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SCIENCE & TECHNOLOGY

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CHAPTER 1

INDIA: SCIENCE & TECHNOLOGY

1.1 Introduction

Being one of the oldest in the world, the Indian civilization has a strong tradition of science and technology. Our contribution to astronomy, mathematics, medicine and practical arts are not adequately acknowledged. The impression that science started only in Europe was deeply embedded in the minds of educated people all over the world. The alchemists of Arab countries were occasionally mentioned, but there was very little reference to India and China.

Thanks to the work of the Indian National Science Academy and other learned bodies, the development of sciences of ancient India has drawn attentions of scholars in 20th century. It is becoming clearer from these studies that India has consistently been a place for people with scientific temperament, right from Vedic to modern times with the usual fluctuations that can be expected of any country.

Indian civilization has a long recorded history of scientific culture that goes back to more than 5000 years. Indian heritage has been known for its various developments like astronomy, mathematics, medicine, physics, agriculture, literature, etc. Many famous mathematicians from India contributed a lot to the development of theories that we still use and applied in majority of fields.

Aryabhatt wrote Aryabhatiya, which is a compendium of mathematics and astronomy. *Varahamihira* was having astonishing knowledge of a variety of subjects like hydrology, meteorology, astrology, astronomy, and seismology. *Bhaskaracharya's SiddhantaShiromani* is considered as the pinnacle of all the astronomical works. *Sushruta* was an ancient Indian Physician and Surgeon known todays as India's Father of Surgery.

1.2 Developments in Modern India

The modern age is the age of science, technology, knowledge and information. All these are interrelated and different aspects of the same thing. They are fundamentally altering the way people live, connect, communicate, transact and perform their economic activities.

India has much to be proud of its scientific and technological developments in modern India. It boasts a thriving pharmaceutical industry that produces low-cost medications desperately needed by the developing world. Then, there is Indian Space Research Organization (ISRO) making headlines in space sciences. India became the first country to reach Mars in its first attempt. Recently, government of India launched an ambitious plan to make India a leader in solar power in the form of International Solar Alliance (ISA) at Paris climate summit.

Today, India is among the topmost countries in the world in the field of scientific research, positioned as one of the top five nations in the field of space exploration. The country has regularly taken space missions like Mangalyaan, Chandrayaan 1 and 2. Currently, it is planning to send first human crew in space in its coveted ***Gaganyaan Mission.*** India has taken a leading role in launching satellites for the SAARC nations, and thus generating revenue by offering its space facilities for use to other countries.

There has been considerable emphasis on encouraging scientific temperament among India's youth through numerous technical universities and institutes, both in the private and government sectors. At present, the country has a total of 23 Indian Institutes of Technology (IITs), 31 National Institutes of Technology (NITs), over 1000 universities awarding about 29,000 doctorate degrees, and about 40 research laboratories run by the CSIR.

India is among the world's top 5 nations in terms of the number of scientific publications. India is gradually becoming self-reliant in nuclear technology. Recently, the Kudankulam Nuclear Power Project Unit-1 (KKNPP-1) with 1,000 MW capacity was commissioned, while the Kudankulam Nuclear Power Project Unit-2 (KKNPP-2) with 1,000 MW capacity is under commissioning.

1.3 Government Ministries and Other Departments

Ministry of Science and Technology is responsible for making policy decisions. It also administers rules and laws regarding science and technology. It has following departments:

Department of Science and Technology (DST)

Department of Science & Technology (DST) was established in May 1971, with the objective of promoting new areas of Science & Technology. The Department has major responsibilities fort the following:

- Formulation of policies relating to Science and Technology.
- Matters relating to the Scientific Advisory Committee of the Cabinet (SACC).
- Promotion of new areas of Science and Technology with special emphasis on emerging areas.
- Futurology.
- Coordination and integration of areas of Science & Technology having cross-sectoral linkages in which a number of institutions and departments have interest and capabilities.
- Undertaking or financially sponsoring scientific and technological surveys, research design and development, wherever necessary.
- Support and Grants-in-aid to Scientific Research Institutions, Scientific Associations and Bodies.

