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“THE ARTICLE ON THE QUALITY OF THE OBSERVATIONS" OF AL-'URDÎ

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"THE ARTICLE ON THE QUALITY OF THE OBSERVATIONS" OF AL-'URDÎ*

BY SEVIM TEKELI**

Introduction

This article includes the critical edition and the translation of the *Risala fî kayfiya al-arsâd wa ma yuhtaja ilâ llmihi wa amalihi min turuq al-muwaddiya ild marifa'auddt al-kawakib (The treatise on the quality of the observations and the teoretical and practical knowledge needed to make them, and the methods leading to understanding of the regularities of the stars) of Al-Urdî.* It gives us a whole description of the instruments of the Maragha Observatory that was constructed by Nasir al-Din al-Tûsî in 1261 under the auspices of Hulagu. Only at the time of Tycho Brahe (in 16th century) did the instruments in Europe become as perfect and precise as the instruments constructed in Maragha Observatory.

Al-'Urdî is a Syrian architect. He constructed the water installations of Damascus. He has also constructed astronomical instruments for Al-Mansur, the ruler of Hims. After 1259, he worked in cooperation with Nasir al-Din al-Tûsî.

We could clearly see from the descriptions given in this article that the constructions of the instruments and their erections were done with great care in order to have accurate results.

An incomplete French translation of this article was made by Amabl Jourdain (in 1909) in *Mémoire sur L'observatoire de Meragah et sur quelques instruments emploiyés poury observer.* In 1928, it is translated into German by Hugo Seemann as Die *Instrumente der Sternwarte zu Maragha nach den Mitteilungen von Al- Urdî.* This German translation is quite complete. Though it is one of the fundamental books in Islamic Astronomy, its text has not been published up to now. The text herein is the comparison of the three manuscripts. Two of these three copies are in Istanbul and the other one is in Paris.[1]

One of the two manuscripts in Istanbul is enlisted in the St. Sophia Library and its number is 2973. According to the information given by the Directory of the Library the description of the manuscript is as follows:

Dimension of the page: 186 x 120 mm.
Written area: 130 x 75 mm.

Quality of the paper: yellowish polished paper. It is without marginal notes and quite correct. It is rarely punctuated and is one of the oldest manuscripts. It does not include the name of the person who has copied this manuscript but it includes the date of its completion: tenth month of the lunar year 864 (H.).
The other manuscript is registered in Nuruosmaniye Library under the number of 2971. According to the information given by the Directory, the description of the manuscript is as follows:

[1] I learned from Professor Sayili that another copy is found in Tehran.

Dimension of the page: 257 x 176 mm.
Written area: 190 x 100 mm.
Quality of the paper: *Abadi.*
Binding: brown leather with head bound.

This is a review which includes different manuals. It is clearly written, but mostly not punctuated.

The third manuscript is in Bibliotheque National of Paris registered under 2544,10. It is clearly written and punctuated. The transcriber has compared two manuscripts and pointed out their differences in the margin. That is why in the text this manuscript is showed P. and p_a as two copies.

P_a stands for the second which was compared to the first one. At the end, it is written that the manuscript has been copied by Hafiz Hasan b. al-Hafiz Mustafa in the year 867 (H.) the 12th of the sixth month of the lunar year.

In the Paris and St. Sophia manuscripts, the name of the copier is not included. But in the Nuruosmaniye manuscript, it is written in the beginning that it has been transcribed by Al-`Urdî of Damascus.

Though the date of the transcription has not been indicated in the manuscripts we can easily deduce from the information given in the text that it has been written after the construction of the Maragha Observatory and before the death of Nasir al-Din Tûsî. In the text, the date of the construction of the instruments is given as 1261/2. Since Nasir al-Din Tûsî died in 1274, we can estimate easily that the manuscript is transcribed between 1262 and 1274. However, since Al-'Urdî indicates that some of the models of the instruments have already been constructed but without saying whether they have been constructed in the Observatory or not, we can make our estimations further then 1274.

According to the grammar rules, it is necessary to accord the verbs but in addition, accords were made in the kind and number of verbs, when this is not conational in order to provide precision and these changes are indicated with notes. The errors thus made in the dictation are different in the manuscripts but still these changes do not require any corrections.

The translation of the manuscript was made word for word. It has been compared to the German translation and the differences were noted. But towards the end of the German translations more emphasis was given to the meaning without a literal translation. That is why the differences were not noted separately.

RISALA FI KAFIYA AL-ARSAD

In the name of Allah, the merciful. Thank God. Praise to prophet Muhammad and his close relations. The grace comes from God.[2]

This article has been written by Mu'ayyad al-Din al-'Urdî of Damascus who is the leader of the scientists, head of the engineers, connoisseur of mathematics and the supporter of the Nation. He says: "I wrote this article in order to explain the techniques of the observations and to give information about the construction

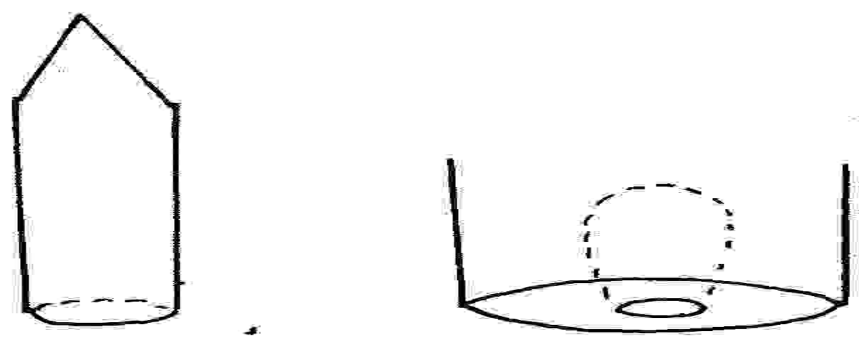
[2] Hugo J. Seeman, Die Instrumente der Slernwarte zu Marâgha nach den mitteilungen von Al-'Urdi, Sitzungsberichte der Physi. medi. Sozietat, Erlangen 1928. P. 23. This pait is missing.

and the use of the observational instruments and the other things necessary in the field of theory and practice to lead us to the knowledge of the movements of the stars, their positions, their distance from the earth and their efficiency when the earth's radius is taken as a unit."

Astronomy that is a branch of mathematical sciences that develops the theoretical sciences and the branch, which is closer to theology than the others, is glorified in two ways: of its subject and the soundness of its arguments. Its subject is the heaven that is one of the unique and wonderful creations of the God, free from all defects. When we come to the arguments, they depend upon mathematics and geometry. That is why we endeavoured all our efforts on this subject. The arguments depend upon our observations and the observations require instruments so we started with the description of the instruments. The ancient and the modern astronomers have constructed many of them. Some of them have defects and the others are difficult to realize. This difficulty does not come from the complexity of its construction; it is the result of the defect in the planning and the fault in the design. We will not mention these in here. We will mention the most accurate of the old instruments and remove every kind of doubt and obstruction befallen on them and we will add the new ones we constructed. These instruments are perfect and precise.

We need to know the meridian of the observatory during the erections of these instruments. Different methods were put forward to determine this. I saw that among these, the best method is the Indian Circle used by our elders. We have discussed the precision of this method in our Risâla-i *ᶜamal al-kura al-kâmila.* This instrument is especially used when the sun is in one of the tropics. With no doubt the Indian Circle gives precise results when the sun is found in one of the tropics, rather then when it is found in any other point.

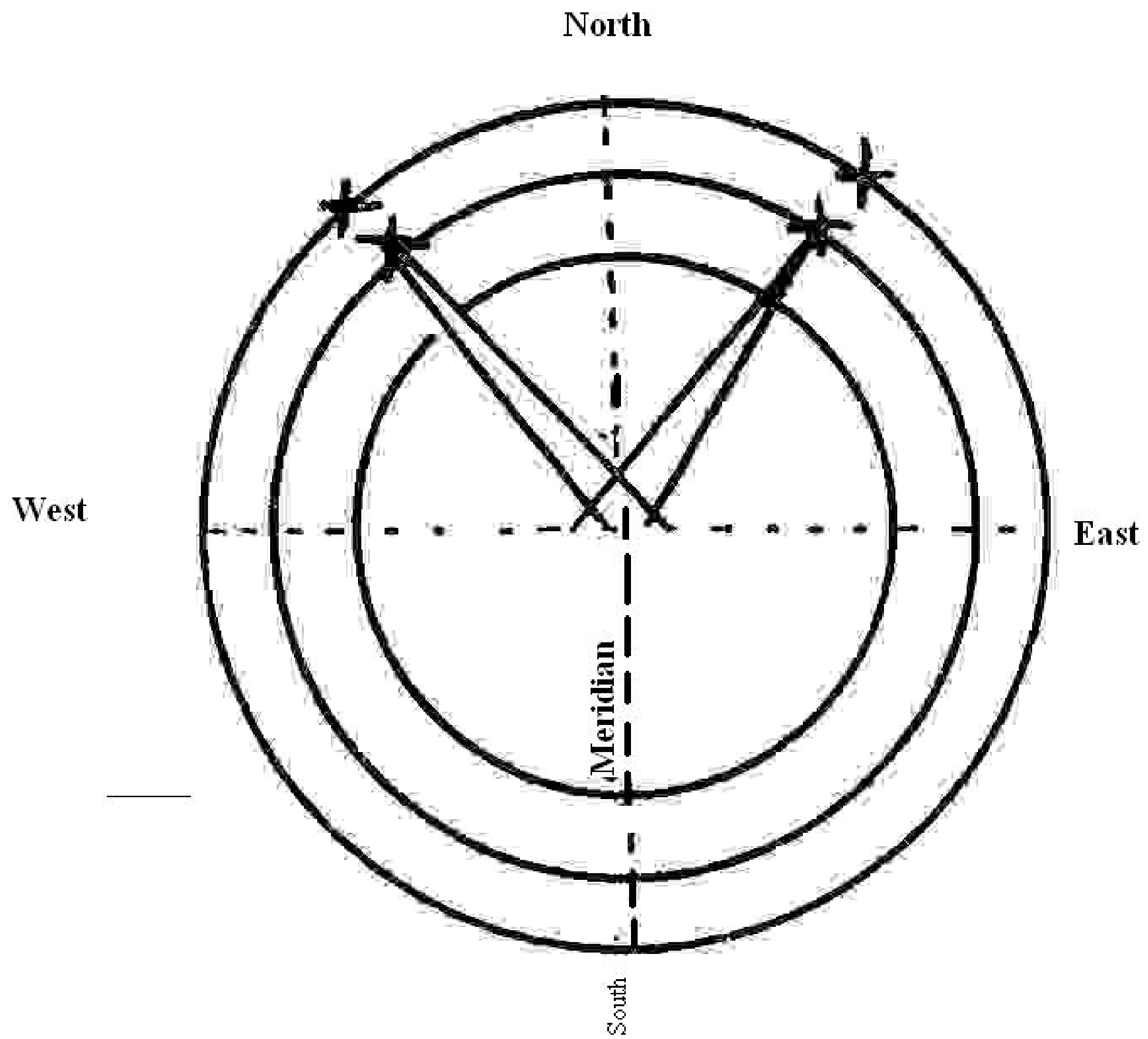
Its construction: we take a wooden or a stone plate, level the upper face, and place it parallel to the horizon. This is done by *fadin* which is a scale of a bricklayer. If this instrument will be used in winter the length of the scale should be 1/4 of the diameter of the largest circle drawn on the plate and if it is going to be used in the summer then the length should be 1/3th[3]. We make a scale with a lathe. This should be in cylindrical form with a pointed top and a round base[4]. If the scale is of copper then its weight is enough but if it is of wood then we make a hole at the centre of the base which is larger at the bottom then at the mouth and fill this hole (not completely) with lead so that when the scale is placed this weight will help to fix the scale (Figure I).



