A HANDBOOK

OF

MAHARAJAH JAISINGH'S

ASTRONOMICAL OBSERVATORY, DELHI

BY

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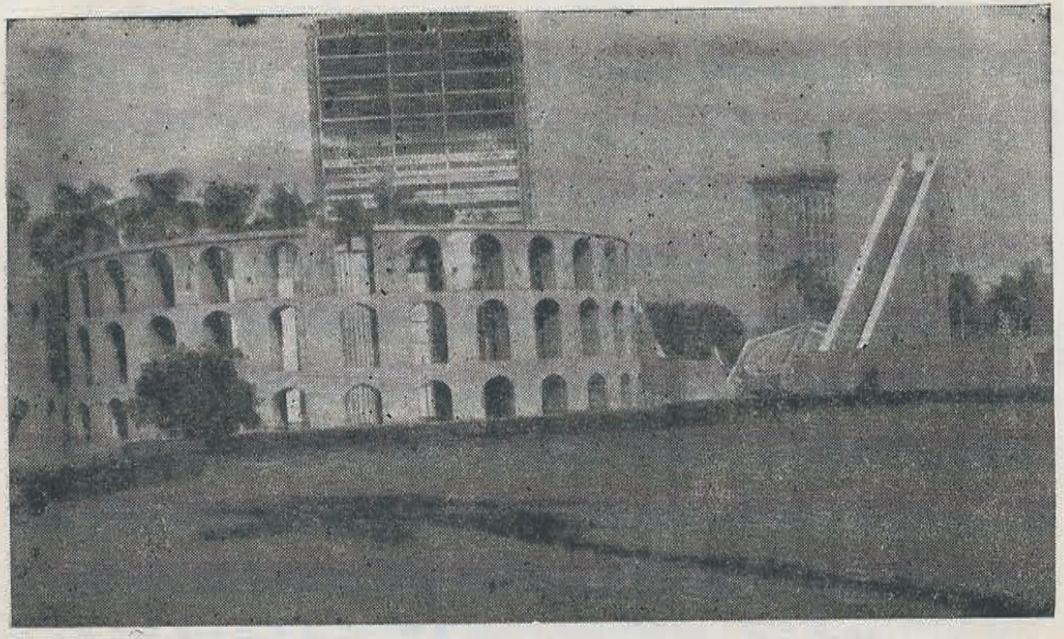


General view of Jantar Mantar (observatory)

PREFACE

The following pages are intended to form a brief hand-book for the use of tourists to Delhi to throw some light upon an old institution—a relic of the past, two centuries old, which might otherwise appear as something inexplicable.

The author has not the proud pretensions to present in these pages systematic exposition of the abstruse subject of Hindu Astronomy, or of the various instruments or queer structures to be met within the institution in question—Maharaja Swami Jai Singh II's Astronomical Observatory at Delhi.

Connected with the Department of construction and repair of state buildings of Jaipur he had to do under C.E. Stotherd Esq., Suptdg. Engineer, and Lala Chiman Lal, Darogai Imarat, with the supervision of the recent work of thorough repairs and restoration of astronomical observatories at Delhi and Banaras, and to make his work interesting, he had to acquaint himself with the construction and use of the instruments.

The account given in the following pages is thus the fruit of his practical work as an engineer, and not as an astronomer in the course of which he has had opportunities of the various instruments of the observatory.

The account thus presented though brief and unpretentious is expected to awaken the interest of the tourist on the

subject, and throw such light as will make "darkness visible".

The reader of these pages will no doubt be struck with wonder admiration at the manner in which accuracy was attained in astronomical observations and calculations, in the days long gone by, when the rare privilege of the use of the highly finished scientific instruments of modern time was not to be availed of.

The author's humble efforts will be amply repaid if by reading these pages, the interest of intelligent and sympathetic tourist is awakened on the subject of how scientific studies were pursued by Hindus of old or, more strictly mediaeval India.