Department of Scientific and Industrial Research (DSIR)

DSIR was announced through a Presidential notification, dated January 4, 1985 contained in the Amendment of the Government of India (Allocation of Business) Rules, 1961. The Department of scientific and industrial research has mandate to carry out activities in industrial sectors.

DSIR endeavours:

- To promote R&D by the industries, support a larger cross section of small and medium industrial units to develop state – of – the art globally competitive technologies of high commercial potential, catalyze faster commercialisation of lab scale R & D, enhance the share of technology intensive export in overall exports strengthen industrial consultancy and technology management capabilities and establish user friendly information network to facilitate scientific research in the country.
- It also provides a link between scientific laboratories and industrial establishments for transfer of technologies through National Research Development Corporation (NRDC) and facilitate investment in R&D through Central Electronics Limited (CEL).

Council of Scientific and Industrial Research (CSIR)

The Council of Scientific & Industrial Research (CSIR), known for its cutting edge R&D knowledge base in diverse S&T areas, is a contemporary R&D organization. CSIR covers a wide spectrum of science and technology – from radio and space physics, oceanography, geophysics, chemicals, drugs, genomics, biotechnology and nanotechnology to mining, aeronautics, instrumentation, environmental engineering and information technology. It provides significant technological intervention in many areas with regard to societal efforts which include environment, health, drinking water, food, housing, energy, farm and non-farm sectors. Further, CSIR's role in S&T human resource development is noteworthy.

Pioneer of India's intellectual property movement, CSIR today is strengthening its patent portfolio to carve out global niches for the country in select technology domains. CSIR is granted 90% of US patents granted to any Indian publicly funded R&D organization. On an average, CSIR files about 200 Indian patents and 250 foreign patents per year. About 13.86% of CSIR patents are licensed - a number which is above the global average. Amongst its peers in publicly funded research organizations in the world, CSIR is a leader in terms of filing and securing patents worldwide.

Department of Biotechnology (DBT)

Department of Biotechnology under the Ministry of Science and Technology, over the past 30 years has given a new impetus to developments in modern biology and biotechnology. The department has provided continuous support to facilitate the journey from nascent sector to a sunrise industry. There have been significant achievements in the growth and application of biotechnology in the areas of agriculture, healthcare, animal sciences, environment and industry.

In 2023, India's bio-technology industry has crossed dollar 92 billion (15% rise) Today, India is among the top 12 biotech destinations in the world and ranks third in the Asia Pacific region. India has the second- highest number of US Food and Drug Administration (USFDA) approved plants, after the USA and is largest producer of recombinant Hepatitis B vaccine.

DBT's vision & strategy is "Attaining new heights in biotechnology research, shaping biotechnology into a premier precision tool of the future for creation of wealth and ensuring social justice specially for the welfare of the poor".

Department of Atomic Energy (DAE)

The Department of Atomic Energy came into being on August 3, 1954 under the direct charge of the Prime Minister through a Presidential Order. According to the

Resolution constituting the Atomic Energy Commission (AEC), the Secretary to the Government of India in the Department of Atomic Energy is ex-officio Chairman of the AEC. DAE has been engaged in the development of nuclear power technology, applications of radiation technologies in the fields of agriculture, medicine, industry and basic research.

DAE comprises of five research centers, three industrial organizations, five public sector undertakings and three service organizations. It has under its aegis two boards for promoting and funding extra-mural research in nuclear and allied fields, mathematics and a national institute (deemed university). It also supports eight institutes of international repute engaged in research in basic sciences, astronomy, astrophysics, cancer research and education. It also has in its fold an educational society that provides educational facilities for children of DAE employees.

Department of Space

Department of Space was first established in the country in June, 1972. The organization is responsible for executing various space related programs in India. It has its centers throughout the country working for the development of space research and other space systems.

The Department of Space of India is engaged in various international space science awareness campaigns, IRS-P3 and SROSS satellite, development of launch vehicles and other activities. ISRO, under this department, is experimenting with Satellite Telecommunication Experiment (STEP) and Satellite Instructional Television Experiment (SITE). The IRS satellites are being launched now by the launch vehicle like PSLV (Polar Satellite Launch Vehicle) and GSLV (Geosynchronous Satellite Launch Vehicle).

