian cyclical philosophy.
- The idea reappears in Arabic writings, one of which contained six perpetual motion devices.
- From the Islamic world the idea reached Europe.

Leonardo Da Vinci’s drawings of perpetual motion wheels

In modern language it says that as a weight moves farther from the rotation axis, the gravitational torque (it is the rotational equivalent of linear force. It is also referred to as the moment, moment of force, rotational force or turning effect) on it is greater, but the moment of inertia of the wheel is simultaneously increased, making the gravitational torque less effective in increasing or sustaining motion of the wheel. The net gain is zero.



- Indigo was used as a dye in India, which was also a major center for its production and processing.
- The *Indigofera tinctoria* variety of Indigo was domesticated in India. Indigo, used as a dye, made its way to the Greeks and the Romans via various trade routes, and was valued as a **luxury product.**
- The cashmere wool fiber, also known as *pashm* or *pashmina*, was used in the handmade shawls of Kashmir.
- The woolen shawls from Kashmir region find written mention between 3rd century BCE and the 11th century CE.
- Crystallized sugar was discovered by the time of the Gupta dynasty, and the **earliest reference to candied sugar comes from India**. Jute was also cultivated in India.

- Muslin was named after the city where Europeans first encountered it, Mosul, in what is now Iraq, but the fabric actually originated from Dhaka in what is now Bangladesh.
- In the 9th century, an Arab merchant named Suleiman makes note of the material's origin in Bengal (known as *Ruhml* in Arabic).
- *Samarangana Sutradhara*, a **Sanskrit treatise by Bhoja** (11th century), includes a chapter about the construction of mechanical contrivances (automata), which included-

-mechanical bees and birds

-fountains shaped like humans and animals

-and male and female dolls that refilled oil lamps, danced, played instruments, and re-enacted scenes from Hindu mythology.

Late Medieval and Early Modern periods (1206–1858 CE)

- Sher Shah of northern India issued silver currency bearing Islamic motifs, later imitated by the Mughal empire.
- The Chinese merchant Ma Huan (1413–51) noted that gold coins, known as *fanam*, were issued in Cochin and weighed a total of one *fen* and one *li* according to the Chinese standards.
- They were of fine quality and could be exchanged in China for 15 silver coins of four-*li* weight each.
- In 1500, Nilakantha Somayaji of the Kerala school of astronomy and mathematics, in his Tantrasangraha, revised Aryabhata's elliptical model for the planets Mercury and Venus.
- His equation of the centre for these planets remained the most accurate until the time of Johannes Kepler in the 17th century.

- Gunpowder and gunpowder weapons were transmitted to India through the Mongol invasions of India.
- The Mongols were defeated by Alauddin Khalji of the Delhi Sultanate, and some of the Mongol soldiers remained in northern India after their conversion to Islam.
- It was written in the *Tarikh-i-Firishta* (1606–1607) that the envoy of the Mongol ruler Hulagu Khan was presented with a pyrotechnics display upon his arrival in Delhi in 1258 CE.
- As a part of an embassy to India by Timurid leader Shah Rukh (1405–1447), 'Abd al-Razzaq mentioned naphtha-throwers mounted on elephants and a variety of pyrotechnics put on display.
- Firearms known as *top-o-tufak* also existed in the Vijayanagar Empire by as early as 1366 CE.

*__Pyrotechnics__ is the science and craft of creating such things as fireworks, safety matches, oxygen candles, explosive bolts and other fasteners, parts of automotive airbags, as well as gas-pressure blasting in mining, quarrying, and demolition.

- By the 16th century, Indians were manufacturing a diverse variety of firearms; large guns in particular, became visible in Tanjore, Dacca, Bijapur and Murshidabad.
- Guns made of bronze were recovered from Calicut (1504) and Diu (1533).
- Gujarat supplied Europe saltpeter (potassium nitrate) for use in gunpowder warfare during the 17th century.
- Bengal and Malwa participated in saltpeter production.
- The Dutch, French, Portuguese, and English used Chhapra as a center of saltpeter refining.

- The construction of water works and aspects of water technology in India is described in Arabic and Persian works.
- During medieval times, the diffusion of Indian and Persian irrigation technologies gave rise to an advanced irrigation system which bought about economic growth and also helped in the growth of material culture.
- The founder of the cashmere wool industry is traditionally held to be the 15th-century ruler of Kashmir, Zayn-ul-Abidin, who introduced weavers from Central Asia.

Colonial Era (1858–1947 CE)

- By the end of the 18th century the postal system in the region had reached high levels of efficiency.
- According to Thomas Broughton, the Maharaja of Jodhpur sent daily offerings of fresh flowers from his capital to Nathadvara (320 km) and they arrived in time for the first religious Darshan at sunrise.
- Later this system underwent modernization with the establishment of the British Raj.

- The Post Office Act XVII (17) of 1837 enabled the Governor-General of India to convey messages by post within the territories of the East India Company.
- Mail was available to some officials without charge, which became a controversial privilege as the years passed. The Indian Post Office service was established on October 1, 1837.
- The British also constructed a vast railway network in the region for both strategic and commercial reasons.