[3] Since the height of the shadow will change according to its presence in the winter or the summer tropics so the height of the scale will get longer or shorter accordingly

[4] The word -MELESE is read like *SULUS* That is why itis translated less than 1/3. P. 26.

Then we draw a small circle [whose diameter is equal to the diameter of the base of the scale] to the centre of the plate; thus, when the scale is placed on the base, their centres coincide and its axis falls perpendicular to the face of the plate. The plate is put parallel to the horizon, when it is fixed to its place with lime or another material, we draw concentric circles so that when the shadow comes and we are unaware, the other one will replace it. When the shadow is not yet inside the circle but on the circumference, the middle of the width of the tip of the shadow is marked on the circumference. The same operation is done with the other circles as well. When the sun passes to the other side of the meridian-this happens when the shadow is the shortest, afterwards it becomes longer-then we follow with our eyes the movement of the shadow when it is at the point of leaving one of the circumferences of the circles marked at the entrance of the shadow. We mark the middle of the width of the shadow before it leaves the circumference. To verify this we repeat the same operation on the other circles. The chord of the arc is divided. After we lift the scale, we connect the centre of the plate with this point by a straight line and extend it at both sides. This straight line is the meridian established in the most precise way. When we drop a perpendicular from the centre to this plane, this is called the east west line (Figure II).



Now, we will mention the instruments we constructed in the Observatory, which is devinely, guarded near the Maragha at the west side hill. These constructions were done in the few years, before 660 (H.) and after 660. (H.)

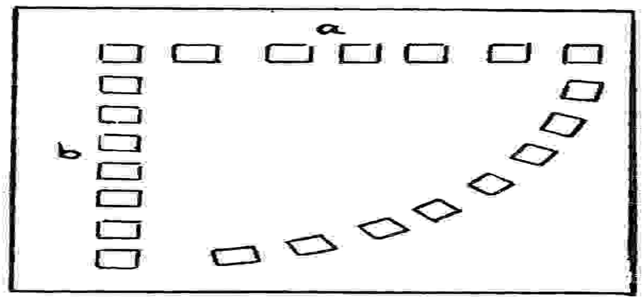
All these were possible with the suggestion of our great leader, the eminent scientist, the perfect investigator, the symbol of the scholars, head of the judges, the most virtuous of not only the savants of Islam but of the entire ancient and the present thinkers. He, who is capable of comprehending all the sciences and the nice behaviour, sound judgement, tenderness, good nature, virtue, of which only one is found in a scientist, is a rare creature of the God who is free from all evil. He gathered all the scientists and strengthened their devotions towards him by donations. He was much more closer to them than a father to his son. We were safe under his protection and happy to see him. As it is said in the poem,

To test him, we vexed him,
But what we found was tenderness in both states.

This rare person, God give him long life, is Nasir al-Din Muhammad ibn al-Tûsî, supporter of the Nation. I heard many things about him before I saw him and I thought these sayings were exaggerated. But when I met him the rumours about him lost their significance. The days, which give us opportunity to work under his leadership, are the most wonderful days. We were away from our children, from our relatives and from our country but we were with him (Al-Tûsî). One who finds him has lost nothing but the one who has lost him loses everything. God should not separate us from him and should let us get as much benefit from his presence.

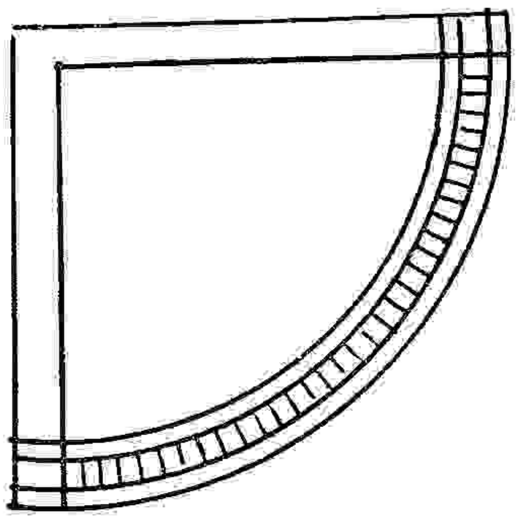
We overtook to construct the instrument called "libne" by Ptolemy. We call it (rub') quadrant.
To construct this we take a wall with a proper width, which is made of brick and lime, parallel to the meridian and which extends from north to south. The height and the length is $6\frac{1}{2}$ of *Hâshimi dhirâ ,* this is the *dhirâ*[5] used in astronomy, and its thickness is one *dhirâ .*

We put wooden-pillows which form an arc up to a span from the surface and which is constructed of wood on the northern surface of the wall. We fix these pillows in equal intervals starting from the southern corner of the wall which is nearer to the base, up to the northern corner of the wall making a quarter of a circle. Besides, we will have other pillows over which the ruler will be fixed to carry the quadrant this will be mentioned in the previous paragraphs (Figure III a, b).

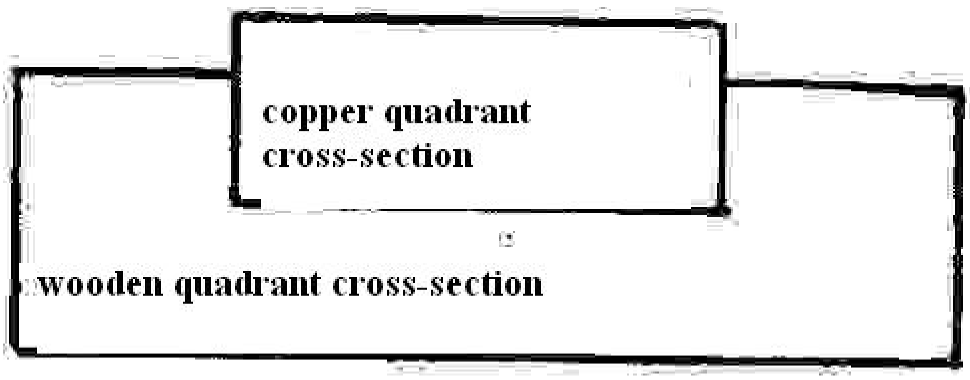


[5] It is missing in the German translation. P. 28.

Afterwards, we make a quadrant from the teak tree[6], which was brought from India, and we fix the ends of this quadrant to the ends of the two rulers which intercept at the centre of the quadrant. The length of the two rulers should not be less than five *dhirấ* (every *dhirâ'* is about three span of a hand). The rulers intercept each other in forming right angles. In order to prevent the bending of the rulers, their thickness is made one fourth of a *dhirâ'.* We construct the quadrant from small sections and fix the ends firmly to the rulers (Figure IV).

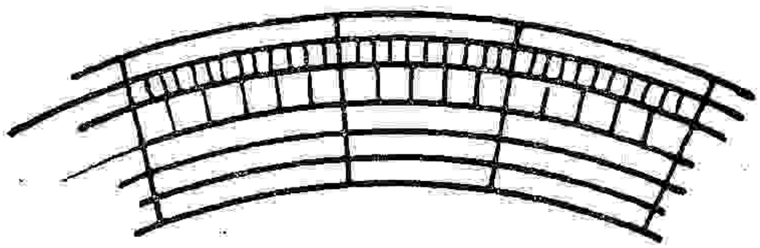


After we make the adjustment very carefully, we open a canal whose depth is half a finger and the width three fingers of hand in the middle of the width. We moulded a quadrant from copper, whose depth, quadrant depth is more than one finger and the width three fingers so that after filing let its dimensions be equal to the dimensions of the canal in the quadrant, exactly in the dimensions we desired it to be. We place the copper quadrant in the wooden canal so that its face will project outwards in respect to the face of the wooden quadrant (Figure V). We fix these two firmly with nails. That is why we file the face of the copper one as much as possible.



[6] It is a big tree, which grows in India. It is like ebony but it is not as dark as it is. Its fruit looks like grape and its leaf is like the leaf of

The vertex of the right angle, formed by the two rulers fixed at the two ends of the wooden quadrant determines the centre of the quadrant. We draw four-quarter circles around the centre, on the surface of the copper quadrant. We extend two strait lines, which intercept each other at the centre up to the end of the copper quadrant. We divide into 90° the band, which is between the two-quarter circles restricted by these two strait lines. Then we divide each one of these degrees into 60 minutes and mark these on the first two outer quarter circles. We divide the bent, which is following the two quadrants into 90 degrees and with it and the ones following it into 18.[7] We start to make divisions of 5° from the north corner of the wall starting from the bottom of the quadrant so that during the observation the height of the culmination will rest outside (to have height of the *zenith)* (Figure VI).