The Department of Space in India is also monitoring various functional space systems, which include the IRS (Indian Remote Sensing Satellite) and the INSAT (Indian National Satellite). The former is mainly used for disaster signals, television broadcasting, communication and other purposes. The latter is being used for resource management. The progress and development of space technology in India wholly depends on the Department of Space - India. Development of launch vehicles, satellites, sounding rockets and many allied fields is the prime objective of the Indian Space Research Organization.

PM-STIAC

The Prime Minister's Science, Technology and Innovation Council is an overarching body which assesses the status of specific S&T domains, comprehends challenges, formulates immediate, mid and long term interventions and presents a roadmap to the Prime Minister.

- The Principal Scientific Adviser coordinates to facilitate and ensure implementation of major interventions by concerned Government Departments, Agencies and Ministries.
- Amongst the terms of reference of the Council are to formulate, converge, collaborate, coordinate and implement multi-stakeholder policy initiatives, mechanisms, reforms and programmes aimed at:
    - Synergizing S&T covering fundamental to applied research in collaboration with multiple stakeholders both in central and state governments.
    - Enabling future preparedness in emerging domains of science and technology.
    - Formulating and coordinating major inter-ministerial S&T missions.
    - Providing an enabling ecosystem for technology led innovations and techno entrepreneurship.
    - Driving innovation and technology delivery towards solving socio-economic challenges for sustainable growth.
    - Fostering effective public-private linkages for driving research and innovation.
    - Developing science, technology and innovation clusters with multiple stakeholders including academia, industry and government.
    - Skilling in current and futuristic technologies.

Department of Defence

The Government of India is responsible for ensuring the defence of India and every part thereof. This is discharged through the Ministry of Defence, which provides the policy framework and wherewithal to the Armed Forces to discharge their responsibilities in the context of the defence of the country. The principal task of the Defence Ministry is to obtain policy directions of the Government on all defence and security related matters and communicate them for implementation to the Services Headquarters, Inter-Services Organisations, Production Establishments and Research and Development Organisations. It is also required to ensure effective implementation of the Government's policy directions and the execution of approved programmes within the allocated resources. Ministry of Defence comprises of five Departments viz. Department of Defence (DOD), Department of Military Affairs (DMA), Department of Defence Production (DDP), Department of Defence Research & Development (DDR&D) and Department of Ex-Servicemen Welfare and also Finance Division.

The Department of Defence deals with the three Services i.e Army, Air Force, Navy and Coast Guard. It also deals with Inter-Services Organization. It is also responsible for the Defence Budget, establishment matters, defence policy, matters relating to Parliament, defence cooperation with foreign countries, and coordination of all defence related activities. It is headed by Defence Secretary who is assisted by Director General (Acquisition), Additional Secretaries and Joint Secretaries. Defence Secretary is also responsible for coordinating the activities of the other Departments i.e DDP, DESW and DRDO in Ministry of Defence. Department of Defence consists of following Wings headed by concerned Joint Secretary/Additional Secretary: 1. Establishment 2. Air 3. Navy 4. Army, 5.PIC 6.Works 7. PG/Coord, 8. Acquisition/CAO.

1.4 Policy Documents

Scientific Policy Resolution (1958)

India adopted a policy on science through the Scientific Policy Resolution (SPR) in 1958. SPR proposed 'to train enough science and technical manpower to fulfil the country's needs in science, education, agriculture, industry and defence.'

The SPR was promulgated with the objective 'to foster, promote, and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects — pure, applied and educational'. SPR was the first authentic document of the Indian Government to declare its intention to make S&T a prime vehicle of national development.

The implementation of SPR resulted in the establishment of many scientific organisations such as Defence Research and Development Organisation (DRDO-1958), the Department of Space (DOS-1972), the Department of Electronics (DOE-1971), the Department of Science & Technology (DST-1971) and the Department of Environment (DOE-1980). Scientific temper was considered as critical but important for India that it earned a place in the Constitution of India, Part IVA Fundamental Duties 51A(h), to 'develop scientific temper, humanism and the spirit of inquiry & reforms'. It also got prominent place in all succeeding policy documents.