- The British education system, aimed at producing able civil and administrative services candidates, exposed a number of Indians to foreign institutions.
- Notable scholars of this period-

Jagadish Chandra Bose (1858–1937), Prafulla Chandra Ray (1861–1944), Satyendra Nath Bose (1894–1974), Meghnad Saha (1893–1956), P. C. Mahalanobis (1893–1972), C. V. Raman (1888–1970), Subrahmanyan Chandrasekhar (1910–1995), Homi Bhabha (1909–1966), Srinivasa Ramanujan (1887–1920), Vikram Sarabhai (1919–1971), Har Gobind Khorana (1922–2011), Harish Chandra (1923–1983), and Abdus Salam (1926–1996)

- Extensive interaction between **colonial and native sciences** was seen during most of the colonial era.
- **Western science** came to be associated with the **requirements of nation building** rather than being viewed entirely as a **colonial entity**, especially as it continued to fuel necessities from agriculture to commerce.
- Scientists from India also appeared throughout Europe.
- By the time of India's independence colonial science had assumed importance within the westernized intelligentsia and establishment.
- French astronomer, **Pierre Janssen** observed the **Solar eclipse of 18 August 1868** and discovered **helium**, from Guntur in Madras State, British India.

Jagadish Chandra Bose (1858–1937)

- Jagdish Chandra Bose was a biologist, physicist, botanist and an early writer of science fiction.
- He pioneered the investigation of **radio and microwave optics**, made significant contributions to **plant science**, and laid the **foundations of experimental science** in the Indian subcontinent.
- IEEE named him **one** of the **fathers of radio science**.
- Bose is considered the **father of Bengali science fiction**, and also invented the crescograph (device for measuring the growth in plants).
- **A crater on the moon** has been named in his honour.
- He founded **Bose Institute**, a premier research institute of India and also one of its oldest.
- Established in 1917, the Institute was the first interdisciplinary research centre in Asia. He served as the Director of Bose Institute from its inception until his death.

"...the first impetus of western education impressed itself on some in a dead monotony of imitation of things western; while in others it awakened all that was greatest in national memory" - J C Bose

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- Bose is said to have **refused salary for three years** while he taught physics in Colonial Calcutta.
- He was revolting against **race colored differences** in **pay scales.**
- His admirers and critics regret his not producing enough "technical physics" knowledge and attribute this to his being seduced into spirituality by prevalent Tagorean sensibilities.
- J C Bose **christened** the scientific instruments he had built with **Sanskrit** words.
- Was this a sign of Bose's "syncretic approach" or is it to be read with anxiety- that of a 'Hindu' scientist eager to culturally traditionalize his modern technological expressions?
- When Bose sat down to pen his first fictional novel, how did the scientist in him reach out to fantasy?
- How did cognitive polarities- the rational and the fantastical merge within the mind of a modernizing Indian researcher?

Prafulla Chandra Ray (1861–1944)

- Sir Prafulla Chandra Ray was the **first Indian chemist** to achieve high international reputation.
- Originally trained at the **University of Edinburgh**, he worked for many years at **Presidency College in Calcutta and then at Calcutta University.**
- He built up a **remarkable school of chemical research** by attracting many outstanding students to work with him and published about 150 papers—many of them in leading British and German journals.
- Ray was highly respected by his British peers and was the first Indian of that era to be **nominated for FRS** (Fellow of Royal Society) , in 1913.

- At the time when his nomination was being considered by the Royal Society, Ray's favorite student, **Nil Ratan Dhar** (1892–1986), who was to become the second Indian chemist to achieve high international reputation, worked in London and Paris for a few years.
- Even when Dhar was merely a 24-year-old student, he lobbied with several leading British chemists for the election of Ray and kept Ray informed in a series of fascinating letters—giving us a rare glimpse of what election to the Royal Society meant for Indian scientists of that era.
- During this time, Ray received a **knighthood** for his contributions to chemistry, and *Nature* published a front-page article on Ray's 'life-work'.
- Many British chemists felt strongly that Ray should be elected FRS and were willing to discuss Ray's case with the young Dhar quite openly. But, rather mysteriously, Ray never got elected.

Satyendra Nath Bose (1894–1974)

- Satyendra Nath Bose **FRS** was an Indian **mathematician and physicist** specializing in theoretical physics.
- He is best known for his work on **quantum mechanics** in the early 1920s, collaborating with Albert Einstein in developing the foundation for **Bose–Einstein statistics and the theory of the Bose–Einstein condensate**.
- A Fellow of the Royal Society, he was awarded India's second highest civilian award, the **Padma Vibhushan** in 1954 by the Government of India.
- Bose received a Bachelor of Science in **mixed mathematics** in 1913 from Presidency College and a Master of Science in the same subject in 1915 from Calcutta University.
- He received such high scores on the exams for each degree that not only was he in first standing but, for the latter, he even created a new record in the annals of the University of Calcutta, which has yet to be surpassed.
- Fellow student Meghnad Saha, who would later work with Bose, came in second standing.

- In 1921, Bose joined the physics department at the University of Dhaka, which had then been recently formed, and went on to establish new departments, laboratories and libraries in which he could teach advanced courses.
- He wrote a paper in 1924 in which he **derived Planck's quantum radiation law without referencing classical physics**—which he was able to do by counting states with identical properties.
- The paper would later prove seminal in creating the field of quantum statistics.
- Bose sent the paper to **Einstein in Germany, and the scientist recognized its importance, translated it into German and submitted it on Bose's behalf to the prestigious scientific journal *Zeitschrift fur Physik*.**
- The publication led to recognition, and Bose was granted **a leave of absence to work in Europe for two years at X-ray and crystallography laboratories, where he worked alongside Einstein and Marie Curie**, among others.

- **Einstein had adopted Bose's idea and extended it to atoms**, which led to the prediction of the existence of phenomena that became known as the **Bose-Einstein Condensate, a dense collection of bosons**

—particles with integer spin that were named for Bose.