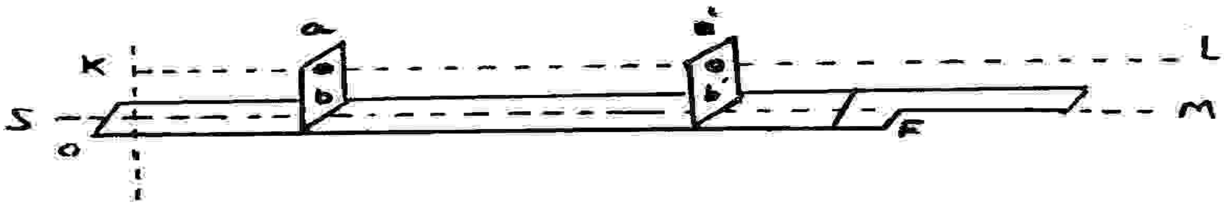
Then we fasten the quadrant and the rulers at the end of the wooden pillows. We place the centre so that it will come over the angle of the upper southern part of the wall. Thus, one of the rulers will be perpendicular and the other one will be parallel to the horizon. Adjust the copper quadrant to the surface of the meridian so that the straight line, which connects the centre and the south end of the quadrant, passes from the zenith. This could be established with the help of the meridian line, which is expelled outside the surface of the horizon with the help of these perpendiculars.[8]

After we establish the necessary position for the instrument, in conformity with the above-mentioned conditions, we fix the instrument on to the pillows firmly with the nails.[9] We make the same thing to the two rulers connected to their ends. We open a hole at the centre of the quadrant so that the centre of the hole and the centre of the quadrant coincide with each other and we fix an iron axis in the form of a cylinder about one finger wide.

Then we construct another ruler from the teak tree whose length is longer than the radius of the quadrant and the cut off section is rectangular. The width of this rectangle is four fingers and its thickness is less than its width. We file it as much as possible. We place copper pieces at their ends, divide the width from the centre, and make a hole at its one end about the size of the diameter of the axis that we have mentioned above. From the other end, we cut off three fingers from the length up to the straight line which connects the centre with the middle of the ruler, to clarify the value of the culmination during its movement over these sections (Figure VII).

Pine-tree. It has white stripes when it is fresh.
[7] This part is different from the German translation. P. 30.
[8] It is missing in the German translation. P. 30.
[9] It is missing in the German translation. P. 35.

The ruler made according to these conditions, the straight line (SM) (Figure VIII) which passes from the centre of the quadrant and the divisions (since the direction of the sun is determined only with the straight line (K L) which connects the holes free from these two points) passes from the centre of the sun. This does not form on the curved ruler only provided when the pinnules (a, a') placed on the surface of the ruler in a raised form should turn towards the centre (o), this should be in such a way that the holes of the pinnules of the ruler (b, b') (with a geometrical precision) should be in the of surface (K L M 0) of the ruler which passes from the centre of the quadrant that is to say the surface (M F) which is determined by the extended surface which is established by the cut end. The interception of the two parallel lines is impossible (in other words they meet in the infinite), that is why one of the straight lines mentioned on the (ruler) with the desired conditions passes as a straight line (S M) through the centre of the quadrant and the cut end which moves over the divisions which evaluates the height of the ruler, and the other one passes through the holes of the pinnules. In this condition, the strait line (K L) which passes through the holes of the pinnules should also pass through the centre (O K) of the axis over which the ruler called *alidade* turns.

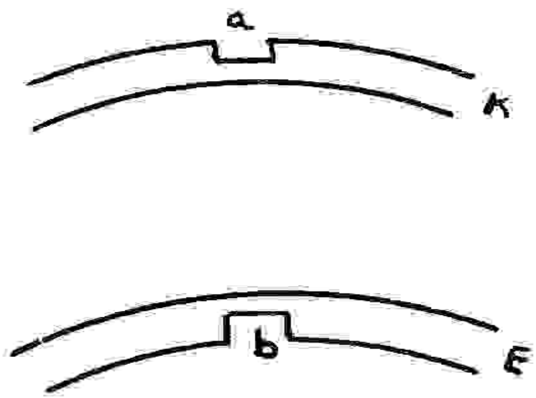


In the case of the construction the ruler of the astrolabe by the astrolabe manufacturers, this production is not done with precision. They do not give much care because in the small instruments small differences are not perceived. But when the instrument gets larger and the division is very small then the differences show themselves clearly and can be perceived easily.

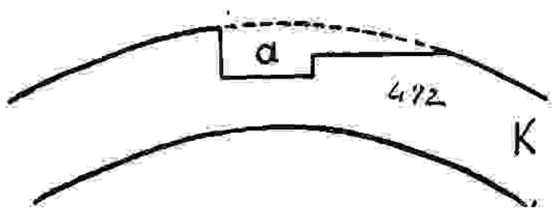
It is necessary to hang a hinge and a hoop at the end of the ruler and a pulley, which moves on the upper part of the wall. There, we have a string strong enough to carry the weight of the ruler, which passes through the pulley and fixed on to the hoop which is at the end of the ruler. The height of the quadrant from its base is about some fractions of a *dhirâʿ.*

One of the instruments we constructed for the guarded Observatory is the armillary sphere *(dhât al-halâk)* with five circles which does not need the ninth circle of Theon of Alexandria and which is not same as the instrument described by Ptolemy as having six circles.

The description of its construction:[10] We make two circles in equal size whose surfaces are parallel to each other and their cut off section in a rectangular form. The radius of each of these circles are three *dhirâ'* according to the observation *dhirâ* and their width and thickness are four fingers. One of these represents the ecliptic circle and the other one represents the polar circle (which passes through four poles).[11] After the termination of the filing of the circle and its division, we make two cavities in the shape of a rectangle at the convex side of the polar circle who face each other and whose depth is equal to the thickness of the circles (Figure IX, K. a). The same way we make two cavities (E, b) in the form of a rectangle at the concave side of the ecliptic circle which face one another. Their depth is one-half of its thickness and their width is equal to the width of the polar circle.



In order to place the ecliptic circle over the polar circle we cut off a section, which will end at the convex side and it, will be a span long with a depth of half of the depth of the cavity, at one of the side of one of the cavities of the polar circle[12] (Figure X).

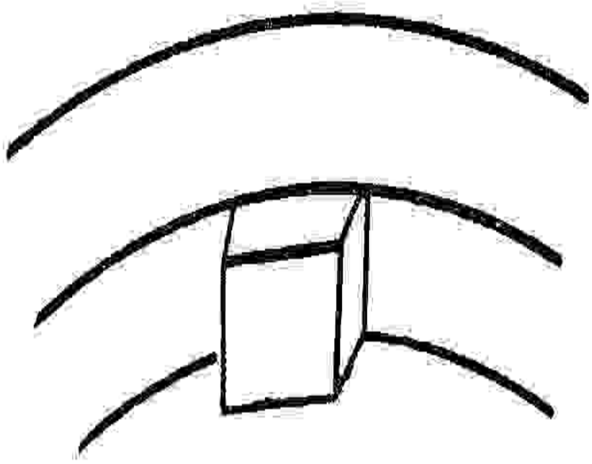


Then they are both placed inside the ecliptic circle in such a way that they form a right angle with each other and their convex sides as well as the concave sides will be on the same spherical surfaces. After a careful filing of the straight and circular surfaces, they are connected to each other. In order to smooth the convex surface, we construct a copper piece having exactly the same dimensions of the segment cut off from the polar circle, we strengthen this by attaching it to the section we want to protect. If the artisan is skilful, he makes the carved section in such a way that it will not need any attaching.

[10] It is missing in the German translation. P. 35.
[11] It is missing in the German translation. P. 35.
[12] A different form is given in the German translation. P. 36.

Then we construct a third circle larger than the others do, which will touch the convex surfaces of the two circles that we have previously constructed. The width of this circle should be equal to the width of the other two circles and its thickness should be one finger smaller than its width.

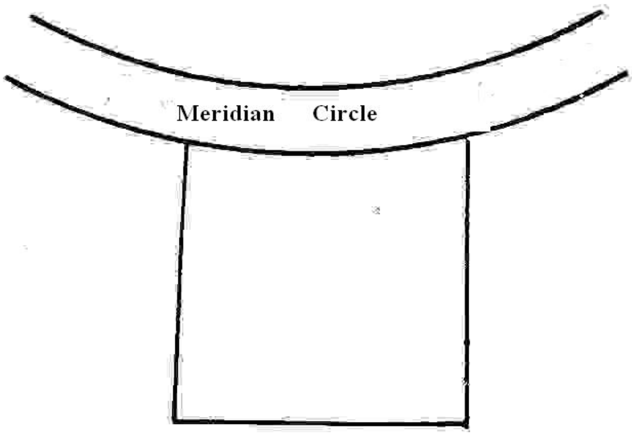
We file it and smooth the roundness of the convex and the concave surfaces. It is necessary and convenient to thicken the width of this circle at each end of one of its diameters, on two opposite surfaces. Their length must[13] be one span and their thickness must be two fingers. We will mention their advantages after we have discussed the filing of the other circles. (Figure XI). This is called the large latitude circle; it rotates on and outside the poles of the ecliptic.



We construct a fourth circle called meridian circle. We place it in such a way that it represents the plane of the meridian. The concave surface of this circle must touch the convex surface of the other circle. Let us make its thickness five fingers. We make one supplusage over the straight surface of the circle, opposite the axis - this is the diameter on which the circles turn -. The length must be three fingers and the height from the straight surface must be one finger. We must have the same supplusages on the opposite side as well. They are useful to strengthen the position of the two holes opened for the poles. On these, we fix two metal axes, which represent the poles of the equator at the armillary sphere and at the places where the circles turn, when our instrument is completed.

For this large circle, we make a base whose thickness is equal to the thickness of the circle, the width and the length is half a *dhirâ* (Figure XII). The function of this base, as is mentioned below, is to fix strongly this section of the instrument on top of the column.[14] We smooth by filing the surfaces, convex and the concave sections.

[13] In the manuscript, though the word is used for *zûl* in German translation it is translated as thickness. P. 36.
[14] In the German translation, the part translated as: "As will be explained below, the middle of the base is placed over a column" is the result of reading the word *nasb* as *nisf.* But this reading cannot be accepted. P. 37.



