Research Methodology
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Lecture - 18
Historical Perspective: Science in Ancient India

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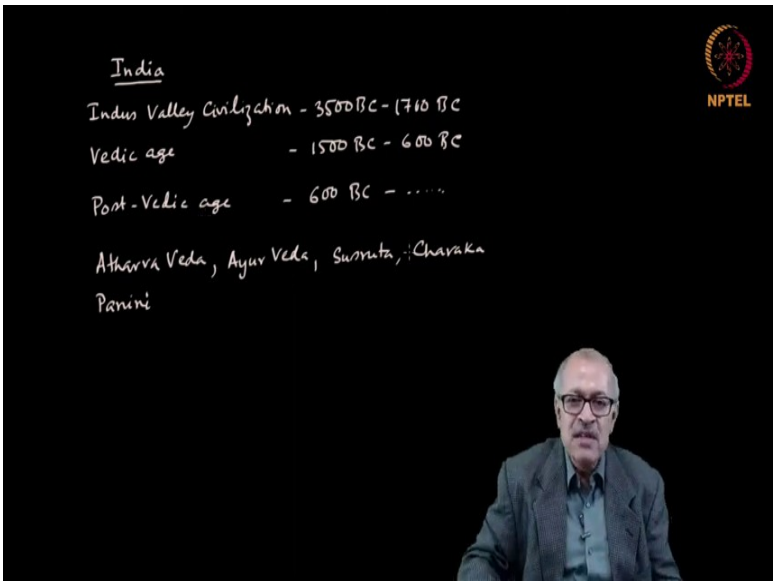

While all this was happening in Europe, what was happening in India? As we have said earlier, the Indus Valley Civilization was approximately from 3500 BC to about 1700 BC and then the Vedic age was around 1500 BC to about 600 BC. The period after that we call the post-Vedic age, which is around, say, 600 BC to ... I will not define exactly when it was. But let us discuss this period. I will not talk about the Indus Valley Civilization because, apart from technology used there, we do not really know much of the thought process or the science that was there.

But in the Vedic age, whatever science was there, we can get some glimpse of it from the Vedic literature. Well, initially in the Vedic age writing was not there. So, things were propagated in *Shruti* and *Smriti*, but after around 1000 BC, writing developed and things started being written up. From that, we get some glimpse of the number system they used.

The number system they used, was a 10 best number system. But there was no zero, there was no place value system. So, in their number system it was basically 1, 2, 3, 4, 5,

6, 7, 8, 9 and then, since there was no 0, one cannot write 1 0 as 10. So, there was a separate symbol for 10 and that symbol followed by 1 would be 11 and so one and so forth.

Again at 20, you will need a separate symbol and this method of writing continued for a long time. In fact, the Kharoshti stone inscriptions at the time of Ashoka also has the same number writing system. One important development that happened in the Vedic age was the Shulvasutras. Shulvasutra, the word, means the rule of the thread, *shulva* means thread.

So, essentially these were instruction manuals for constructing alters for *yagnas* and in that, they had to tackle some theoretical problems. For example, how to identify the exact East-West line? They could figure that out. How to construct a circle of the same area as a square or how to construct a square of the same area as a circle? These are problems that were tackled in the Shulvasutras and we see in the Shulvasutra the first statement of what is today known as the Pythagoras theorem.

The Vedic age ended and the post-Vedic age started with the onset of the Jainism and Buddhism, because after about 100 years of Buddha's life, practically the whole subcontinent became Buddhist. So after that time we say that the Vedic age had ended and the post Vedic age started.

In this transition period and in the early post-Vedic period, we see a lot of developments. Most notably, there was a development of medical science. Towards the end of the Vedic age we see the Atharva Vedas being written up and in the early post-Vedic period, in continuation of that Atharva Veda tradition, the AyurVeda was written up.

We see great medical practitioners like Charaka, Sushruta in that early period of the post Vedic age. Sushruta, in fact, introduced surgery and that is unprecedented anywhere in the world. Surgery per se was not practiced anywhere in the world at that time. So, it was a great development for that matter.

I was so far talking about the Atharva Veda and Ayur Veda and we talked about Sushruta, Charaka and there were other important medical practitioners. For example, Athreya, Jivaka. Jivaka was the court physician of Bimbisar. I am now talking about Panini, the greatest grammarian of antiquity, around 5th Century BC.