- After his stay in Europe, Bose returned to the University of Dhaka in 1926.
- Although he did not have a doctorate, Einstein had recommended he be made a professor, and so Bose was made head of the physics department.
- But upon his return, Bose did not publish for a significant period of time.
- According to a July 2012 *New York Times* article in which Bose is described as the **"Father of the 'God Particle,'"** the scientist's interests wandered into other fields, including philosophy, literature and the Indian independence movement.
- He published another physics paper in 1937, and in the early 1950s worked on unified field theories.

- After 25 years in Dhaka, **Bose moved back to Calcutta in 1945** and continued to research and teach there until his death in 1974.
- Several Nobel Prizes were awarded for research related to the concepts of the boson and the Bose-Einstein Condensate.
- **Bose was never awarded a Nobel Prize**, despite his work on particle statistics, which clarified the behavior of photons and "opened the door to new ideas on statistics of Microsystems that obey the rules of quantum theory.“
- According to physicist Jayant Narlikar, who said Bose's finding was one of the top 10 achievements of 20th-century Indian science.

- The Indian government honored **Bose in 1954 with the title Padma Vibhushan**, the second-highest civilian award in India.
- Five years later, he was appointed as **the National Professor**, the highest honor in the country for a scholar. Bose remained in that position for 15 years.
- Bose also became an adviser to the Council of Scientific and Industrial Research, as well as **president** of the **Indian Physical Society** and the National Institute of Science.
- He was elected general president of the Indian Science Congress and president of the Indian Statistical Institute.
- **In 1958, he became a Fellow of the Royal Society**.

Meghnad Saha (1893–1956)

- The name of Professor Meghnad Saha would always remain associated with the theory of thermal ionization and its application to the interpretation of stellar spectra in terms of the physical conditions prevailing in the stellar atmospheres.
- The theory had all the simplicity and inevitableness which usually characterize a fundamental and epochal contribution.
- It was almost a direct consequence of the recognition that the laws of thermodynamics and the kinetic theory of gases can be extended to a gas of free electrons.
- Apart from astrophysics, the theory later found numerous other important applications, such as, to mention some of them, in the study of the ionosphere, conductivity of flames, electric arcs and explosion phenomena.
- Saha's researches in astrophysics and physics extended over a wide range of subjects.

- He was from the beginning a member of the Council of Scientific and Industrial Research constituted by the Indian Government in 1942, and member (or chairman) of several of the research and other committees of the Council.
- He was the Chairman of the Council's Indian Calendar Reform Committee.
- He was an elected independent member of the Indian Parliament.
- He took the keenest interest in problems of national planning, particularly in relation to science and industry.
- He was an active member of the National Planning Committee appointed by the Indian National Congress in 1938 with Jawaharlal Nehru as chairman.

- In his criticism of things and men, Saha was fearless and trenchant, and he was motivated by a deep earnestness and sincerely, though often tenaciously, held convictions.
- His memory and versatility were amazing. He was extremely simple, almost austere, in his habits and personal needs.
- He was a man of undaunted spirit, resolute determination, untiring energy and dedication.
- On 16 February 1956, on his way to the Office of the Planning Commission in New Delhi, he succumbed to a sudden heart-attack (some hundred yards from the Office of the Commission).
- At the age of sixty-two, a career superb in science and great in its promotion and dissemination was tragically closed.

C. V. Raman (1888–1970)

- **Sir Chandrasekhara Venkata Raman** FRS, was an Indian physicist known mainly for his work in the field of light scattering.
- With his student K. S. Krishnan, he discovered that when light traverses a transparent material, some of the deflected light changes their paths (wavelength and amplitude).
- This phenomenon was a hitherto unknown type of scattering of light and was subsequently termed as the Raman effect or Raman scattering.
- Raman received the 1930 Nobel Prize in Physics for the discovery and was the first Asian to receive a Nobel Prize in any branch of science.

- In 1917, he was appointed as the first Palit Professor of Physics by Ashutosh Mukherjee at the Raja bazar Science College under the University of Calcutta.
- On his first trip to Europe, seeing the Mediterranean Sea motivated him to identify the prevailing explanation for the blue color of the sea at the time, namely the reflected Rayleigh-scattered light from the sky, as being incorrect.
- He founded the *Indian Journal of Physics* in 1926.
- He and Krishnan discovered on 28 February 1928 a novel phenomenon of light scattering, which they called "modified scattering," but more famously known as the Raman effect.
- The day is celebrated by the Government of India as the National Science Day every year.

- Raman moved to the Indian Institute of Science in Bangalore in 1933 to become its first Indian Director.
- There he founded the Indian Academy of Sciences the same year.
- He established the Raman Research Institute in 1948 where he worked to his last days.
- In 1954, the Government of India honored him with the first Bharat Ratna, its highest civilian award.
- He later smashed the medallion in protest against Prime Minister Jawaharlal Nehru's policies on scientific research.

- Raman qualified for the Indian Finance Service with first position in the entrance examination in February 1907.
- He was posted in Calcutta as Assistant Accountant General in June 1907.
- It was there that he became highly impressed with the Indian Association for the Cultivation of Science (IACS), the first research institute founded in India in 1876.
- He immediately befriended Ashutosh Dey, who would eventually become his lifelong collaborators, Amrita Lal Sircar, founder and secretary of IACS, and Ashutosh Mukherjee, executive member of the institute and Vice Chancellor of the University of Calcutta.
- With such a connection, he obtained permission to conduct research in his own time even "at very unusual hours", as Raman later reminisced.