Technology Policy Statement (1983)

During the 1980s, strategic and front-running technologies became increasingly difficult to import. By now India had constructed a strong industrial and agricultural base and developed a qualified pool of scientific manpower. The Indian government, therefore, instituted a policy for 'attainment of technological self-reliance, a swift and tangible improvement in the conditions of weakest sections of the population and the speedy development of backward regions.

The Government of India promulgated its technology policy as the Technology Policy Statement-1983. It was a national vision document that recognised the role and importance of technology in the economic growth of the country. It should be noted that the policy statement was issued during a period of technology denial. Developed countries refused to transfer technology in key areas of economic development. Political independence without economic independence is a lame duck as was realised by the policy makers long back. The emphasis of the policy document was on self- reliance and strengthening the technology base. India had aspired to engage the entire Indian population with science and technology in order to develop a scientific and technological temper to solve the problems of daily living. This was a clarion call for a change in the mindset of the people.

Science & Technology Policy (2003)

By the beginning of new millennium-2000 it was felt to rationalise and amalgamate both- science and technology with a merged policy. The then Prime Minister, Shri Atal Bihari Vajpayee, stated: "We must take science to the people."

Key Components

- To ensure that the message of science reaches every citizen of India, man and woman, young and old, so that we advance scientific temper, emerge as a progressive and enlightened society, and make it possible for all our people to participate fully in the development of science and technology and its application for human welfare.
- To ensure food, agricultural, nutritional, environmental, water, health and energy security of the people on a sustainable basis.
- To vigorously foster scientific research in universities and other academic, scientific and engineering institutions; and attract the brightest young persons to careers in science and technology, by conveying a sense of excitement concerning the advancing frontiers, and by creating suitable employment opportunities.
- To provide necessary autonomy and freedom of functioning for all academic and R&D institutions so that an ambience for truly creative work is encouraged, while ensuring at the same time that the science and technology enterprise in the country is fully committed to its social responsibilities and commitments.
- To accomplish national strategic and security-related objectives, by using the latest advances in science and technology.

Science Technology and Innovation Policy (2013)

Key Elements

- Promoting the spread of scientific temper amongst all sections of society.
- Enhancing skill for applications of science among young from all strata.
- Making careers in science, research and innovation attractive enough for talented and bright minds.
- Establishing world class infrastructure for R&D for gaining global leadership in some selected frontier areas of science.
- Positioning India among the top five global scientific powers by 2020.
- Linking contributions of science, research and innovation system with the inclusive economic growth agenda and combining priorities of excellence and relevance.
- Creating an environment for enhanced private sector participation in R&D.
- Enabling conversion of R&D outputs into societal and commercial applications by replicating hitherto successful models as well as establishing of new PPP structures.
- Seeding S&T- based high risk innovations through new mechanisms.
- Triggering changes in mind-set and value system to recognise, respect and reward performers which create wealth from S&T derived knowledge.
- Creating a robust national innovation system.

Decade of Innovation in India (2010-2020)

Innovation today is increasingly going beyond the confines of formal R&D to redefine everything. It means using ideas to develop new products and services, new processes and structures to improve performance in diverse areas, organisational creativity. Innovation is being seen as a means of creating sustainable and cost effective solutions for people at the bottom of the pyramid, and is being viewed as an important strategy for inclusive growth in developing economies.

Realising that innovation is the engine for the growth of prosperity and national competitiveness in the 21st century, the then President of India declared 2010-2020 as the *'Decade of Innovation'*. To take this agenda forward, the (former) Office of Adviser to the PM on Public Information Infrastructure and Innovations (PIII) worked on developing a national strategy on innovation with a focus on an Indian model of inclusive growth. The idea is to create an indigenous model of development suited to Indian needs and challenges.

The former Prime Minister set up the ***National Innovation Council (NInC)*** under the Chairmanship of Mr. Sam Pitroda to discuss, analyse and help implement strategies for inclusive innovation in India and prepare a Roadmap for Innovation 2010-2020. NInC was the first step in creating a crosscutting system which will provide mutually reinforcing policies, recommendations and methodologies to implement and boost innovation performance in the country. India has a long tradition of innovation and a significant pool of qualified people, both within country as well as the diaspora, engaged in innovative activities. This talent pool has to be leveraged to drive the innovation agenda.