BHOLA NATH

1. A brief account of the observatory and its founder

Tourists to Delhi often find it worth their while to pay a visit to Qutab Minar the famous and great tower of Delhi. On their way to the Qutab the attention of many of them has been drawn and their curiosity awakened on sight of a huge structure in masonry, towering high to their left on Parliament Street but they have found little satisfaction on interrogating their guide as to the structure, who simply answers, "This is Jantar Mantar".

The lofty structure, is one of the instruments of Maharajah Jai Singh's astronomical observatory whose position it marks for miles around and as Yantra in the Sanskrit word for instrument, people have come to call it Jantar Mantar.

Maharajah Jai Singh, founder of the city of Jaipur, ruled Jaipur State formerly known as Amber after its ancient capital Amber from 1699-1743 A.D. corresponding to the reign of the Moghul Emperors Aurangzeb, Shah Alum, Farrukseer and Muhammad Shah at Delhi. He had special taste for Mathematical Sciences specially astronomy in which hard application and lucid brains gained him supremacy over the astronomers of the day. Not satisfied with the results obtainable from the calendars current in those days and finding that the actual observations of heavenly bodies did not tally with the results deducted from the calendars, set up to frame new tables of his own for which the help of accurate instruments were required. With that object in view he built astronomical observatories at Delhi, Jaipur, Banaras, Ujjain and Mathura all of which places he was more or less connected as ruler or governor.

The Delhi observatory was built in the 1710 A.D. before others which were constructed to check the observations made at Delhi.

II. General explanation of terms used in the description of construction and use of instruments.

Astronomy is the science which treats of the heavenly bodies, their magnitude, distance, composition, movements and the forces regulating these movements etc. The knowledge of the subject, enables us to make deductions as the time of eclipses, motion of heavenly bodies, their time of rising and setting etc. By observation of their position with respect to ourselves at different times and to one another. For this the observation and record of their position is necessary.

Just as for recording the position of an object on the earth surface we take its bearing *i.e.* we observe the angle at the point of observation formed by two lines, one of which is the lines joining the point observation and the object and the other joining the north and the object. Similarly for observation and record of the position of heavenly body we make use of a similar method by observing its *bearing* which is also called *azimuth.* But to fix its position, its height is called *altitude,* above the horizon has to be taken into consideration, which *i.e.* the angle formed at the point of observation by two lines one of which is the horizontal line and the other formed by joining the point and the body.

In order to measure these angles we make use of angular instruments—Compass, saxtant, theodolite are the instruments in common use these days but in the days of Maharajah Jai Singh no such instruments were available, nor could be thought of making them for himself in metal, due to the

want of skill required to manufacture and graduate such delicate instruments by the artisans of the day. The instruments extent in the Observatory made in stone and masonry served him in place of angular instruments made in metal, in use now.

Thus we see that the position of a heavenly body at certain time can be observed and recorded by taking its *azimuth* and *altitude*.

In addition to the system of recording by means of *azimuth* and *altitude* there are others as explained below :

In the Geography of the globe we have read the meanings of the pole, meridian, equator, latitude and longitude as follows :

The ends of earth's axis are poles known as North and South poles.

Meridians are lines supposed to be drawn round the earth running North and South and round the earth midway between the poles.

Equator is the line supposed to be drawn round the earth midway between the poles.

Latitude is the distance of a place North or south of the equator.

Longitude is the distance of a place East or West from a fixed prime meridian. In English Geography the meridian of Greenwich is counted as longitude.

Carrying over the symmetry between the terrestrial and celestial sphere we have in the latter also its, axis, pole meridians, equator & latitude. The heavens like earth are revolving round an axis, the end of which are the North and South poles in the heavens.

Meridian of a place is the circle passing through the North and South poles and the highest point in sky just over observers head called *Zenith.*

Equator is the great circle passing equidistant from North and South poles.