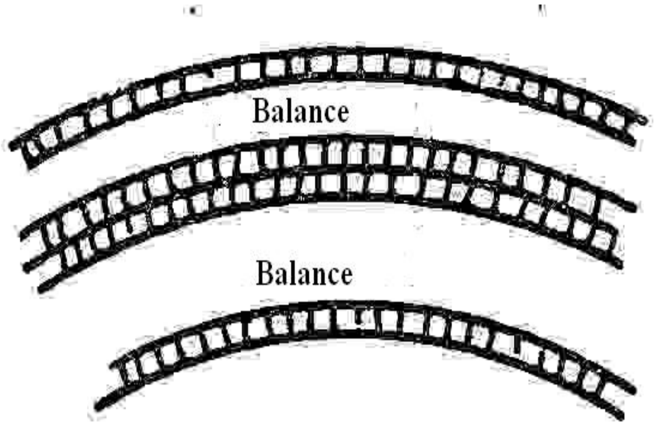
We construct a fifth circle smaller than the first two circles; whose thickness is only two fingers and the width is equal to the width of the first two circles. The convex section of this fifth circle perfectly touches the concave section of the first two circles. Inside this circle, we make a diameter, which is constructed as a single piece with the circle, whose width, and the thickness is equal to the width and the thickness of the circle.[15] We give a circular form to the centre of the diameter, so that the hole we are going to open will not weaken it. This circle is called small latitude circle, which is the smallest of all the circles, because it turns about the poles of the ecliptic. The best thing to do is to start the construction from this circle, because the centre of the diameter of this circle is at the same time the centre of all circles.

When we make the necessary corrections of the small latitude circle, the correction of the concave face of the ecliptic or polar circles becomes easier. When we adjust their convex sections, the correction of the concave face of the larger latitude circle becomes easier; when we adjust the convex section the correction of the concave section of the largest circle (meridian) becomes easier. We place the circles one within the other and in perfect adaptation. These are the small and the large latitude circles, one of the two equal circles and the meridian. We turn them thus one within the other, and change the equal circles. In this way, if we adjust concave and the convex sections with the straight surfaces, then the same way we can adjust the concave section of the circle, which is exactly touching everywhere the convex surface.[16]

When we are through with the correction and the construction then we can start the division. Only three needs to be divided from these, ecliptic, the small latitude circle and the largest circle to say the meridian.

When we come to the division of the ecliptic circle; First of all as mentioned above, we draw its two diameters. We divide into equal ninety degrees each quadrant divided by these diameters, and mark these divided parts over the two sides of the straight surfaces of these quadrants.. We divide into 90° both sides of the convex surface of each quadrant. We write the names of the twelve signs over the ecliptic circle between divided rows of the concave and the convex surfaces. There is no damage in repeating the names of the signs, whereas the names can be useful during the observation (Figure XIII).

[15] In the German translation it is translated as a part is added, both translations are acceptable. P. 38.
[16] It does not correspond with the German translation. P. 39.

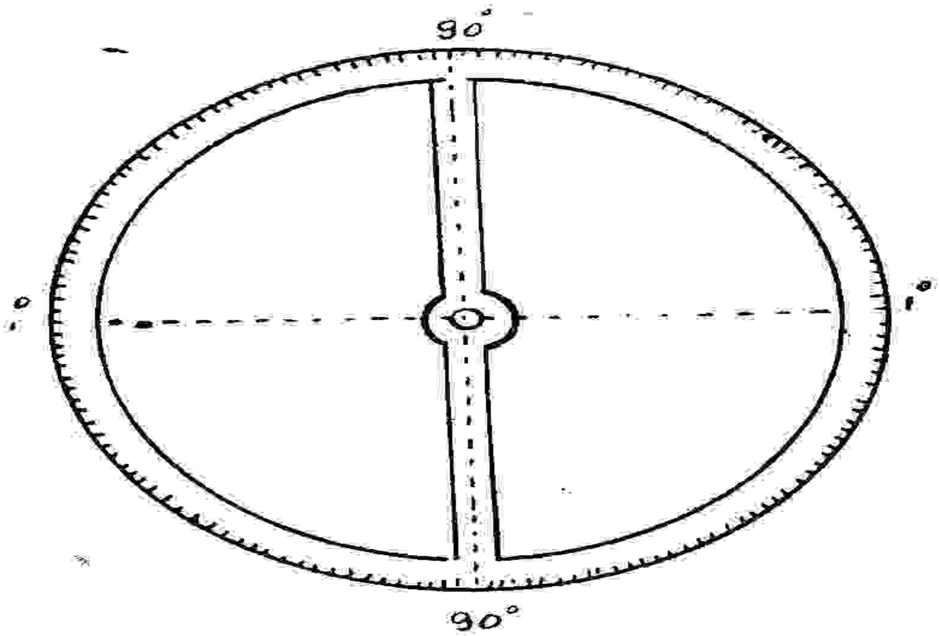


We start to mark down the signs, by writing the head of the Cancer into the middle of one of these holes. And we write the *head* of the Capricorn into the middle of the hole, opposite this one. In a habitual way, we put in order the rest of the signs. We make divisions of thirty degrees and five degrees by the side of each sign (Figure XIV).

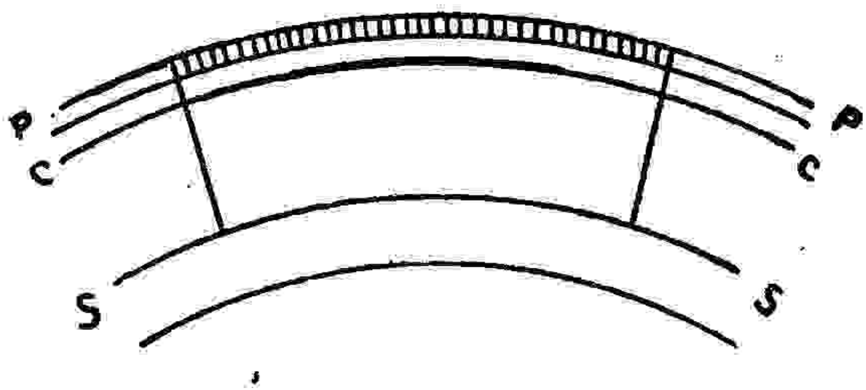
We must not forget the following when we are connecting the ecliptic circle with the polar circle: the middle of the hole into which we write the head of the Cancer must be near the one assigned to the north pole of the equator. The names of the signs will follow one another from the east and it will be written from right to left.

When we come to the division of the small latitude circle, we draw the diameter, which divides the width of the copper diameter into two (Figure XV). Then we take out the diameter which makes right angle at the centre with the first one (b). We divide into 90 degrees[17] the space between the two concentric circles, which are drawn close to each other on one of the straight surfaces. Then we draw a third circle whose distance is three times from the inner circle of the first two circles. We divide each quarter of this circle into 18 and mark this division up to 90, five by five. So that they will terminate with 90 degrees at both sides of the strait line, which divides the width of the copper diameter and starts at both ends of the second diameter.

[17] In the German translation though the transcription has not been followed word by word, they have rested loyal to the meaning. P. 39.



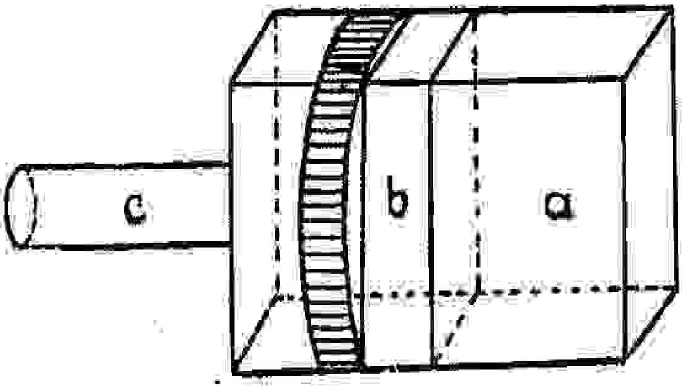
When we come to the division of the meridian circle: we draw the second diameter which forms a right angle with the first (Figure XVI) and divides the base into two and then we draw three concentric circles on the centre over the straight surface. In order to mark the degrees between the two circles (pc) at the concave side, these must be drawn close together. The third largest circle must be placed from the middle circle in an interval equals to three times the space between the two circles (s). We divide quarter of the external circle into 90 degrees and the internal circle into 18 sections. We write the degrees of fives so that it will end at both end of the first diameter at the degrees of nineties. We divide every degree of the external division into smaller sections as possible.



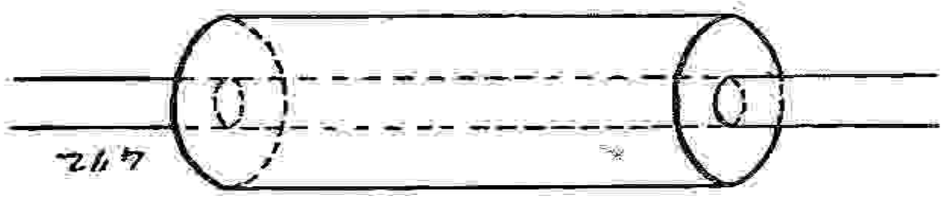
When we come to the axes and their positions this is done, as I will describe it and not at random. This way we will compose the instrument soundly and without any defect.

We must be sure not to have any inaccurate results because of the axis over which the circles turn, during the movement of the ensemble.[18]

We shape one of the two ends which are connected into the meridian circle and which is towards the pole of the universe, in the form of a plate. The width of this section is three fingers,[19] and the thickness is about one finger. (Figure XVI, a). The section which enters the holes of the large latitude circle and whose thickness is equal to the thickness of this circle is in a form of a plate (b). To reinforce it, we shape it in such a way that its cut off section becomes circular and its middle becomes thicker. And the rest will be in a shape like cylinder (c), and its length will be equal to the thickness of the polar circle and its thickness will be equal to the size of the small finger. The polar circle and the other circles inside it turn around this section. Its middle (of the geometric axis) divides the plate into two equal parts.[20]



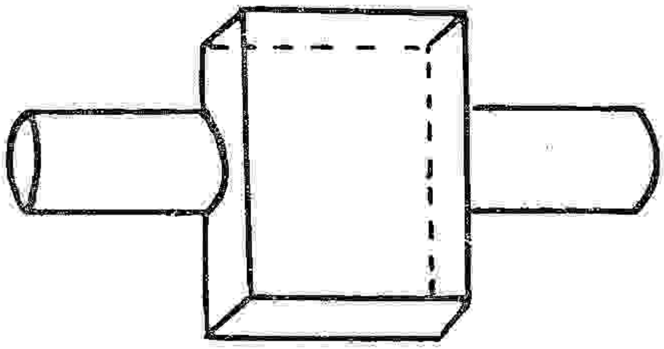
The axis opposite this one is in a form of *A.* cylinder whose thickness is one finger[21] and the length twelve fingers. We cover the external part of this axis with a strong metal whose interior is open from one end to the other. This is placed in the middle of the axis, between the polar circle and the meridian circle so that it can carry the weight of the circle (Figure XVIII). In this way the circle does not fall down. The height of this metal part must be equal to the thickness of the large latitude circle. This is a support between the meridian circle and the polar circle.