- Up to that time the institute had not yet recruited regular researchers, or produced any research papers.
- Raman's article "Newton's rings in polarized light" was published in *Nature* in 1907 from the institute.
- The work inspired IACS to publish a journal *Bulletin of Indian Association for the Cultivation of Science* in 1909 in which Raman was the major contributor.
- In 1909, Raman was transferred to Rangoon, British Burma, to take up the position of currency officer. After only a few months, he had to return to Madras as his father succumbed to a fatal illness.
- The subsequent death of his father and funeral rituals made him stay there for the rest of the year. Soon after he resumed office at Rangoon, he was transferred to Nagpur, Maharashtra in 1910.
- Even before he served for a year in Nagpur, he was promoted to Accountant General in 1911 and again posted to Calcutta.

- From 1915, the University of Calcutta started assigning research scholars under Raman at IACS.
- Sudhanshu Kumar Banerji (who later become Director General of Observatories of India Meteorological Department), a PhD scholar under Ganesh Prasad, was his first student.
- From the next year, other universities followed suit including University of Allahabad, Rangoon University, Queen's College Indore, Institute of Science, Nagpur, Krisnath College, and University of Madras.
- By 1919, Raman had guided more than a dozen students.
- Following Sircar's death in 1919, Raman received two honorary positions at IACS, Honorary Professor and Honorary Secretary.
- He referred to this period as the "golden era" of his life.

- Raman was chosen by the University of Calcutta to become the Palit Professor of Physics, a position established after the benefactor Sir Taraknath Palit, in 1913.
- In 1924, he was elected a Fellow of the Royal Society. However, he resigned from the fellowship in 1968 for unrecorded reasons, the only Indian FRS ever to do so.
- He was the President of the 16th session of the Indian Science Congress in 1929.
- He was the founder President of the Indian Academy of Sciences from 1933 till his death. He was member of the Pontifical Academy of Sciences in 1961.
- In 1930, he won the Nobel Prize in Physics "for his work on the scattering of light and for the discovery of the effect named after him.“
- He was the first Asian and first non-white to receive any Nobel Prize in the sciences. Before him, Rabindranath Tagore had received the Nobel Prize for Literature in 1913.

Subrahmanyan Chandrasekhar (1910–1995)

- Subrahmanyan Chandrasekhar was an Indian-American astrophysicist who spent his professional life in the United States.
- He was awarded the 1983 Nobel Prize for Physics with William A. Fowler for:

- Theoretical studies of the physical processes of importance to the structure and evolution of the stars.

- His mathematical treatment of stellar evolution yielded many of the current theoretical models of the later evolutionary stages of massive stars and black holes.
- The Chandrasekhar limit (is the maximum mass of a stable white dwarf star) is named after him.

- Chandrasekhar was the nephew of C.V. Raman.
- He became a naturalized citizen of the U.S. in 1953.
- Chandrasekhar died of a sudden heart attack at the University of Chicago Hospital in 1995, having survived a prior heart attack in 1975.
- In 1979, NASA named the third of its four "Great Observatories" after Chandrasekhar. This followed a naming contest which attracted 6,000 entries from fifty states and sixty-one countries.
- The Chandra X-ray Observatory was launched and deployed by Space Shuttle *Columbia* on 23 July 1999.
- The Chandrasekhar number, an important dimensionless number of magnetohydrodynamics, is named after him.
- The asteroid 1958 Chandra is also named after Chandrasekhar.
- The Himalayan Chandra Telescope is named after him.

Homi Bhabha (1909–1966)

- Homi Jehangir Bhabha was a multifaceted personality - *scientist, visionary and institution builder*.
- After finishing schooling, Bhabha's parents sent him to Cambridge University, UK for higher education in mechanical engineering.
- They had dreams of Bhabha becoming a successful engineer but, in 1928 he wrote to his father
- -*…that business or job as an engineer is not the thing for me, I am burning with a desire to do physics... I earnestly implore you to let me do physics.*
- In response, his father assured him to support for further studies in theoretical physics, provided he completed his mechanical engineering.
- In 1930, Bhabha completed mechanical engineering in first class and his father supported extended stay for the degree in physics.

- After completing his degree in 1932, Bhabha continued his research at Cambridge University.
- His first paper appeared in 1934, based on theoretical explanation of shower production in cosmic rays.
- Bhabha was on vacation during 1939, when the second world war broke out and he could not go back abroad to continue his research.
- He then joined Indian Institute of Science, Bangalore as a Reader in Department of Physics, headed by Sir C. V. Raman and set up a cosmic ray research unit.
- Bhabha was instrumental for the formation of Atomic Energy Commission in 1948 and the Department of Atomic Energy in 1954 and he chalked out a focused research and minerals exploration programmes for nuclear energy.
- He was such a visionary that he had realized the importance of nuclear power programme way back in 1950s and enunciated a three stage nuclear programme so as to meet the energy security of the nation.

Homi Bhabha’s Nuclear Passion and Dream for India

- The Indian Nuclear Weapons program traces its history to the establishment of the Atomic Energy Commission in 1948 with Dr. Homi Bhabha as Founding Chair.
- While Homi Bhabha was a proponent of the acquisition of nuclear weapons, the then Prime Minister of India, Jawaharlal Nehru had an ambiguous stance on the issue.
- While he had earlier stated his favour towards research in nuclear physics, he had staunchly refused to entertain the possibility of India acquiring nuclear weapons.

- The early years of Indian Atomic development were largely marked by nuclear cooperation with Canada, the USA, UK, and France and focused on the peaceful use of nuclear energy alone.
- However, Bhabha had recognised the immense possibility of the weapon and its strategic value.
- During a conference, he said, “nuclear weapons coupled with an adequate delivery system can enable a State to destroy more or less totally the cities, industry, and all-important targets in another State.
- It is then largely irrelevant whether the State so attacked has greater destructive power at its command.
- With the help of nuclear weapons, therefore, a State can acquire what we may call a position of absolute deterrence even against another having a many times greater destructive power under its control.”