Further, there is also a need to capture innovations happening in various domains such as government, R&D labs, universities, and across sectors, to give an impetus to the innovation process in the country. NInC acts as a platform to facilitate this engagement and collaboration with domain experts, stakeholders and key participants to create an innovation movement in India. The aim is to herald a mindset change and create a push at the grassroots level so that more and more people in education, business, government, NGOs, urban and rural development engaged in innovative activities are co-opted and are part of shaping the national level innovation strategy.

The five point agenda for the Indian Decade of Innovation were:

1. Create a 21^{st} Century National Innovation Ecosystem
2. Launch an Inclusive Innovation Initiative
3. Build Innovative Indian Institutions
4. Build Innovative Indian Industry
5. Build Innovative Indian Minds as well as Mindsets

The drivers of inclusive innovation would be:

- Targeted funding,
- Institutional mandates to drive the 'Indian inclusive innovation' agenda,
- Suitably designed incentivisation (including fiscal) for all stake holders,
- Government procurement and price preference on products meeting the 'inclusive innovation' mandate,
- Conducive policy frameworks to promote 'Indian inclusive innovation'.

Science Technology and Innovation Policy (STIP), 2020

Aim

To identify and address the strengths and weaknesses of the Indian STI ecosystem to catalyse socio-economic development of the country and also make the Indian STI ecosystem globally competitive.

Main Philosophy

- Unlike previous STI policies which were largely top-driven in the formulation, this policy follows core principles of being decentralized, evidence-informed, bottom-up, experts-driven, and inclusive.
- It aims to be dynamic, with a robust policy governance mechanism that includes periodic review, evaluation, feedback, adaptation and, most importantly, a timely exit strategy for policy instruments.
- The STIP will be guided by the vision of positioning India among the top three scientific superpowers in the decade to come; to attract, nurture, strengthen, and retain critical human capital through a people-centric STI ecosystem

The Open Science Framework

Open Science fosters more equitable participation in science through:

- Increased access to research output;
- Greater transparency and accountability in research; inclusiveness;
- Better resource utilization through minimal restrictions on reuse of research output and infrastructure and
- Ensuring a constant exchange of knowledge between the producers and users of knowledge.

Inclusion principles

- The STIP proposes that at least 30 per cent representation be ensured for women in all decision-making bodies, as well as "spousal benefits" are provided to partners of scientists belonging to the LGBTQ+ community.
- Among the proposals in the policy is the removal of bars on married couples being employed in the same department or laboratory.
- As of now, married couples are not posted in the same department, leading to cases of loss of employment or forced transfers when colleagues decide to get married.
- The policy says that for age-related cut-offs in matters relating to the selection, promotion, awards or grants, the "academic age" and not the biological age would be considered.

Funding improvements

- At 0.6% of GDP, India's gross domestic expenditure on R&D (GERD) is quite low compared to other major economies that have a GERD-to-GDP ratio of 1.5% to 3%.
- This can be attributed to inadequate private sector investment (less than 40%) in R&D activities in India; in technologically advanced countries, the private sector contributes close to 70% of GERD.
- STIP has made some major recommendations in this regard, such as the expansion of the STI funding landscape at the central and state levels.
- It has enhanced incentivisation mechanisms for leveraging the private sector's R&D participation through boosting financial support and fiscal incentives for industry.

The Science, Technology and Innovation Policy will be guided by the following broad vision:

- To achieve technological self-reliance and position India among the top three scientific superpowers in the decade to come.
- To attract, nurture, strengthen and retain critical human capital through a 'people centric' science, technology and innovation (STI) ecosystem.
- To double the number of Full-Time Equivalent (FTE) researchers, Gross Domestic Expenditure on R&D (GERD) and private sector contribution to the GERD every 5 years.
- To build individual and institutional excellence in STI with the aspiration to achieve the highest level of global recognitions and awards in the coming decade.