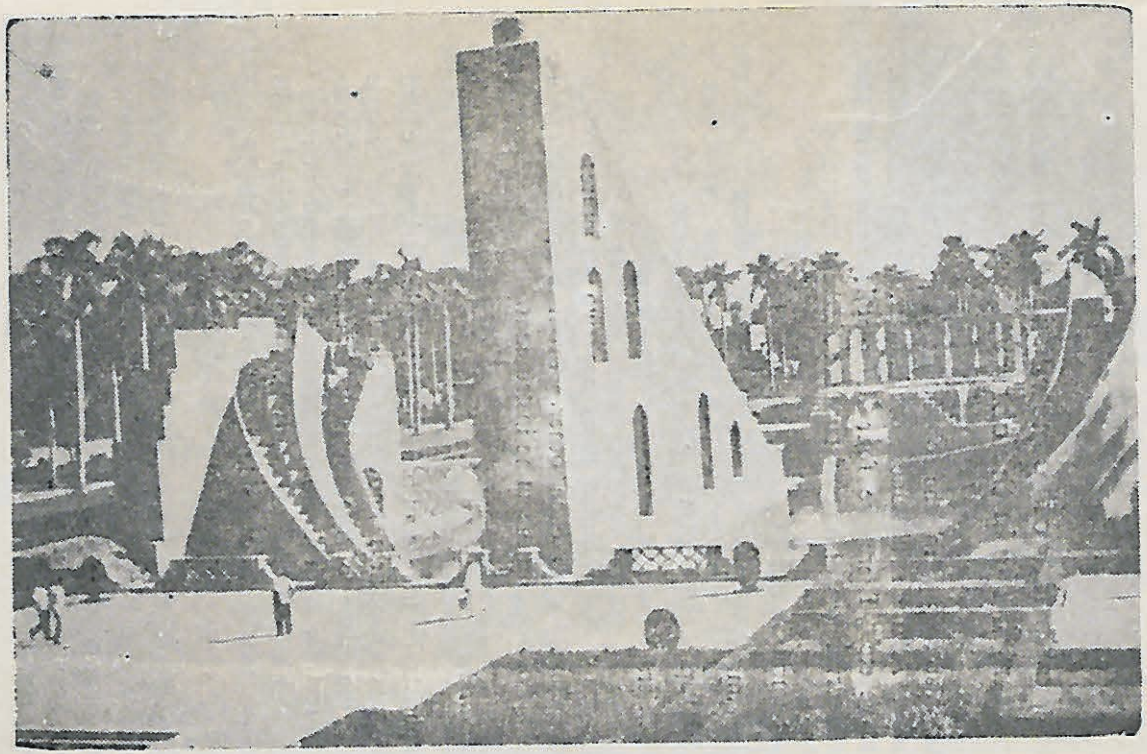
Corresponding latitude and longitude we have declination and Rights Assension.

To fix the position of a place on Earth we need, (1) its latitude *i.e.* the distance in degree North or South of the equator. Corresponding to this to fix the position of a heavenly equator, (2) its longitude *i.e.* its distance East or West of Meridian of Greenwhich. Similarly in the heavenly sphere we note its Right Ascension, *i.e.* its distance East or West of the points where the ecliptic and equator cut at the time of Vernal equinox.

Thus we see that the second system of observing and recording the position of heavenly bodies is by means of declination and right ascension. In the second system sometimes in place of right ascension, the hour angle of the body is observed in addition to declination. Hour angle of a heavenly body is the angle between two circles, one of which is the meridian circle of the observer and the other is the circle passing through the North and South poles and the body

observed. The magnitude of the arc of the equator intercepted between the points where the above two circles cut it, determine the value of hour angle.

Note—In northern hemisphere the North pole is always above the horizon and its altitude is equal to the latitude of the place. Thus in Delhi latitude 28° 39″ North of the pole is towards the North at a height of 28° 39″ abve the horizon. The equator being 90° from the pole is 28° 39″ South of Zenith.