When we come to the axes of the two latitude circles: these are at the same time the poles of the ecliptic. The cut off section of the middle part of the upper axis is in square form and the length of this section is equal to the thickness of the polar circle. The remaining upper and lower sections are in cylindrical form

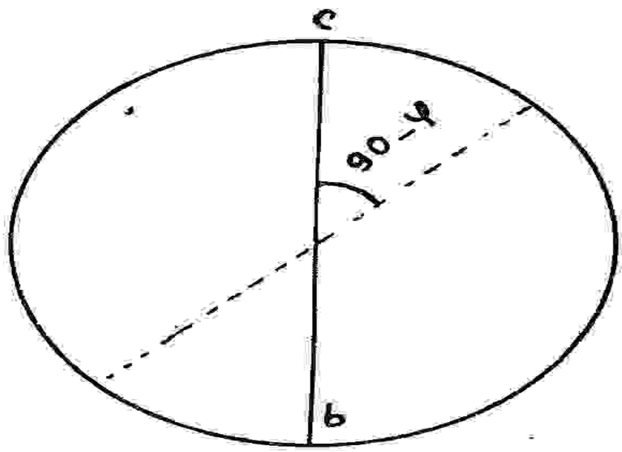
[18] The German translation does not correspond to the manuscript. P. 39.
[19] In German translation, it is 1/3 finger. It is possible to read the word as 1/3th but the word finger which comes after it is in plural so it is not really possible to read it 1/3. Anyway, this is too thin for an axis that carries so many circles. P. 41.
[20] We cannot find the last sentence in the translation. P. 42.
[21] In the translation, it is written as 12 fingers. P. 42.

and, as thick as the latitude circle. (Figure XIX). The large latitude circle turns around the upper and the small latitude circle turns around the lower part.



The lower one is in a shape of a cylinder. The length of the two axes is eight fingers[22] and their thickness is one finger. This length is equal to the sum of the thickness of the two latitude circles with the polar circle.

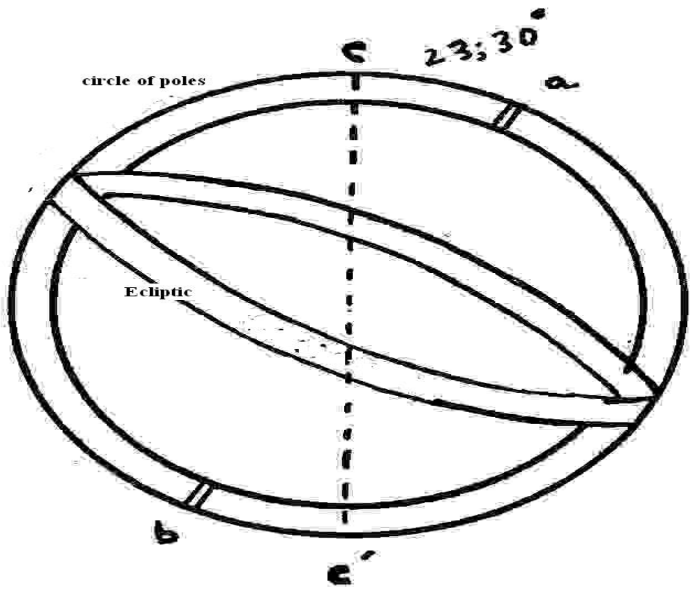
In the case of the holes, we opened in the circles for these axes: the upper one of the meridian circle is in the middle of the convex section of the circle, in a rectangular form, and its length is equal to the length of the pole in a plate form mentioned above. The distance of the middle of this hole (Figure XX), [the centre of the base, (b),] to the zenith, the diametrically opposite, must be equal to the complement of the latitude established by the observation. The complement of the latitude for Maragha is 52; 40°. That is why we constructed this instrument first. Because it is possible to find the distance between poles of the equator and the ecliptic, also the latitude of the place. The end of the plate can be pasted in its place by heating the circle.[23]



[22] Since the addition of the thickness of the three circles is 9 fingers, this must be nine also. In the German translation, it is 9 but no explanation is given below. P. 42.
[23] We cannot find this in the German translation. P. 43.

The hole facing this is round as the shape of the axis.

We make two holes on the polar circle, at the sections facing each other. Their centres are in the middle of the width of the convex section, and the distance of each from the middle of the ecliptic circle is equal to one forth of the polar circle. The hole at the north (Figure XXI, a) is in the shape of a square whose side is equal to the cut off section of the middle part of the axis. The hole facing this is as wide as the axis (b). As regards to the holes we made on this circle for the poles of the equator around which the whole instrument turns, the distance of the north of these (c) to the distance of the northern pole of the ecliptic (a) is equal to the greatest obliquity. At the end of the observations, we conducted in Maragha and in other observatories; we found its value as 23; 30°.

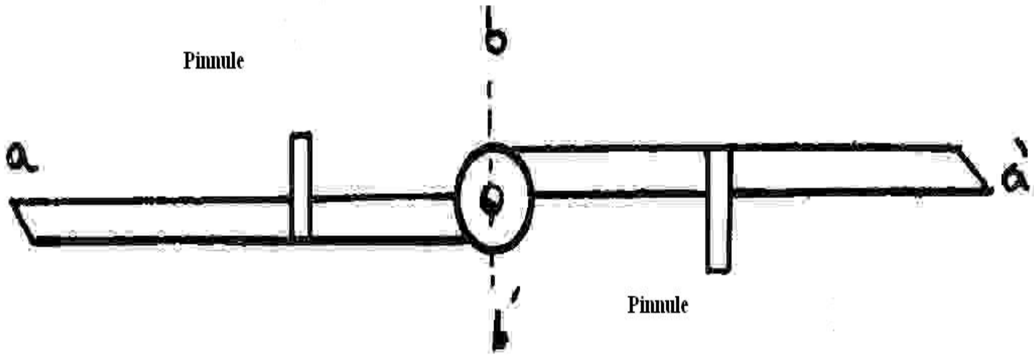


In the middle of the convex section of the polar circle, we put two marks whose distance to the eclectic poles is 23; 30° on the sections facing each other .The construction becomes easier by the help of the parts of the convex section of the ecliptic circle, which is equal to our circle. We name the one between the ecliptic pole and the head of the Cancer the North Pole. The South Pole faces the North Pole. We open two holes as large as the width of the ends of the axis mentioned above, and take these points as centres.

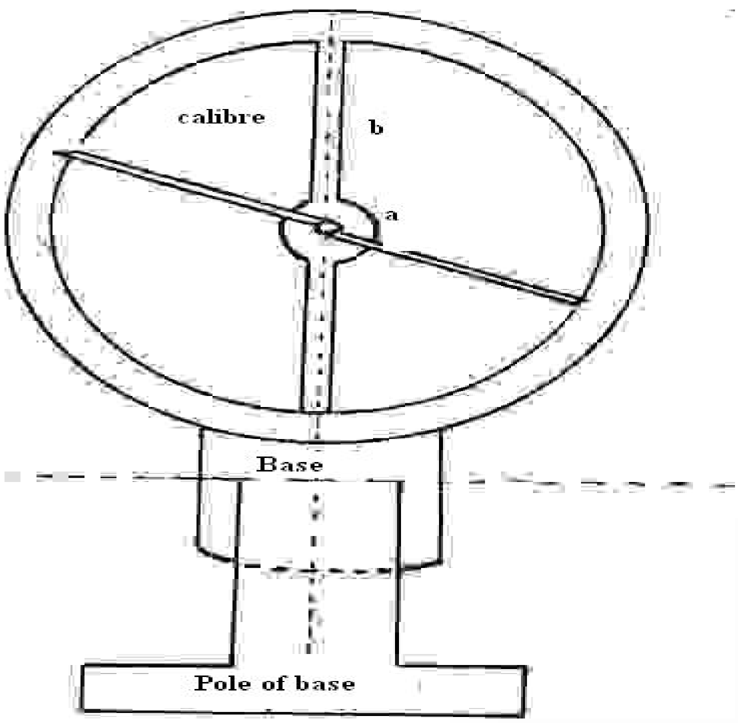
We make two holes (circular) on the large latitude circle at the ends of the axis which represent the poles of the ecliptic and which project to the middle of the width from each side of the polar circle.

In regards to the small latitude circle, we open two circular holes on the convex section from both ends of the "second" diameter which is perpendicular to the copper diameter. The end of the ecliptic axis which forms a knob inside the polar circle is placed at the end of these.

After we finish the correction and the investigation of all these and complete the five circles, we construct a ruler whose length is as long as the small latitude circle and the width is equal to the width of the copper diameter (Figure XXII). We pierce the centre of this circle and shape as a circle the middle of its length. We pierce the centre of the circle at the middle of the copper diameter which is at the same time the centre of all the circles, and fix the ruler with a pivot to the centre of the diameter as is done always. Sometimes we cut off parts limited by the straight line (b b') which passes from the centre, and the line dividing the width (a a') of the ruler from opposite directions. The ends of the ruler become in opposite directions. Then over it we make two pinnules which have covers equal to each other and they have the shape of a square. We pierce the middle of their widths and fix covers over them. The distance between the two holes is a span.