In the Vedic age, Sanskrit was developed as a language, but it did not have a uniform form. Panini formalized Sanskrit grammar and gave it a very structured form so that it could become the link language of the whole Indian subcontinent. Not only link language, but also the language of the educated class. And the way we write our alphabets, that is also a contribution of Panini. So, Panini was one of the greatest grammarians of antiquity.

And after that, we find that the Jains, the Jain lineage, created a group of mathematicians called the Jain mathematicians. So far, in the Vedic age—the mathematics that I just mentioned, the shulvasutras—these were mathematics for the service of religion, religious practices, while the Jain mathematicians took it out of the religious practice and made mathematics stand on its own feet. They conceived large numbers, even infinity and things like that.

The greatest development in the post-Vedic age in mathematics was the introduction of zero. The absence of anything is also a number—conceiving that was not easy. That happened in the Indian subcontinent, though I must admit that at that time there were trade between India, China, Indo-China and all those regions and it is somewhat uncertain as to where zero originated first. The idea could have originated in any of these places and through trade routes, that might have come to the other places, because the oldest inscription of the symbol 0 is found in a temple in today's Cambodia. So, it is not in the Indian land per se, but nevertheless it is normally believed that, early on, Indians took up this zero and the place value system.

And when you introduce a new kind of writing numbers, the whole mathematics has to be redone. So, the ways of addition, subtraction, multiplication, division, square, square root and all that had to be invented afresh. It was done in Indian subcontinent.

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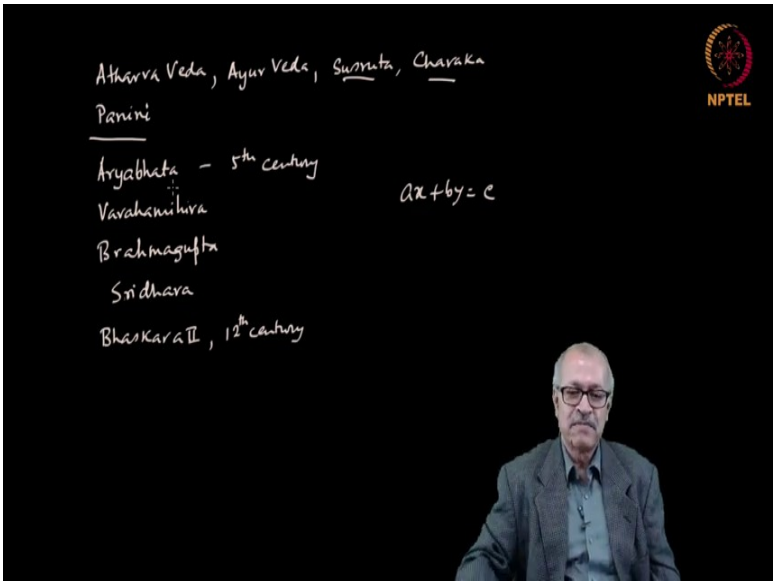

And then we see a plethora of great mathematicians and astronomers. We see Aryabhata (5th century), we see Varahamihira (6th century), we see Brahmagupta (7th century), Sridhara (11th century), and many such mathematicians.

But crowning all that was Bhaskara. I would say Bhaskara II, because there was another Bhaskara I. Bhaskara II was in the 12th century. Aryabhata was in the 5th century and they were in 6th century, 7th century, 9th century and so on and so forth.

So, in this period we see a lot of developments. What did they do? Aryabhata, for example, found the value of pi (π) much more accurately than anybody contemporary to him. He expressed it as a fraction, but when you evaluate that you find 3.1416, which is correct.

At that time astronomy and mathematics was developing hand in hand. The primary incentive for doing mathematics came from astronomy because things in the sky always aroused curiosity. People had been looking at the things in the sky initially for the purpose of making a calendar because calendar is necessary in any agricultural society.

In order to make a calendar you have to find some repetitive events, cyclic events, and the motion of the sun, the motion of the moon are such cyclic events. So, the ancients of India of that time minutely observed the motion of the sun and the moon. They observed that the sun does not rise in the same place every morning. So, it goes toward South and then again goes towards North.