Samrat Yantra (Sun Dial)

III. Description of construction and use of instruments in the observatory.

The instruments in the observatory provide means of measuring Azimuth altitude, declination, right ascension, hour angle etc. There are four different instruments in the Delhi Observatory which consists of six different structures.

1.	Samrat Yantra	1
2.	Rama Yantra	2
3.	Jayaprakash Yantra	2
4.	Misra Yantra	1

For each of Nos. 2 and 3 there are two structures which are supplementary to each other. From supplementary, I mean parts of one and the same instrument.

1. *Samrat Yantra*

It consists in the main of a right-angled triangle called gnomon and two arcs known as Quadrants. The triangle stands in the plane of the meridian. *i e.* exactly in North-South direction; with its longer side on the ground accurately levelled, and its shorter side vertical. The inclination of its hypotenuse to the larger side is 28° 39″ equal to the latitude of Delhi and hence it points towards the pole.

The quadrants are arcs of circles described in the plane of the equator with their centres on the edge of the gnomon. For the upper edge of quadrant the centre will be found higher up the hypotenuse and for the lower edge, lower down. Thus on both the edges of gnomon there are four points as

centres, two for each quadrants the gnomon and two quadrants are graduated.

The graduations on the quadrants serve to measure hour angles, and those on the gnomon determine the declination of a heavenly body by the method explained below.

In the morning the shadow of the gnomon falls on the higher end of the Western quadrant, as the sun rises higher and higher the shadow descends till at noon there is no shadow at all. When the noon is past the shadow appears on the Eastern quadrant just near where it joins the gnomon, and as sun goes down the shadow gradually ascend on the Eastren quadrant till at last the whole of the Eastern quadrant is covered by the shadow. This motion of shadow is regular and is in proportion to the time that elapses after or before the noon. The space on the quadrants is divided into parts to show hours, minutes and seconds, and observing the coincidence of the shadow, with any of the graduations, time can directly be read off.

Time means the hour angle of sun. As the earth goes round the sun in a day, *i.e.*, describes an angles of 360° in 24 hours hence 1 hr.=360/24° =15″. And similarly parts of multiples of an hour are equal to the same parts of multiples of 15 degrees.

The graduations on the gnomon begin from the central points of the quadrants on the edge of gnomon and proceed upward and downwards both ways. They are formed by engraving scale of tangents for different angles. The divisions counted upwards give the declination North of the equator

and those downwards give the declination of South of the equator. To measure the declination of the sun equator; hold a metal rod with a sharp edge or point upright on western edge of the gnomon before noon and on the eastern edge afternoon and observe its shadow. Move the rod up or down on the graduation of the gnomon to find when its shadow coincides with an edge of the quadrant.

The graduation on which the rod stands marks the declination of the sun at the time of observation. If the declination is towards north the shadow of rod should be observed on the upper edge, if south then the lower edge. Thus by making the shadows, as explained above the hour angle and declination of other heavenly bodies may also be observed with the aid of Samrat by holding a thread touching graduations on gnomon and the quadrant. The thread should be moved along the graduations on the gnomon and the edge of the quadrant until the heavenly body to be observed comes in line with it. When this is so the reading on the quadrant will give the hour angles and that on the gnomon, the declination. A horizontal sun-dial has been made and placed on a circular pillar of masonry made on the top of the gnomon.