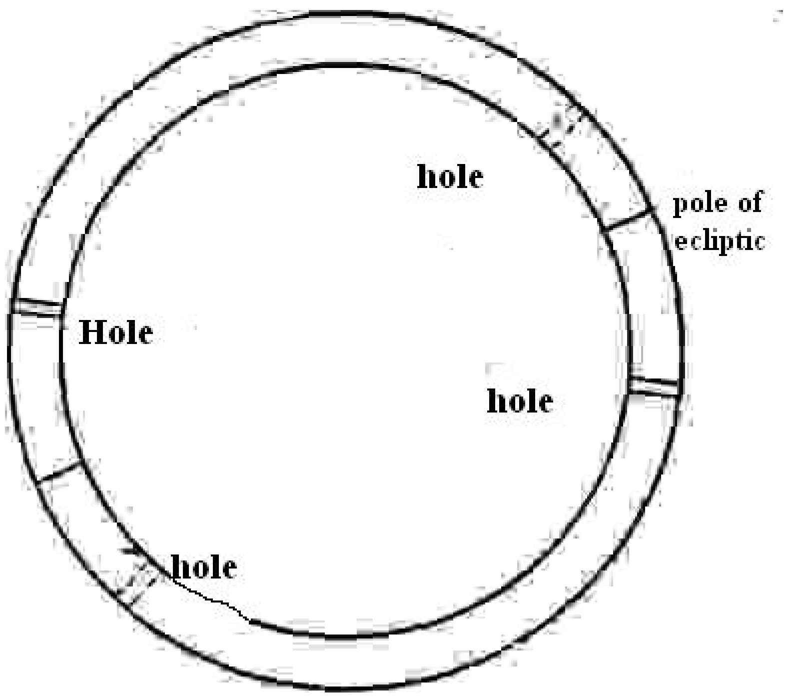
We place a stone column (c) over the foundation constructed for this instrument. We draw the meridian line on the upper section, and construct a canal at this place from north to south in a rectangular form. To this canal, we fix the base of the meridian circle, the largest of all. We make it parallel to the meridian plane by adjusting it with the help of the plumb. We arrange it in such a way that the straight line which connects the zenith with the centre of the base over the circle, forms a right angle (Figure XXVIII, ZT MM). We make these adjustments by leaning the instrument towards different directions accordingly, and by using plumb - line. After the instrument takes the desired form, we pore lead to fill up the empty parts on both sides of the base and to this canal as well. Then we place the rest of the circles inside the meridian circle and the axes prepared for them. We fix the other poles to their places, attach the metal part in its place so that it will carry the weight of the polar circle, and place the two latitude circles over the ecliptic poles. Thus, the parts of the instrument are put together and the instrument is placed firmly on its base.



The additions that should be made to perfect (even more then is done up to know) the instrument will be mentioned herein. I will draw the pictures of the circles and the axes and explain their advantages.

In regards to the additions over the meridian circle and on the sides of the holes made for the opposite two axes, these are added to reinforce the holes for the axis.

The inverse corresponding additions of the large latitude circle are for the two holes, which are opened over the large latitude circle so that the axis of the equator will be able to enter. These (the two axes of the equator) cross from the meridian circles to the polar circles, and that is why they prevent the fitting of the large latitude circle to the polar circle and obstruct it from making half a tour. As a result of this, the coinciding of the large latitude circle over the plane of the ecliptic circle is not completed and consequently we made additions and holes at these places.[24] (Figure XXIII).



The additions on the face of the circles, at the sides of the poles are made only to protect these from breaking.

In regards to ruler, this does not necessitate the sixth circle placed inside the fifth circle by Ptolemy in order to obtain the latitudes of the stars. However, we obtain the latitudes of the stars with a ruler and its two pinnules. Now we are going to explain the error and the insufficiency of the sixth circle, these errors are not found in the rulers. The construction and the utilization of the ruler are easier than the sixth circle. It is necessary that the sixth circle should turn inside the fifth circle and their surfaces should stay on the same plane. That is why; we need clutches to prevent the overlapping of the surface of the sixth circle from the fifth circle. These impediments are done in two ways: one of these is to open a canal surrounding the middle of the convex surface of the sixth circle and to fix some nails, which will pass through the concave surface of the fifth circle and enter into the opened canal.

[24] In the translation, this part is summarised. P. 46.

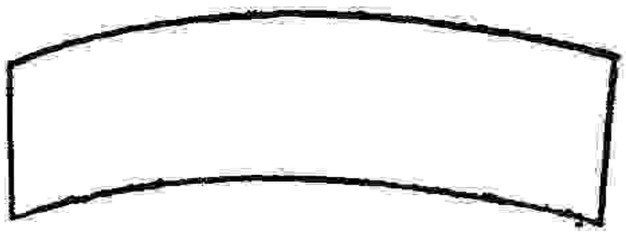
As we come to the second of these impediments: we fix some clutches on the two straight surfaces of the sixth circle, which will project from the surface of the fifth circle, to prevent the projection of the sixth circle from the surface of the fifth circle. We cannot fix these clutches on the fifth circle. If the clutches are on the fifth circle, it will prevent the movement of the sixth circle because the tracer, which shows the division, moves on the surface of this circle.[25] If the fifth one is closely contacted with the sixth one, it will be difficult for the observer to move the instrument because of its great size. But if they are not in perfect connection, the sixth circle will fall down because of its weight and its centre will not correspond to the centre of the fifth circle.

Another disadvantage is the following: when the instrument gets larger, the distance between the two pinnules increases as well so that the observer cannot seethe star through the holes of the pinnules. To construct a straight pipe, which connects these two, will be very difficult. If the light, which penetrates from one to the other, is used, the light will get shady and dispersed and its verification will be very difficult.

If the instrument is small then it is not sound and is not useful. Whereas, when we replace it with ruler, it is very easy to place the pinnules on the ruler and nothing will obstruct of our doing so. In this way, we make use of the centre of the fifth circle and its fixed position. On the other hand, we will presume that the circles meet at one centre when we have an instrument without ruler to fix this centre. That is why in the construction of the instrument, the need for this centre is immense, but to fix and to make use of this common centre is impossible.

To file and to make corrections on surfaces of the circles is not an easy job. I constructed some levelling instruments to make the necessary corrections of the circles.

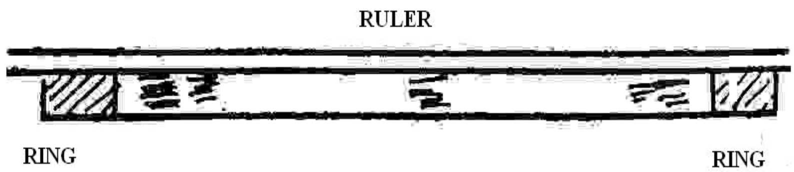
We construct strong plates from copper whose width is three fingers after the filing and the length half a *dhirâ.* We draw an arc on one of the sides of these with a diameter equal to the diameter of the concave surface of the first circle, which needs correction. We file the section outside the arc. Then we draw an arc, which coincides, to the circumference of the convex surface of the circle and file the section included in the concave section of the arc. This way we have convex surface on one side of the plate and a concave surface on the other side (Figure XXIV)[26]. We correct the convex surfaces of the circle with the concave side of the plate and vice versa. When the concave and the convex surfaces of the circles are not equal, we make a new plate for each.



[25] It is like this in Ptolemy, *Almagest,* Book 5, P. 166, The Great *Books of the Western World.* Vol. 16. Seeman explains the form it takes when the conditions in the Book of Ptolemy is not present. P. 46.

[26] One can be contented with one plate since the concave of every circle is equal to the convex of every other circle. This is missing in the German translation. P. 47.

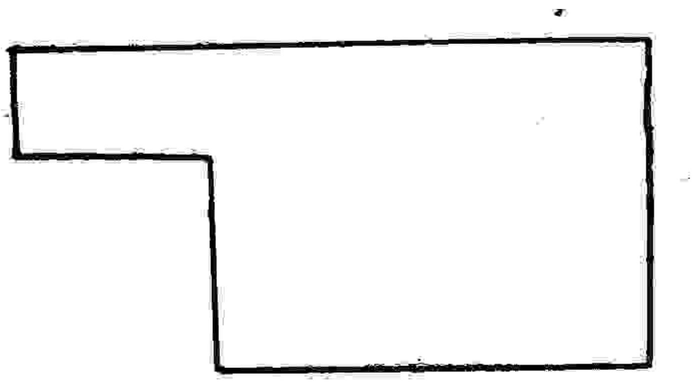
As we come to the straight surfaces of the circles: we construct two rulers. One of them is longer than the diameter of the greatest circle and the other is in three spans. To understand whether the surfaces of the circle are smooth the first ruler is put on each division. If the ruler coincides inner and the outer borders of circle this part is levelled (Figure 25)



If the middle part of the circle lifts the ruler then we see light at the outside and the inside of the circle. The higher part is cut off with a file. If the light is seen from the inside we take two outside borders, on the contrary if it is seen from the outside then we take two inner borders.

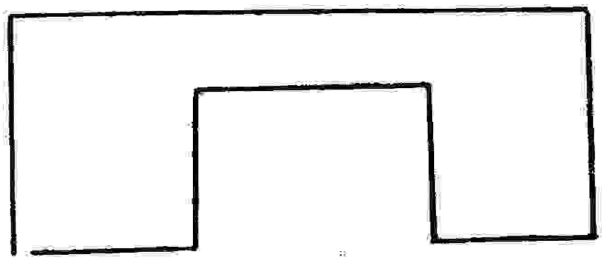
In regards to the small ruler, this can be placed on every part of the circle successively, and the section where its face touches the circle is smooth. If the light is seen through the two ends of the ruler, the middle is bulged. We remove the excess parts with a file until the surfaces coincide with each other.

We take a short plate and make a hole in the shape of a right angle in one of its corners (its depth will be equal to the width of the circle). With this, we correct the circle from the convex and the concave sections. And again with it we learn the position of the four corners, whether the two inner circles are equal to each other and the centres of these two circles are found at the axis of the arc. The position of the two other circles is established in the same way (Figure XXVI).[27]



We take another plate and over it we open a rectangular hole. With it, we measure the widths of all the circles. We circle it ones around the inner circumference and ones around the outer circumference. In this situation, one side whirls around one of the straight surface and the other whirls around the other straight surface. (Figure XXVII).

[27] This part is not literally translated in the German translation P. 48.