1.5 Indian Gems in Science and Technology

India has been a land of sages and scientists, since ancient times India has marked its feet in the world of scientific inventions and discoveries much before the modern form of laboratories came into existence. From making the best steel in the world to teach the world to count, there are numerous ground breaking contributions. Account of some of these great inventors and discoverers along with their unending contributions are mentioned below:

Aryabhatta

Aryabhatta, born in 476 A.D., was the greatest astronomer and mathematician of the Gupta period. Aryabhatiya, a *compendium of mathematics and astronomy*, was extensively referred to in the Indian mathematical literature and has survived to modern times. The mathematical part of the Aryabhatiya covers ***arithmetic, algebra, plane trigonometry, and spherical trigonometry***. It also contains continued fractions, quadratic equations, sums-of-power series, and a table of sines.

The *Arya-siddhanta* work appears to be based on the older *Surya Siddhanta* and uses the midnight-day reckoning, as opposed to sunrise in Aryabhatiya. It also contained a description of several astronomical instruments: The gnomon (shanku-yantra), a shadow instrument (chhaya-yantra), possibly angle-measuring devices, semi-circular and circular (dhanur-yantra/chakra-yantra), a cylindrical stick yastiyantra, an umbrella-shaped device called the chhatra-yantra, and water clocks of at least two types, bowshaped and cylindrical. His works in astronomy includes explanation of motions of solar system, eclipses, sidereal periods, heliocentrism. Aryabhata's work was of great influence in the Indian astronomical tradition and influenced several neighbouring cultures through translations.

Varahamihira

Varahamihira, born in 505 A.D., Varahamihira was unique in that he had astonishing knowledge of a variety of subjects like ***hydrology, meteorology, astrology, astronomy, and seismology***. His magnum opus is ***BrihatSamhita***, which deals with all these subjects.

The Brihat Samhita, a work on Samhita consists of 106 characters with a total of nearly 4000 slokas (verses in Sanskrit). The range of subjects dealt with is very large, including the effects of movements of the planets and natural phenomena on human life, geography, characteristics of Khadga (sword), Angavidya, architecture, iconography, auspicious and inauspicious characteristics of people and animals, omens, manufacture of cosmetics, botany, and science of precious stones (gemmology). The subjects dealt with are ***cloud formation, rainfall, the appropriate planetary conjuctions, signs of immediate rain, hurricanes, etc.*** Varahamihira's mathematical work included the discovery of the ***trigonometric formulas***. Varahamihira improved the accuracy of the ***sine tables of Aryabhata I. In Arithmetic, he defined the algebraic properties of zero as well as of negative numbers***. He was among the first mathematicians to discover a version of what is now known as the Pascal's triangle. He used it to calculate the binomial coefficients. He respected learning wherever it was found and was intimately acquainted with astrological literature of the Greeks to whom he made reference in his works.

Bhaskaracharya

Bhaskaracharya's *SiddhantaShiromani* is considered as the pinnacle of all the astronomical works of those 700 hundred years. It can be aptly called the essence of ancient Indian Astronomy and mathematics. It is divided into four parts, Lilawati, Beejaganit, Ganitadhyaya and Goladhyaya.

Astronomical Achievements of Bhaskaracharya

- The Earth is not flat, has no support and has a power of attraction.
- The north and south poles of the Earth experience six months of day and six months of night.
- Earth's atmosphere extends to 96 kilometers and has seven parts.
- There is a vacuum beyond the Earth's atmosphere.
- He had knowledge of precession of equinoxes. He took the value of its shift from the first point of Aries as 11 degrees. However, at that time it was about 12 degrees.

The concepts and methods developed by Bhaskaracharya are relevant even today.

Jagadish Chandra Bose

Jagadish Chandra Bose studied physics at St. Xavier's but botany continued to enthrall him. He would pull out germinating plants to check their roots and grew flowering plants and closely observed their growth. Bose carried out experiments on refraction, diffraction, and polarization. Bose even fabricated the equipment needed by sheer ingenuity. The experiments performed in the makeshift laboratory finally resulted in the invention of a device for producing electromagnetic waves.

In November 1894, Bose gave the first public demonstration of ***wireless transmission*** using ***electromagnetic waves*** to ring a bell and to explode a small charge of gunpowder from a distance. He used microwaves with wavelengths in the millimeter range, not radio waves. Later, Bose made the use of Galena crystals for making receivers, both for short wavelength radio waves and for white and ultraviolet light.