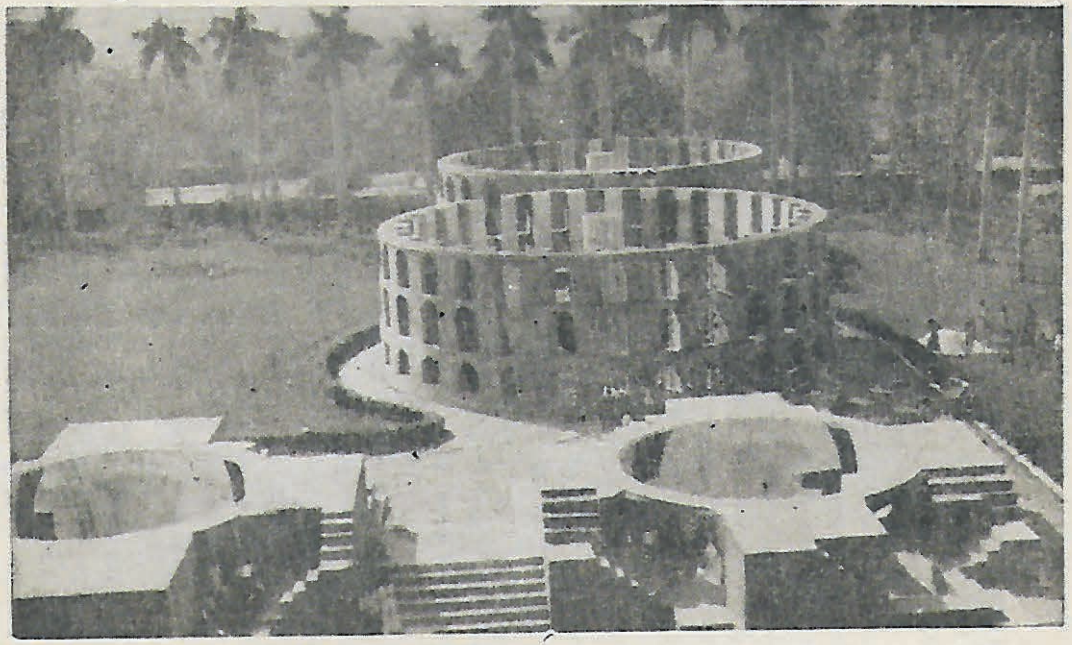
Other instrument known as Sasthansa Yantra now extinct, existed at the bottom of the gnomon in the part which is now under water. Its use was to observe altitude and declination of the sun.

2. *Rama Yantra*

It consists of two circular buildings, with masonry pillars in their centres, stone and lime sectors radiating from the

central pillar and ending at the circular walls. The two buildings are part of one and the same instruments which could have been made only one by having the circular floor and was continuous without leaving vacant spaces in them, but two make room for the access of the observer to all parts of the instrument, the circular floor has been divided into sectors and only alternate sectors made in stone and lime, the others, being left in one instrument. In the other instrument those left in one are made. Thus the vacant space in one corresponds with the sectors and *vice versa*. The instruments are thus supplementary *i.e.* part of one and the same instrument. Similarly pillars of the circular wall in one instrument correspond with openings in other and *vice versa*. The use of instrument is to measure *altitude* and *azimuth* of heavenly bodies. With this object the wall and the sectors are graduated. The top of the wall is counted as O and descending from the top scale of tangents of degree from 1° to 40° has been engraved, 45° at the junction of the wall and the sectors. And again from the junction to the foot of the circular pillars tangents of degrees, 90° coming at the foot of the pillars. This is for the observation of the *altitude*. For the *azimuth* the sectors of the both jointly forming a circular floor are divided into 360 equal parts to show degree from the North. The observation can be made in one or the other instrument accordingly as at the time of observation were the *azimuth* or *altitude* which happens to all on the made portion of one or the other.

To observe the *altitude* and *azimuth* of the Sun we observe the shadow of the central pillar. At sun-rise the shadow of pillar just falls on the top of the wall meaning its *altitude* as O. As the sun rises the shadow descends on the wall, until when it has gone 45° above the horizon, the shadow touches the junc-



Rama Yantra and Jayaprakash Yantra

tion of the wall and the sectors. When the sun rises higher, the shadow moves on towards the pillar, until there is no shadow at all when the highest point is reached by the sun *i.e. altitude*, its *altitude* is 90°. The line bisecting the thick shadow of the pillar will mark on the radial graduations the *azimuth* of the sun.