- In 1965, Homi Bhabha had declared on All India Radio that he could make India a nuclear-armed country within 18 months if given the go-ahead.
- This sent shivers down the spines of world powers. So, within a year, Homi Bhaba is suspected to have been killed by the United States' CIA.
- Bhabha was killed when Air India Flight 101 crashed near Mont Blanc on 24 January 1966.
- A 'misunderstanding' between Geneva Airport and the pilot about the aircraft position near a mountain is cited as the official reason of the crash which saw India's brightest and most decisive nuclear physicist losing his life.

- A book titled Conversations with the Crow, which contains the transcripts of journalist Gregory Douglas's interview with former CIA operative Robert Crowley claimed the CIA got rid of Bhabha to "paralyse" India's nuclear programme.
- Crowley claims it was a bomb in the cargo section of the aircraft which brought it down in the Alps.
- The fact that there has been no substantive investigation into the air crash which killed Homi Bhabha is a statement of how the West conspired to derail and paralyse India's nuclear programme.
- Indeed, India suffered a setback with the killing of Homi Bhabha, but the man's contributions, research, and studies continue to guide India and the world at large to this very day.

Srinivasa Ramanujan (1887–1920)

- **Srinivasa Ramanujan** was one of India's greatest mathematical geniuses. He made substantial contributions to the analytical theory of numbers and worked on elliptic functions, continued fractions, and infinite series.
- In 1900 he began to work on his own on mathematics summing geometric and arithmetic series.
- In 1911 Ramanujan approached the founder of the Indian Mathematical Society for advice on a job.
- After this he was appointed to his first job, a temporary post in the Accountant General's Office in Madras.
- It was then suggested that he approach Ramachandra Rao who was a Collector at Nellore.
- Ramachandra Rao was a founder member of the Indian Mathematical Society who had helped start the mathematics library.

- On 16 March 1916 Ramanujan graduated from Cambridge with a Bachelor of Arts by Research (the degree was called a Ph.D. from 1920).
- He had been allowed to enroll in June 1914 despite not having the proper qualifications. Ramanujan's dissertation was on *Highly composite numbers* and consisted of seven of his papers published in England.
- On 18 February 1918 Ramanujan was elected a fellow of the Cambridge Philosophical Society and then three days later, the greatest honour that he would receive, his name appeared on the list for election as a fellow of the Royal Society of London.
- On 10 October 1918 he was elected a Fellow of Trinity College Cambridge, the fellowship to run for six years.
- Ramanujan sailed to India on 27 February 1919 arriving on 13 March. However his health was very poor and, despite medical treatment, he died there the following year.
- Ramanujan left a number of unpublished notebooks filled with theorems that mathematicians have continued to study.

Some Interesting Facts on Ramanujan

- Srinivasa Ramanujan was a self-taught mathematician who contributed to the theory of numbers.
- Born in Erode, Tamil Nadu, in 1887, Ramanujan grew up in poverty, his father working as an accounting clerk, while his mother earning a small amount as a temple singer.
- At the age of 15, Srinivasa Ramanujan obtained a copy of Synopsis on Elementary Results in Pure and Applied Mathematics, which contained 5,000 theorems, but had either brief proofs or did not have any.
- C Ramanujan then took to solving each of the theorems, eventually succeeding. Ramanujan had obtained a scholarship for the University of Madras, but he ended up losing it because he neglected his studies in other subjects in favour of mathematics.

- Srinivasa was in such poverty that he often sustained on minimal foods and did not even have enough money to obtain paper for his studies. As a result, he used slates for his mathematics and cleaned them with his elbow, leading to bruises and marks.
- Even with little formal training in mathematics, Ramanujan published his first paper in the Journal of Indian Mathematical Society in 1911.
- In 1913, Ramanujan started communicating with Godfrey H Hardy, a British mathematician. This led him to obtaining a scholarship from University of Madras and a grant from Trinity College in Cambridge, after which he travelled to England and started to work on some research with Hardy.

- Even as Ramanujan did not have much knowledge about modern mathematics due to no formal guidance, no living mathematician equaled in his knowledge of continued fractions.
- After his advances, especially in the field of partition of numbers, and the publication of his papers in several English as well as European journals, he was elected to the Royal Society of London in 1918.
- The genius mathematician left as his legacy three notebooks and a huge bundle of pages, which contained unpublished result which were being verified by mathematicians many years after his death.
- Dev Patel starrer biopic ***The Man Who Knew Infinity*** (April 29, 2016).

Vikram Sarabhai (1919–1971)

- **Vikram Ambalal Sarabhai** was an Indian physicist and astronomer who initiated space research and helped develop nuclear power in India.
- He was honoured with Padma Bhushan in 1966 and the Padma Vibhushan (posthumously) in 1972.
- He is internationally regarded as the Father of the Indian Space Program.
- Known as the cradle of space sciences in India, the Physical Research Laboratory (PRL) was founded in 1947 by Vikram Sarabhai.
- PRL had a modest beginning at his residence, the "RETREAT", with research on cosmic rays.

- The institute was formally established at the M.G. Science Institute, Ahmedabad, on 11 November 1947 with support from the Karmkshetra Educational Foundation and the Ahmedabad Education Society.
- Prof. Kalpathi Ramakrishna Ramanathan was the first Director of the institute.
- The initial focus was research on cosmic rays and the properties of the upper atmosphere.
- Research areas were expanded to include theoretical physics and radio physics later with grants from the Atomic Energy Commission.