So, *uttarayana* and *dakshinayana* were identified and when it reaches the last point in the North, when it is the last point in the South—these were identified. Not only that, people realized that the sun and the moon go in a particular strip and all the planets go in the same strip.

Today we know that as the zodiacal strip, and in order to identify the position of the sun and the moon, the ancients in India named 27 stars along that zodiacal strip. They named the *rashis* that we know today as the constellations. The Leo, the Libra and all those constellations were named.

Aryabhata, for the first time realized that, we see the sun going from one side to the other, from the East to the West, we see the moon going from the East to the West, we see all the stars and the whole sky going from the East to the West, and he realized that the easiest solution of all that is to assume that Earth itself is spinning on its own axis.

This was the first in the world when somebody could make the comment that the Earth itself is not static; it is in fact, a spinning globe. The people contemporary to Aryabhata even a century or couple of centuries later, like Varahamihira, Brahmagupta—they did not accept Aryabhata's idea that the Earth is a spinning globe. But they also had their own contributions in Mathematics and Astronomy.

Well Aryabhata was not the first to introduce the sine tables and cosine tables because, as I said earlier, the Greek Astronomers Aristarchus and Hipparchus introduced the sine and cosine in order to make their observations correctly. Aryabhata made a sine table of one degree steps. So, sine 1 degree, sine 2 degree, sine 3 degree, cosine 1 degree, cosine 2 degree—he made tables like that. And when we really look at the table we find that it satisfies the $\sin^2 \theta + \cos^2 \theta = 1$ rule. So, that rule was also definitely known to them. And whatever trigonometric relationships we learn in school, the simple ones, all these were discovered by Aryabhata, Varahamihira, Brahmagupta.

In fact, in Brahmagupta's book *Brahmasphuta Siddhanta*, you see most of the simple trigonometric relationships that one learns in school today. So, those things were introduced on the Indian soil. Algebra was done using Sanskrit alphabets: *ya* was to represent today's *x*.

And if there was x and y, that means, two unknowns, then that was represented by the first letters of the color names. So, red and blue: the first Sanskrit letters of the color names were used and people wrote equations with that. Not only that, one of the peculiar mathematical developments in India was the solution of indeterminate equations.

Something like ax+by=c, an equation like that cannot be solved because there are two unknowns. But some Indian mathematicians noticed that if a, b, c are whole numbers and x and y are also whole numbers, then there are solutions. And they found such solutions. Brahmagupta introduced what is known as the quadratic equation and its solution, and it was formalized by Sridhara. So, sometimes it is called Shridhara's equation.

The last of that sequence of mathematicians was Bhaskara. He was a great mathematician. In all fields of mathematics he had contributions and I will not elaborate on each of them.

All that I want to point out was that after Bhaskara there was practically nothing, at least in the main part of India. There was one lamp still lit in the corner of the Indian subcontinent, in Kerala, which is called the Kerala School of Mathematics and Astronomy. They were followers of Aryabhata and continued that tradition and developed mathematics at a later time.

But after the 11th century practically science was dead in India. Bhaskara was, you can say, an outlier. He was actually not in Northern India, he was in today's Karnataka. After that center of learning moved further South, to Kerala.

So, you see that in India also a lot of developments happened. And in the last class I pointed out that in India also, both the material school as well as the ideal school existed, were fighting for intellectual space, were influencing people. For example, the names that I mentioned Sushruta, Charaka, Aryabhata—most of them subscribed to this or that school of materialist philosophy, but the idealist philosophy was also very much there.

In the 7th century, idealist philosophy started on an ascent with the work of Shankara. He forcefully made the point that the world is an illusion. The material world, as you see it, is illusion, is *Maya*. And following his time, slowly the ideal school become stronger and stronger, and as a result, the materialist school became weaker and weaker.

Acharya P.C. Ray identifies the decline and fall of science after the 11th century to three factors. In his book 'The History of Hindu Chemistry', he writes that the first reason for the decline was the ascent of the caste system. The decline started around 9th century and after the 11th century, science was not there in India any further. The caste system was there earlier, but it was not entrenched in the society in a very strong manner and after that time it became a very strongly entrenched caste system.

Prafulla Chandra makes the point that, in order for science to flourish, the doers and the thinkers either have to be the same people, or have to be in close touch with each other. But after the caste system was introduced, the doers and the thinkers were separate castes with no contact between them.