Azimuth and *altitude* of other heavenly bodies may be observed by moving a thread attached to the centre of central pillar against the wall or the sectors according to the *altitude* which is less or more than 45° till the body observed comes in line with it. The *altitude* and *azimuth* can then be read directly by observing where the end of the thread is on the graduations.

3. *Jayaprakash Yantra*

This instrument is also like the Rama Yantra as described above & is in two parts. One supplementing from the other. It could have been made in one, but two give access for observation to the different part of the instrument, parts have been left vacant to correspond with the made part of the other.

The instrument consists of hollow hemispherical cavity in the ground plastered and polished over and graduations laid thereon. It is a representation of the heavenly sphere an exact model of it on which lines have been drawn to represent *altitude* and *azimuth* circles meridian, equator, Zenith, etc. The circles forming the rim of the instrument on the ground represent the horizon. It is divided into degrees and minutes. The point in the lower-most centre represents the Zenith and through the Zenith a circle passes from the North

and South points. On this line in the South direction a point has been taken 28° 39″ below the horizon to represent the South pole. Similarly a point 28° 39″ above the horizon towards the North will represent North pole. Round the South pole a circle has been drawn, with the pole as centre, at a distance of 23-28″ from it which is the maximum declination of the sun. Similar circle is to be drawn round the North pole but it is not present in the instrument due to the North pole not being shown in it. On the Southern circle thus drawn points are marked representing the position of the rising of the twelve signs counting from the upper intersection of the meridian with this circle towards the East. With the twelve points thus marked as centres, and radius equal of the radius of the hemisphere of this instrument, circles are drawn to represent different positions of the ecliptic.

The equator circle is drawn by taking pole as centre and radius to the hemisphere of the instrument starting from the point where the meridian and the equator intersect, the meridian circle is divided into degree and minutes to show the angle of declination.

Altitude circles are drawn by taking the zenith as centre and radius from this to each degree on the meridian circles. Azimuth circles have been drawn for each degree with centres on the horizon.

By observation of the sun, image falling on the graduation through the hole we can read directly its declination, azimuth altitude, etc. For the purpose of observation, cross wires have been fixed exactly North, South, East and West and at the point of inter-section a circular piece of metal with a hole in

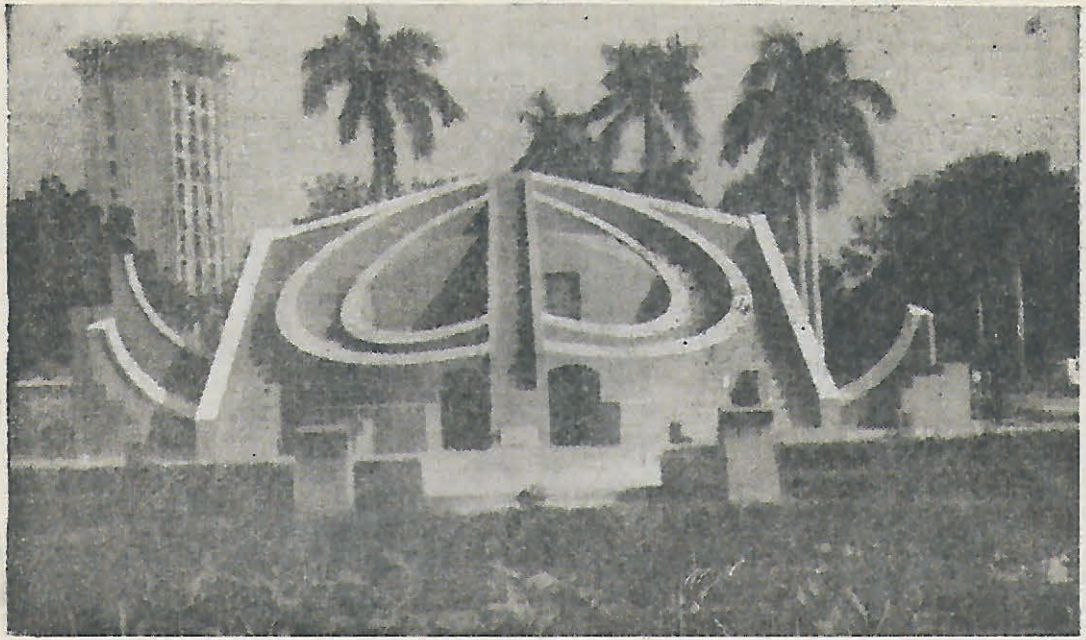
the centre is attached. The image of the sun passing through the hole marks the position of the sun.