- He led the Sarabhai family-owned business conglomerate. His interests varied from science to sports to statistics.
- He set up the Operations Research Group (ORG), the first market research organization in the country. Most notable among the many institutes he helped set up are the **Nehru Foundation for Development in Ahmedabad, the Indian Institute of Management Ahmedabad (IIMA), the Ahmedabad Textile Industry's Research Association (ATIRA) and the (CEPT).**
- Along with his wife Mrinalini Sarabhai, he founded the Darpana Academy of Performing Arts.
- Other projects and institutions initiated or established by him include the **Fast Breeder Test Reactor (FBTR) in Kalpakkam**, **Variable Energy Cyclotron Project in Calcutta, Electronics Corporation of India Limited (ECIL) in Hyderabad and Uranium Corporation of India Limited (UCIL) in Jaduguda, Jharkhand.**

- Sarabhai started a project for the fabrication and launch of an Indian satellite.
- As a result, the first Indian satellite, Aryabhata, was put in orbit in 1975 from a Russian cosmodrome.
- He was the founder of **Indian Space Research Organisation**.
- On 30 December 1971, Sarabhai was to review the SLV design before his departure for Bombay the same night. He had spoken to A. P .J. Abdul Kalam on the telephone.
- Within an hour of the conversation, Sarabhai died at the age of 52 due to cardiac arrest in Trivandrum.
- **The Vikram Sarabhai Space Centre, (VSSC),** which is the Indian Space Research Organization's lead facility for launch vehicle development located in Thiruvananthapuram (Trivandrum), capital of Kerala, is named in his memory.

Har Gobind Khorana (1922–2011)

- Har Gobind Khorana was an Indian American biochemist.
- While on the faculty of the University of Wisconsin–Madison, he shared the 1968 Nobel Prize for Physiology or Medicine with Marshall W. Nirenberg and Robert W. Holley for research that showed the order of nucleotides in nucleic acids, which carry the genetic code of the cell and control the cell's synthesis of proteins.
- Khorana and Nirenberg were also awarded the Louisa Gross Horwitz Prize from Columbia University in the same year.
- Born in British India, Khorana served on the faculties of three universities in North America. He became a naturalized citizen of the United States in 1966, and received the National Medal of Science in 1987.

- In addition to sharing the Nobel prize (while he was working at the University of Wisconsin–Madison in the U.S.), Khorana was elected as Foreign Member of the Royal Society in 1978.
- In 2007, the University of Wisconsin–Madison, the Government of India (DBT Department of Biotechnology), and the Indo-US Science and Technology Forum jointly created the Khorana Program.
- The mission of the Khorana Program is to build a seamless community of scientists, industrialists, and social entrepreneurs in the United States and India.
- Khorana died on 9 November 2011, in Concord, Massachusetts, at the age of 89.

Harish Chandra (1923-1983)

- **Harish Chandra** was one of the outstanding mathematicians of his generation.
- An algebraist and analyst, and one of those responsible for Transforming Infinite dimensional group re-presentation theory from a modest topic on the periphery of mathematics and physics into a major field central to contemporary mathematics.
- He was born on October 11, 1923 in Kanpur in North India. His father Chandra Kishor was a civil engineer. Harish Chandra spent his childhood at his maternal grandfather's home in Kanpur.
- **Harish Chandra** accompanied Dirac to Princeton from 1947 to 1948 and worked as this assistant.

* **Paul Dirac** was one of the greatest theoretical physicists in history. He completely reshaped quantum mechanics with the astounding **Dirac** Equation.

- At Cambridge he obtained his PhD in 1947.
- He was a member of the National Academy of Sciences and a Fellow of the Royal Society.
- He was the recipient of the Cole Prize of the American Mathematical Society, in 1954.
- The Indian National Science Academy honoured him with the Srinivasa Ramanujan Medal in 1974.
- In 1981, he received an honorary degree from Yale University.
- The Indian Government named the Harish-Chandra Research Institute (Prayagraj, Allahabad), an institute dedicated to Theoretical Physics and Mathematics, after him.
- He was also a recipient of the Padma Bhushan in 1977.

Abdus Salam (1926–1996)

- Mohammad Abdus Salam, was a Pakistani theoretical physicist.
- He shared the 1979 Nobel Prize in Physics with Sheldon Glashow and Steven Weinberg for his contribution to the electroweak unification theory.
- He was the first Pakistani and the first from an Islamic country to receive a Nobel Prize in science and the second from an Islamic country to receive any Nobel Prize, after Anwar Sadat of Egypt.

Abdus writes: *"As a physicist in Pakistan I was completely isolated. It was very difficult to get scientific journals and keep in touch with my subject. I had to leave my country to remain a physicist. It is the lack of contacts with other physicists that is the biggest curse of being a scientist in a developing country. You simply do not have the funds, the opportunities, which those from richer countries enjoy as a matter of course. There are no communities of people thinking and working in the same field… There must be possibilities for scientists to remain in their own country, meet people working on the same subject, and learn new ideas. You must return to your own country with a mission to change the image of science and technology in your own country."*

On Abdus Salam

Abdus Salam was asked by the Islamabad government to become Pakistan's first Advisor on Science. In four years, Salam built Pakistan's scientific infrastructure. He became Director of SUPARCO (the Space and Upper Atmosphere Commission), developed theoretical physics and was responsible for Pakistan's National Research for Nuclear Energy and Weapons Program.

Salam was invited by the Imperial College in London to set up a Department of Theoretical Physics. His unorthodox research paved the way for his getting the Nobel Prize in 1979 for "the theory of the unified weak and electromagnetic interaction between elementary particles." He turned the award into a fund in the memory of his parents in order to help the brightest and most deserving pre-university students from schools in the district of Jhang, Punjab, Pakistan.