The second point he made was specifically in the context of the medical practitioners because, as I said, surgery was an important thing. Prafulla Chandra made the point that, in order for a teacher to teach surgery to a student, you cannot do it without dissecting dead bodies. By dissecting dead bodies, you can show what is inside and in which position, so that when you actually perform a surgery on a living body, the person must know what he is cutting and where to find what. When the *Manu-samhita*, the strictures of Manu, was introduced, then it became impossible for a Brahmin or somebody of the upper caste to touch a dead body because that was only to be done by a *shudra*. The learned people no longer could touch the dead body. So, dissecting the dead body became impossible and naturally the whole cult of surgery fell into disuse.

The third point that Prafulla Chandra makes is that the ascent of the philosophy of Shankara, the idealist philosophy of Shankara, which saw the material world as illusion. He says that, in order for you to do science, you have to believe that the material world exists. You have to ask questions about the material world and have to seek answers. If you believe that the material world is an illusion, you can do no science. So, when this philosophy captured the intellectual space, then science slowly died out.

As you know, there was an eclipse period of science in Europe during the Middle Ages. There was an eclipse period in science in India also, which started, as I said, in the 9th century and after the 11th century science was practically eclipsed. There was no science in India for that matter, except a few work that we find in the Kerala School of Mathematics.

Again India started doing science proper in what is known as the Indian Renaissance. Raja Ram Mohan Roy and Vidyasagar in the 19th century were enlightened by the ideas of European Renaissance. They brought that idea of European Renaissance and tried to enlighten the Indian populace.

Vidyasagar tried to change the Indian education system and through that, a new cult started—the cult of doing science. In the next stage we see a great number of mathematicians and scientists. We see Jagadish Chandra Bose, we see Prafulla Chandra Ray, we see Raman, we see Ramanujan, we see Meghnad Saha, Satyendra Nath Bose and many others: great scientists doing great science in a very difficult situation.

So, India also had its very rich history of doing science. India also had its history of science being eclipsed by idealism and again the ascent of science at a much later period.

In the next class we will continue our journey with European science, because then a lot of things were happening in Europe. But before leaving the history of science in India, let me tell you that in India, a lot of fantastic developments happened in science which influenced the science of the rest of the world.

The science of Aryabhata, Varahamihira, Brahmagupta and people like that, the books by them were translated by the Arabic scholars when there was a golden age, as it is called the ‘Islamic Golden Age’, where the center of learning was practically in Baghdad and places like that. There the Khalifas employed people to get literature from different places and to translate them into Arabic and they translated these books by them.

Not only that, an Indian scholar was invited by the Khalifa in Baghdad and he stayed therefore some time and conveyed our number system to them. And then the Arabic world accepted our number system, the zero, the place value system, the decimal system and the from them the Europeans got it. And that is why these numbers are still called the Arabic number systems. But actually these were originated in the Indian subcontinent.

Exchanges happened through trade routes especially after Alexander’s invasion into India. The Greeks had their kingdoms in different places in the Middle East and various Indian states had trade relationship with them. Through that, Greek ideas reached India. The Indian ideas reached various other places in Europe.

So, the developments that happened in India did not really remain in India. It spread in other places and influenced others. Arabic astronomy was influenced by Indian astronomy, but the Arabs developed it further and their specific focus was on making star charts and they call it ‘Zij’. They produced various star charts.

And again, when Indian science was eclipsed, those star charts came back to India from the Arabs. Their technique of producing the star charts was by using great observatories, masonry based observatories, and those things were actually perfected in the Arab world and came back to India.

So, there was exchange of ideas between the Arab world, between India and the European lands, but very little during the Dark Age of Europe. Only after the Renaissance started, they translated the work of the Arab scholars, and Arab scholars in turn had inherited some of the knowledge from the Indian scholars.

So, there was exchange of ideas; many of these had actually originated in India. We have to be proud of that. But, I must also say that we should understand what really happened in India, rather than harbouring fanciful ideas regarding things that actually did not happen.

There was no aircraft in India, there was no plastic surgery that could plant an elephant head on a human torso, there was no stem cell research in India at that time, there was no biotechnology that could give birth to 100 sons of one lady. So, these are actually mythological stories. We should not put any science behind them.

But there was hard science that was done on Indian soil and we have to be proud of it.