In 1901, Bose submitted to the Royal Society a preliminary note on the Electric Response of Inorganic Substances, in which he showed how he had obtained strong electric response from plants to mechanical stimuli. However, the paper was not published due to the opposition of Sir John Burdon Sanderson, the leading electro-physiologist of the time.

In 1904, Bose submitted a series of papers, once again to the Royal Society, showing the similarities of both the electric and mechanical responses of plants and animals.

His interest in physiology gave an impetus to his inventive genius. For obtaining the records of mechanical response of plant tissues, he first introduced the *optical lever in plant* physiology to magnify and photographically record the minute movements of plants. He perfected the resonant recorder that enabled him to determine with remarkable accuracy, within a thousandth part of a second, the latent period of response of the *touch-me-not plant*, *Mimosa pudica*.

He also devised the oscillating recorder for making minute lateral leaflets of the telegraphic plant automatically record their pulsating movements. He even took up the problem of recording micrographic growth movements of plants by devising the *Cresco graph*. With his instrument, he obtained a magnification of 10,000 times, and was able to record automatically the elongation growth of plant tissues and their modifications through various external stimuli. Later, he perfected his magnetic Cresco graph obtaining a *magnification from one to ten million times*.

C.V. Raman

Chandrasekhara Venkata Raman was one of the greatest *experimental physicists of the century* and the *first Asian scientist to win the Nobel Prize*. His spirit of inquiry and devotion to science laid the foundations for scientific research in India, for not only did he win honour as a scientist but also inspired several generations of students.

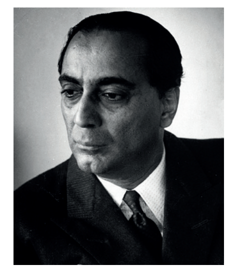
Raman Effect and Nobel Prize

He was so bewitched by the physical properties of the diamond that at one time every researcher in his laboratories was working on the physics of this simplest of all crystal structures. And then came Raman's discovery of the *scattering of light* that catapulted him to the world fame. The Raman effect, as it is more popularly known, had its origin in the wonderful blue colour of the Mediterranean Sea. Lord Rayleigh had attributed the colour of the sea to the blue of the sky reflected by the water.

After returning to Calcutta, he came to the definite conclusion that it was the scattering of light molecules by the oceanic waters that made them look blue. After this success, Raman and his students carried out several experiments and established the various laws of molecular scattering of light in diverse media and 56 original research papers were published from Raman's laboratory.

Raman finally decided to clinch the issue and asked K. S. Krishnan to take up the experimental work on the anomalous scattering in liquids and vapours, in collaboration with him. The phenomenon captured the attention of research workers all over the world and it became famous as the *Raman Effect*. The spectral lines in the scattered light are now known as *'Raman Lines'*. In 1954, Raman was bestowed with the greatest honour the Government of India - the Bharat Ratna.

Homi Bhabha



Homi Jehangir Bhabha is the *architect of India's nuclear energy programme*. He made important contribution to quantum theory and cosmic radiation. He was the *first chairman of Atomic Energy Commission of India*.

The Commission's responsibilities included:

- Survey of Indian soils for the materials required for nuclear research.
- Construction of atomic reactors.
- The purification of atomic materials, conducting fundamental research, and development 184 training programmes.

The Commission utilized the services of scientists at TIFR. Soon the Commission's scope was enlarged and the Atomic Energy Programme began to take shape. The *Department of Atomic Energy* thus came into existence as a separate Department of the Government of India in 1954, under the direct control of Prime Minister Nehru. Shortly after the formation of the Department of Atomic Energy, it was decided to create the Atomic Energy Establishment at Trombay for the application of atomic energy to peaceful purposes.

Bhabha worked to make the country self-reliant in the nuclear field. He stressed that while India needed to draw on the expertise already built up in other countries, her objective must be to exploit her own resources of scientists and technologists as well as the raw materials.

Reactors like Apsara, uranium and zirconium plants, the Van de Graff and cyclotron equipment's were all Bhabha's gifts to the nation. The crowning success of Bhabha's lifelong passion came on May 18, 1974 when India conducted its first nuclear explosion for peaceful purposes at Pokhran in Rajasthan and became the world's sixth nuclear power.