P.C. Mahalanobis (1893 -1972)

- **P.C. Mahalanobis**, in full **Prasanta Chandra Mahalanobis**, **Indian statistician** who devised the **Mahalanobis distance** and was instrumental in formulating **India's strategy for industrialization in the Second Five-Year Plan (1956–61).**
- Born to an academically oriented family, Mahalanobis pursued his early education in Calcutta.
- After graduating with honours in physics from Presidency College, Calcutta, in 1912, he moved to England to study physics and mathematics at the University of Cambridge.
- Just before Mahalanobis left the university in 1915, he was introduced to statistics by one of his tutors.
- When he returned to India, he accepted a temporary position teaching physics at Presidency College, and he became a professor of physics there in 1922.

- However, his interest in statistics had evolved into a serious academic pursuit, and he applied statistical methods to problems in anthropology, meteorology, and biology.
- On December 17, 1931, he established the **Indian Statistical Institute in Calcutta.**
- Mahalanobis devised a measure of comparison between two data sets that is now known as the Mahalanobis distance.
- He introduced innovative techniques for conducting large-scale sample surveys and calculated acreages and crop yields by using the method of random sampling.
- He devised a statistical method called fractile graphical analysis, which could be used to compare the socioeconomic conditions of different groups of people.
- He also applied statistics to economic planning for flood control.

- With the objective of providing comprehensive socioeconomic statistics, Mahalanobis established the National Sample Survey in 1950 and also set up the Central Statistical Organization to coordinate statistical activities in India.
- He was also a member of the Planning Commission of India from 1955 to 1967.
- The Planning Commission's Second Five-Year Plan encouraged the development of heavy industry in India.
- And it relied on Mahalanobis's mathematical description of the Indian economy, which later became known as the Mahalanobis model.

- Mahalanobis held several national and international portfolios.
- He served as the chairman of the United Nations Sub-Commission on Sampling from 1947 to 1951.
- He was also appointed as the honorary statistical adviser to the government of India in 1949.
- For his pioneering work, he was awarded the Padma Vibhushan, one of India's highest honours, by the Indian government in 1968.

Post-Independence

- After independence, Jawaharlal Nehru initiated reforms to promote higher education and science and technology in India.
- The Indian Institute of Technology **(IIT)**

—conceived by a 22-member committee of scholars and entrepreneurs in order to promote technical education

—was inaugurated on 18 August 1951 at **Kharagpur in West Bengal by the minister of education Maulana Abul Kalam Azad.**

- More IITs were soon opened in **Bombay, Madras, Kanpur and Delhi** as well in the late 1950s and early 1960s along with the regional **RECs** (later National Institutes of Technology -NIT).
- Beginning in the **1960s**, **close ties with the Soviet Union enabled the Indian Space Research Organisation to rapidly develop the Indian space program and advance nuclear power in India** even after the first nuclear test explosion by India on 18 May 1974 at Pokhran.

- Post Independence, India aimed to **convert India's economy into that of a modern state** and to fit her into the nuclear age and do it quickly.
- It was understood that India had not been at the forefront of the Industrial Revolution, and hence made an effort **to promote higher education, and science and technology in India**.
- Planning Commission (1950):

-fixed investment levels

-prescribed priorities

-divided funds between agriculture and industry

-and divided resources between the state and the federal governments

- The result of the efforts between 1947 and 1962 **saw** the area under irrigation increase by 45 million acres (180,000 km^2), food production rise by 34 million metric tons, installed power generating capacity increase by 79 million kilowatts, and an overall increase of 94 percent in industrial production.
- The enormous population rise, however, would balance the gains.
- The economically harassed country was nevertheless able to build a large scientific workforce, second in numbers only to that of the United States and the Soviet Union.
- Education—provided by the government of India—was free and compulsory up to the Age of 14.

- More emphasis was paid to the enhancement of vocational and technical skills.
- J. P. Naik, member-secretary of the Indian Education Commission, commented on the educational policies of the time-

“The main justification for the larger outlay on educational reconstruction is the hypothesis that education is the most important single factor that leads to economic growth [based on] the development of science and technology.”

- As mentioned before, on 18 August 1951 the minister of education Maulana Abul Kalam Azad, inaugurated the Indian Institute of Technology at Kharagpur in West Bengal.
- Possibly modeled after the Massachusetts Institute of Technology these institutions were conceived by a 22-member committee of scholars and entrepreneurs under the chairmanship of N. R. Sarkar.
- The Sino-Indian war (1962) came as a rude awakening to **military preparedness**.
- Military cooperation with the Soviet Union—partially aimed at developing advanced military technology—was pursued during subsequent years.
- **The Defence Research and Development Organisation** was formed in 1958.

- **Radio broadcasting was initiated in 1927 but became state responsibility only in 1930.** In 1947 it was given the name *All India Radio* and since 1957 it has been called *Akashvani*.
- Limited duration of television programming began in 1959, and complete broadcasting followed in 1965.
- The Indian Government acquired the EVS EM computers from the Soviet Union, which were used in large companies and research laboratories.
- The roots of nuclear power in India **lie in early acquisition of nuclear reactor technology from a number of western countries**, particularly the American support for the Tarapur Atomic Power Station and Canada's CANDU reactors.
- The peaceful policies of Mohandas Karamchand Gandhi may have delayed the inception of nuclear technology in India.