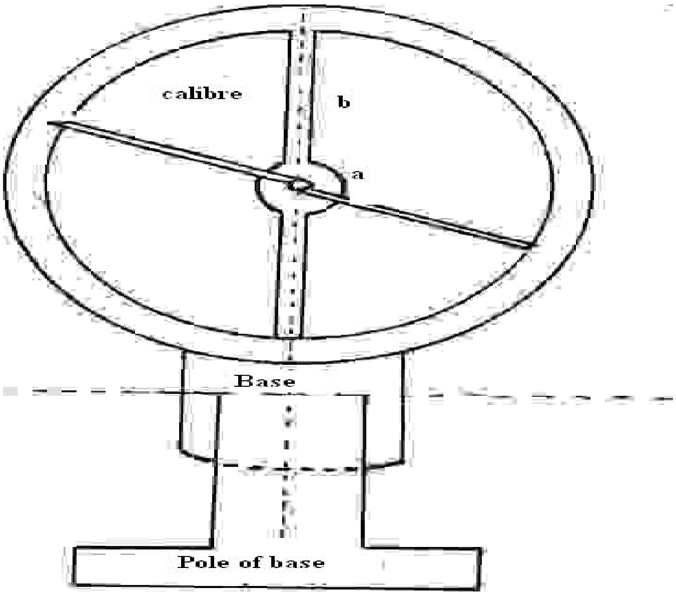
With it we find out whether the width of the circle is proportional.

If we want to improve the precision of the correction of the surfaces of the circles to a limit, we bring the surface of the circles over a smooth place, from every side, (as much as possible), into a horizontal position by an instrument called Fadin. We take from the mud that is used for making pots, inside it; we make a canal, which will encircle the concave side. The base of the canal will be lower than its surface and its inner border is higher than the surface of the circle. We fill the canal with water in a place or at a time so that the water will not undulate. We pour over the surface of the water the powdered ashes of the plants. We control the parts where the level of the water is lower than the surface of the circle and file the higher parts so that the water overflows from every part, the same way. The other circles are also filed accordingly.

One of the old instruments to measure the obliquity of the ecliptic is a circle, which is fixed on the surface of the meridian. The largest inclination of the ecliptic to the equator is brought forward with this circle. It must be large so that it can be divided into small sections of three, two, or one minute.

Ptolemy has mentioned this in his Almagest. He has placed another circle inside it, which moves towards south and north, and its surface stays inside the surfaces of the first two circles. He has constructed two pinnules over one of the surfaces of the circle across the diameter, and he has placed at their centres two indicators, which moves over the surface of the first circle. With it, we find the altitude of the sun and the stars when they are in the meridian. From the inner circle, we get only the up and down movement of the indicators and the pinnules over the divisions. The same kind of corrections made on the sixth circle of armillary sphere is mentioned in here also. In this instrument, we make a circle whose width and the thicknesses are four *dhirâ* and the diameter five *dhirâ*. We construct a diameter casted of a single piece whose width is three spans as we have done in the fifth circle of the armillary sphere.

We make a base in the shape of the base of the meridian circle of the armillary sphere as is described above. The constructed diameter (Figure XXVIII) (a) extends between the centre of the base and the section opposite its diameter (b) and when the instrument is set upright then it caries the weight of the circle.



We construct a ruler for it as we have made for the fifth circle. The circumference of the circle is divided into 360 degrees and every degree is divided into possible smaller sections. When the diameter of the smallest circle drawn on its face is five *dhirâ* then the circumference of the largest of these circles does not become less than $16\frac{2}{3}$ *dhirâ.* And half of the 1/8 of this, (this is more then three spans), corresponds to the 22; 30° over the circumference of the largest circle and every degree will be larger then one finger of *dhirâ.*[28] Every one of them can be divided 60 or 30 sections, distinctly separated from each other.

We draw from the centre, the diameter that divides the base into two and cuts through the entire length of the copper diameter. When the instrument, is placed upright, this diameter passes from the zenith. After the division is completed, we regulate the commencement of the division as 90 degrees in the end of the diameter, which passes through the zenith.

We construct two pinnules whose height and width are equal to each other over the ruler. The straight line, which passes through the centre of the circle, which is at the same time the centre of the ruler, divides the widths of every pinnule from the middle and we open two round holes, which are in equal distance over the upper surface of the ruler. The straight line which passes through their centres (which divides the ruler from its middle), is parallel to the straight line which passes from the common centre of the circle and the ruler. We construct a straight pipe. We connect these two holes with it in such a way that the eye's radiations will be able to pass from one of the holes, cross the pipe and will go out from the other hole. Whether this is a radiation or any other thing will not make any difference.[29] We know the degree of the height from the indicator of the ruler, which is towards us.

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[28] This part does not correspond with the German translation. P. 55. In the notes also it is being marked as wrong. Note 7. P. 57.
ş = 12 fingers f = 11 fingers

32 $\frac{2X32}{3X16}P = 32\frac{4}{3} = 33\frac{1}{3}\ \frac{> f}{< ş}$

[29] During the ᶜUrdî's time the sight was explained by rays which are projected from the eye according to some optical sand geometrical laws. But there were also people who did not believe this. ᶜUrdî in here must have pointed out this. He must have mentioned the rays,

This instrument has other advantages. This is to find the latitude of the place of the observation in regards to the altitude of the circumpolar stars. This star is found on the surface of the instrument during the upper and the lower culmination, half of the sum of these two is equal to the height of the pole. And this is equal to the latitude of that country.

In regards to its fixation on its base and the problem of establishing a certain way in its orientation, this is done exactly as it is done in the circle of the meridian circle of the armillary sphere.

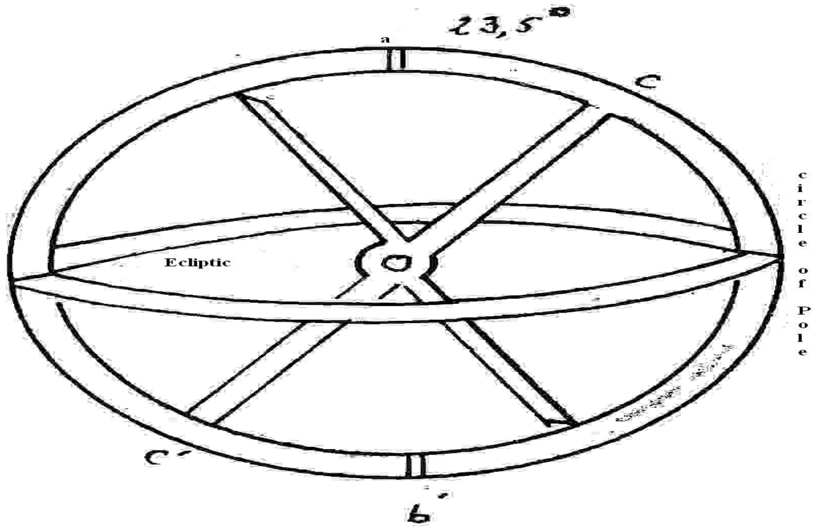
The fourth one is an instrument used by the ancients, and which is named by Ptolemy in his Almagest as equatorial armillary, which informs us that the sun has reached the equinoxes and which represents the plane of the equator. This is a copper circle having four perpendicular surfaces. Its construction and its control are like the construction and the control of the armillary sphere.

In regards to its setting up, this is done after the determination of the latitude of the place of the observatory. The latitude of the place gives us the distance of the equator to zenith, which is to say of the surface of the circle; from here we can find out the inclination of the equator in regards to the surface of the horizon. When the circle is placed according to our purposes, the parallel surfaces of the circle will be parallel to the plane of the equator.
When one of the sides shadows the other, the both concave sections will be lighted in equal degrees and at this moment, the sun will be at one of the equinoxes.

When this instrument is placed over the horizons that have latitudes (besides the equator), we have to give some inclination to the circle. That is why the position of the instrument will be disturbed because of this inclination and at the same time to place, the instrument will not be easy.

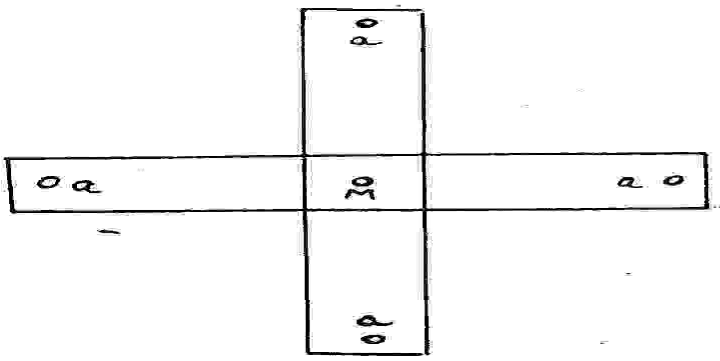
When we come to its mounting, as it should be done properly, I described this operation. According to me, it is necessary to use a meridian circle instead of an inside circle and fix the previous on this meridian circle. The connection of this circle should make a right angle with the meridian as we have done with the circles of ecliptic and poles. The distance of the middle of the hole (Figure XXIX) at the place of the connection of the equator circle with the zenith must be equal to the latitude of the place of the observatory. At the places where there are these holes, we make some additions to protect them. The meridian circle carries its weight and prevents the upset of its position. If we place this circle inside the meridian circle, we construct the latter lighter and larger than the concave section of the meridian circle. We thicken the convex section of the meridian circle (the carrier of the other circle) because of the two holes. We make the division of the meridian inside the concave section so that the circle of the equator can be placed over the end of the ruler. All these are very clear. In this condition, it is placed on the surface of the equator. It is easy to control its inclination, and the setting is not difficult at all. Its inclination can be measured with the help of the meridian circle.

which were projected from the objects.