S.N. Bose

Satyendra Nath Bose was a Bengali-Indian physicist and mathematician, best known for his work with Albert Einstein on the *'Bose-Einstein Condensate'* as well being the namesake of the *boson particle*.

The boson in the *Higgs Boson particle* also known as *God particle*, whose search and ultimate detection was one of the longest and most expensive in the history of science owes its name to Bose. The paper laid the basis of describing the two classes of subatomic particles – Bosons named after Bose and Fermions named after Italian physicist Enrico Fermi.

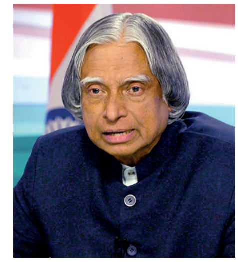
The fifth state of matter is the Bose-Einstein condensate. A Bose-Einstein condensate is a group of atoms cooled to within a hair of absolute zero. When they reach that temperature the atoms are hardly moving relative to each other; they have almost no free energy to do so. At that point, the atoms begin to clump together, and enter the same energy states. They become identical, from a physical point of view, and the whole group starts behaving as though it were a single atom. His work proved to be a path breaking incident for CERN.

S. Chandrashekhar

S Chandrashekhar is remembered as a great astrophysicist who strongly influenced the later developments of our understanding of stellar objects, black holes, white dwarfs etc. His remarkable works are on Newton's Principia stellar dynamics, stochastic process, radiative transfer, the quantum theory of the hydrogen anion, hydrodynamic and hydro magnetic stability, turbulence, equilibrium and the stability of ellipsoidal figures of equilibrium, general relativity, mathematical theory of black holes and theory of colliding gravitational waves. *He won a Nobel Prize for Physics in 1983 "for his theoretical studies of the physical processes of importance to the structure and evolution of the stars"*.

As he sailed from India to England, he thought a lot about the death of stars. He determined what is known as the "*Chandrasekhar limit*"—that a star having a mass more than 1.44 times that of the Sun does not form a white dwarf but instead continues to collapse, blows off its gaseous envelope in a supernova explosion, and becomes a neutron star.

A.P.J Abdul Kalam



A great scientist, phenomenal teacher and people's President. At Indian Space Research Organisation, he was project director of the SLV-III, India's first indigenously designed and produced satellite launch vehicle. Rejoining DRDO in 1982, Kalam planned the program that produced a number of successful missiles, which helped earned him the nickname "*Missile Man*." His contribution to science, humanity and technology cannot be elucidated ever. Here are some top contributions of Dr. A.P.J Abdul Kalam that turned him into a living legend for the entire country:

1. **Satellite Launch Vehicle:** During the 1970s, when India had hardly dreamt of its SLV, Dr. A.P.J Abdul Kalam launched SLV III in July 1980, which deployed Rohini in near earth orbit. It was nearly a decade's hard work of Kalam, which made this task possible.
2. **Integrated Guided Missile Development Program:** Dr. Kalam was appointed as the CEO of this high-end program. Rather than backing off from this responsibility, Kalam tried in the best way possible to make it successful. As a result of his hard work and devotion, missiles like AGNI (a ballistic missile) and PRITHVI (surface-to-surface missile) came into existence.
3. **Pokhran-II Nuclear Tests:** During his tenure as Secretary of the Defence Research and Development Organization and Chief Scientific Advisor to Prime Minister between July 1992 and December 1999, he took some great decisions. Dr.Kalam's intensive technical and political help in Pokhran-II nuclear tests earned him a lot of media coverage and established him as the best living nuclear scientist in the country.
4. **Kalam-Raju Tablet:** Dr. Kalam and Soma Raju, a well-known cardiologist, came up with a rugged tablet computer in 2012 to take care of the health of underprivileged people in rural India. It helped the government fight many health issues.
5. **Mission 2020:** Dr. A.P.J Abdul Kalam was a visionary man who saw a dream of India becoming a developed nation by the year 2020. He always believed that education and the dominant young Indians could take the nation to greater heights. He will not be there to witness India's success in the coming days, but his guidance and blessings will surely help the country to fulfil his dream.