- **The Indian space program received only financial support from the Soviet Union, which helped the Indian Space Research Organisation achieve aims** such as:

-establishing the Thumba Equatorial Rocket Launching Station

-launching remote sensing satellites

-developing India's first satellite—Aryabhata

- and sending astronauts into space

- India sustained its nuclear program during the aftermath of Operation Smiling Buddha, the country's first nuclear tests.

* **Operation Smiling Buddha** (Ministry of External Affairs designation: **Pokhran-I**) was the assigned code name of India's first successful nuclear bomb test on 18 May 1974. The bomb was detonated on the army base Pokhran Test Range (PTR), in Rajasthan, by the Indian Army under the supervision of several key Indian generals.

- Though the roots of the **Steel Authority of India Ltd. lie in Hindustan Steel Private Limited (1954)**, the events leading up to the formation of the modern avatar are described below:

-The Ministry of Steel and Mines drafted a policy statement to evolve a new model for managing industry.

-The policy statement was presented to the Parliament on 2 December 1972.

-On this basis the concept of creating a holding company to manage inputs and outputs under one umbrella was mooted.

-This led to the **formation of Steel Authority of India Ltd. The company, incorporated on 24 January 1973 with an authorised capital of Rs. 2000 crore, was made responsible for managing five integrated steel plants at Bhilai, Bokaro, Durgapur, Rourkela and Burnpur, the Alloy Steel Plant and the Salem Steel Plant.**

-In 1978 SAIL was restructured as an operating company.

- In 1981, the **Indian Antarctic Programme** was started when the **first Indian expedition was flagged off for Antarctica from Goa.**
- More missions were subsequently sent each year to **India's base Dakshin Gangotri.**
- Indian agriculture benefited from the developments made in the field of biotechnology, for which a separate department was created in 1986 under the Ministry of Science and Technology.
- Both the Indian private sector and the government have invested in the medical and agricultural applications of biotechnology.
- **Massive biotech parks were established in India** while the government provided tax deduction for research and development under biotechnological firms.

- **The Indian economy underwent economic reforms in 1991, leading to a new era of globalisation and international economic integration.**
- Economic growth of over 6% annually was seen between 1993 and 2002. Same year **a new permanent Antarctic base Maitri was founded and remains in operation till date.**
- **On 25 June 2002 India and the European Union agreed to bilateral cooperation in the field of science and technology.**
- A joint EU-India group of scholars was formed on 23 November 2001 to further promote joint research and development.
- India holds Associate Member State status at CERN, while a joint India-EU Software Education and Development Centre is due at Bangalore. Certain scientists and activists, such as MIT systems scientist VA Shiva Ayyadurai, blame caste for holding back innovation and scientific research in India, making it difficult to sustain progress while regressive social organization prevails.

* European Organization for Nuclear Research- *Conseil européen pour la recherche nucléaire (French)*

- In 2016**, India became an associate member of European Organization for Nuclear Research.**
- The Government of India has passed four policy documents on science and technology:

-Science Policy Resolution 1958

-Technology Policy Statement 1983

-Science and Technology Policy 2003

-Science, Technology, and Innovation Policy 2013

-The fifth policy, the National Science, Technology, and Innovation Policy, is in the draft and public consultation stage.

- **The Mars Orbiter Mission, also called "Mangalyaan", was launched on 5 November 2013 by the Indian Space Research Organisation (ISRO).**
- It is India's first interplanetary mission, making ISRO the fourth space agency to reach Mars, after the Soviet space program, NASA, and the European Space Agency.
- **The first Asian nation to reach Mars orbit and the first nation to do so on its first attempt was India.**
- On 18 November 2008, the Moon Impact probe was released from Chandrayaan-1 at a height of 100 km (62 mi).
- During its 25-minute descent, Chandra's Altitudinal Composition Explorer (CHACE) recorded evidence of water in 650 mass spectra readings gathered during this time.
- **On 24 September 2009 *Science* journal reported that the Chandrayaan-1 had detected water ice on the Moon.**

- **Chandrayaan-2 was launched on 22 July 2019.** It was a partial success: The team wanted to send an additional lander with rover Vikram with the original orbiter in it, to mark India's terrestrial presence on Moon, but the signal connection was lost about 2.1 km (1.3 mi) above the lunar surface.
- Over several months team tried to resume contact with lander, but ended up with no success.
- Later, by the late February 2020, it was claimed that an Indian software engineer from Chennai living in USA studied the NASA data of the proposed crashed site and found the Lander.
- Chandrayaan-3 is a next planned mission of sending only the lander with rover inside on the Moon, with the Japan's JAXA (Japan Aerospace Exploration Agency**)**. It was delayed due to COVID-19 pandemic.

- **Science academies in India**

- The idea of science academies in India has evolved along with the Indian independence movement. The three major science academies -

-**Indian National Science Academy, Indian Academy of Sciences and the National Academy of Sciences, India were all founded in the pre-independence era (1930 and 1935).**

- **Indian Academy of Sciences**

-Also referred to colloquially as the "Bangalore Academy", Indian Academy of Sciences (IAS) was founded in 1934 by C. V. Raman, the eminent physicist of his time in Bangalore (now Bengaluru), Karnataka.

- **National Academy of Sciences, India**

-The founder and first president of the National Academy of Sciences, India (NASI) was Meghnad Saha in 1930 in Allahabad (Prayag), Uttar Pradesh, India.

- **Indian National Science Academy**

-Founded in 1935 based on a proposal by the Indian Science Congress Association (ISCA) and National Institute of Science of India (NISI) with Meghnad Saha's blessings, Indian National Science Academy (INSA) is based in New Delhi, India.

-According to its charter, the historical aim of the INSA was to be similar to the Royal Society, London, a gathering of learned people to exchange ideas and further science.

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