Misra Yantra :

It is a complex instrument consisting of (1) a central gnomon with two semi-circles on its two sides and (2) two outer gnomons on its East and West with their quadrants. It comprises variety of four instruments (1) Samrat Yantra (2) Dakshinobhitti, (3) Niyat Chakra Yantra and (4) Kark Rashivala.

1. Samrat Yantra as explained earlier is the instrument for finding time and declination. In this instrument instead of being made one it has been made in two parts, one half towards the East and the other half to the West, the first serving for observations in the afternoon and the second before it. The method of observation is the same as described under the first instrument called Samrat Yantra.

2. Niyat Chakra Yantra—It consists of four semi-circles ending at the central gnomon, two on each of the East and West sides of it. The centres of the semi-circles lie on the gnomon and there are holes in the centre to hold a rod, pencil or stick. The use of the instrument is (1) find the declination of the sun at 6.52 and 7.24 in the morning and 4.36 and 5.8 in the evening, (2) to observe the noon of the four important observatories in the East and West. If a rod or stick be held in the centre hold at 6 hours 52 minutes its shadow will fall on the outer semi-circle towards the West at 7 hours 52 minutes on the inner semi-circle the same side, and the reading on the graduation on the circle will give the



Misra Yantra (Niyat Chakra Yantra)

declination of the Sun. Similarly at 4.36 the shadow will fall on the inner circle towards the east and at 5.8 hours on the outer circle that side, and the declination can be read on the graduations of these circles. The shadow of the rod will fall on the semi-circles only at the time indicated above.

Of the morning hours 6.52 denotes noon at Notke in Japan
" " " 7.24 Saritchen in pic island in the Pacific ocean

Of the evening hours 4.36 denotes noon at Zurich (Switzerland)
" " " 5.8 " Greenwich (England)

Noon at above places coincides exactly with the time, at which the shadow of the rod fixed in the centre hole falls on the four circles. Thus when the shadow falls on the outer circle towards the West it is noon at Notke, when it falls on the inner circle of same side it is noon at Saritchen. Similarly when the shadow falls on the inner circle towards the East it is noon at Zurich and when it falls on outer circle East side It is noon at Greenwich.

3. Dakshinobhitti—This consists of a graduated arc described on the eastern wall of this instrument which is made exactly in the North and South line. At the centre of the arc a peg is fixed. The use of this instrument is to find the altitude or Zenith distance of heavenly body when it comes on the meridian. To make observation the observer fixes one rod of a thread to the centre holding his eye near the peg and gets his assistant to move the thread round the circle, until the body to be observed comes in line with it. The readings on the graduations of the arc will give him zenith distance or altitude accordingly as they are read from the middle of the arc or from its ends.

4. Kark Rashivala—O on the face of the back wall of this instrument a semi-circle has been engraved in plaster, at the centre of which a peg is fixed. Starting from O on the east and west ends of the semi-circle there is 90 at the bottom and space divided between degree and minutes. This is used at the time when the first point of cancer is on the meridian to know in what sign the sun is passing. The method of observation is the same by aligning the object with a thread as in Dakshinobhitti. By taking reading on the graduations of the semi-circle the sign can be known.

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