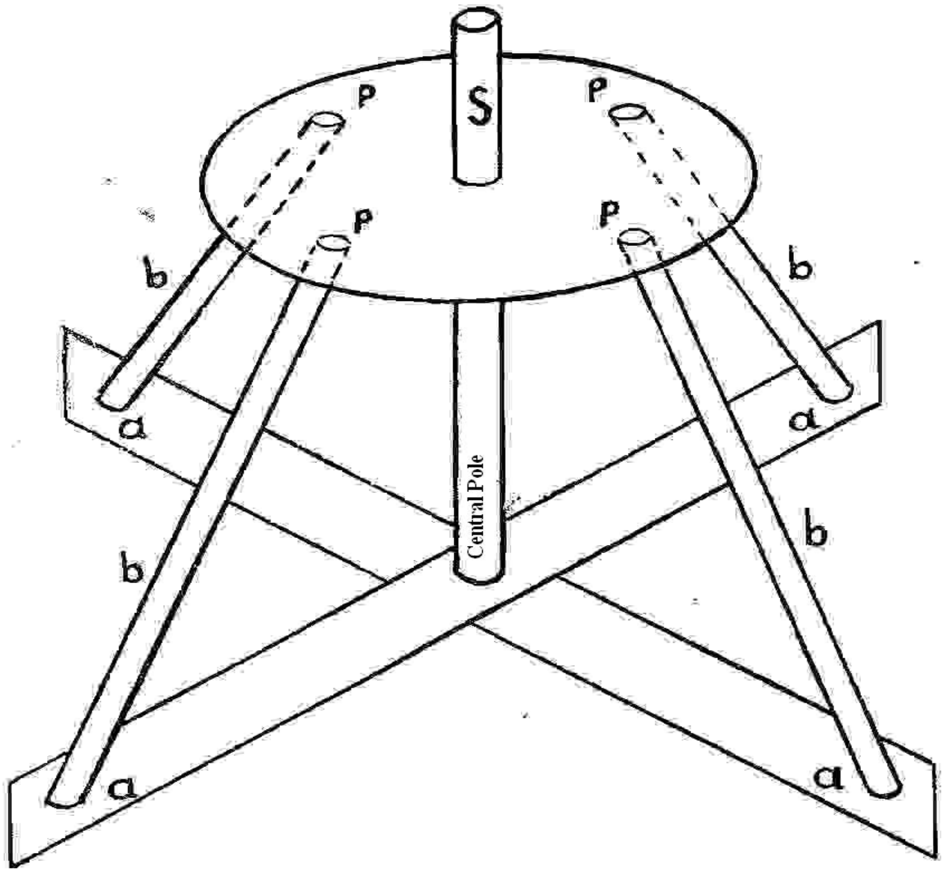


If we use one inclined circle then the error, which is seen in one of the largest circles mounted in the Porch of Alexendria as is mentioned by Ptolemy, will produce itself. This circle was lighted twice in one equinox. One of the old instruments called dioptra known with two pinnules possesses a mobile pinnule, Ptolemy in his Almagest mentioned its name only, and did not describe it.

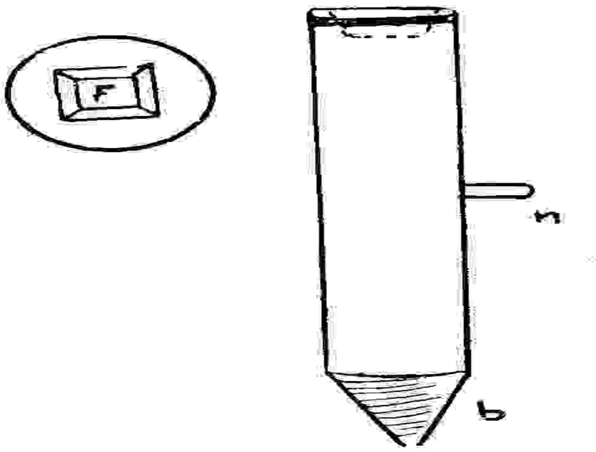
We start by constructing a base, which will carry the instrument and hold the axis which will help to turn it. Its shape: we make a base from two wooden pieces in the form of rectangles whose length is four *dhirâ* and who intercept each other at right angles (Figure XXX).



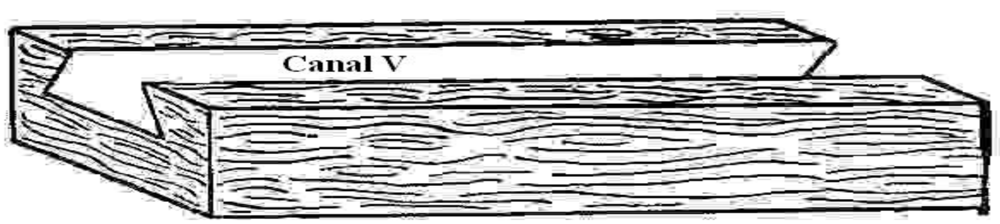
We mark the centre of their intercepting surfaces so that it will perform the duty of a mutual centre (m). We open holes (b) at each end of the wooden pieces (a). And on these holes we fix four columns leaning to the central column (Figure XXXI, s). The other end of the columns encounter a strong circle whose height is two *dhirâ* (from the start of the central column) and whose thickness is 1/4 *dhirâ* and the diameter 2/3 *dhirâ.* These four ends are fixed into the four sockets (p) over the diameters of the circle so that they will support the circle from the sides by their corresponding inclinations. Then we open a hole whose diameter is five fingers by hand on the centre of this circle.



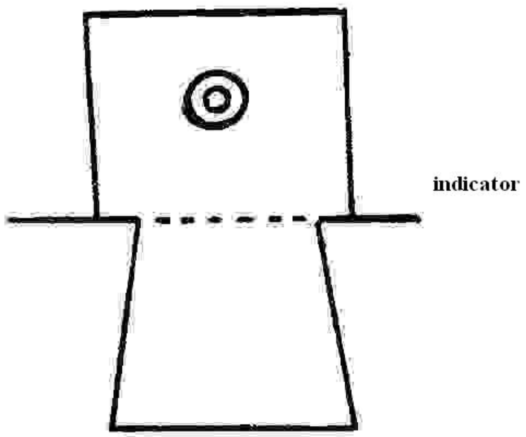
We construct a central column whose thickness is equal to the hole at the centre of the circle and the length is four *dhirâ'* and who is in the form of a cylinder made of wood. At its lower end, let there be an iron pole which turnes on this mentioned centre (Figure XXXII, b). Let there be a hole (F) in a rectangular form, whose bottom is narrower than the upper part and whose depth at the top of the section which is over the base is five fingers towards the length of the central column. We fix a bar at the side of the central column, (n). With this bar, we turn the central column. A metal ring is placed around the top of the central column to reinforce the hole of the central column. This is the description of the base and the central column.



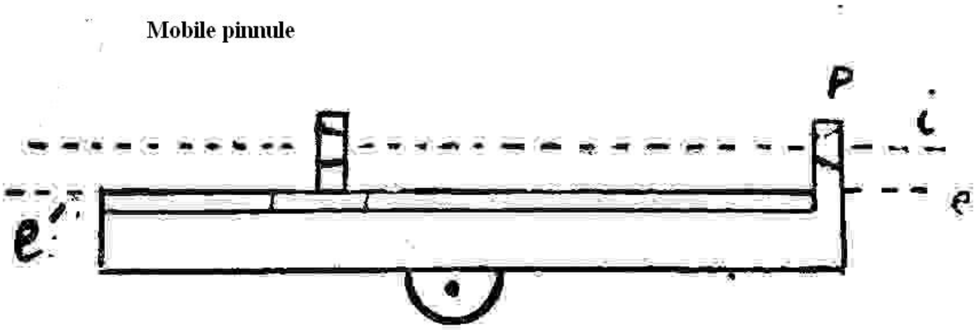
In regards to the ruler with a mobile pinnule, we construct a four-sided ruler from teak tree half a *dhirâ'* in width, and $4\frac{2}{3}$ *dhirâ'* in length and whose surface is in a rectangular form and parallel. At the middle of its width, all along its length, we construct a canal (Figure XXXIII, v) whose depth is half a finger and the width 1/3 of the width of the ruler. We construct the base larger than the upper section and file it in such a way that it will be parallel to the surface of the ruler.



We construct a copper segment whose dimensions are equal to the dimensions of the canal, its width equal to the width of the canal, its thickness is the same in every part, the lower part is wider than the upper part, its depth is equal to the depth of the canal, and its length is one span. This segment fills the canal in such a way that it can move within the canal without vibrating and quite freely. We construct a ruler over one of its ends so that it makes a right angle with the surface. Its width must be one small finger larger than the width of the ruler. So that at its sides, there are the two projections which move at both sides of the canal. Two indicators, which show the divisions, are attached to these (Figure XXXIV). We open a hole in the shape of a truncated cone on the upper part of the pinnules. The larger section of the hole must be turned towards the longer part of the mobile section. And the narrower part must be turned towards the shorter part of the section. The diameter of this narrow hole is half a finger this is mentioned before as of *dhirâ'* finger.



We construct another pinnule at the end, of, the ruler whose width and length is equal to the width and the length of the first one and which is set up in to the canal, we open a narrow hole in it (Figure XXXV, p). The straight line (ii) which passes through the centres of the holes of these two pinnules must be parallel to the straight line (e é) which divides the width of the ruler into two. We construct the part of the narrow hole which turnes towards the end of the ruler, wider then the part, which turns towards the mobile pinnule.[30]



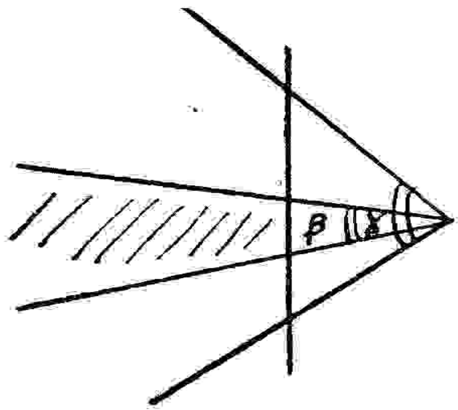
We take two brass circles who have a handle in between them. The diameter of the larger of these is 2 £fold larger than the diameter of the narrow circle, one of the two circles over the mobile pinnule, and the diameter of the smaller one is equal to the diameter of the circle over the mobile pinnule. This is called the diaphragm.

We divide both edges of the ruler on which the two indicators of the mobile pinnule move, in such a way that every section will be equal to the diameter of the narrow circle of the mobile pinnule. The starting point of the division is in front of the surface of the fixed pinnule, which is turned towards the eye, and the end as 220 is at the other end of the ruler. We divide every one of these sections into 12 parts. These represent the diameter - fingers of the sun and the moon. We number them starting from the fixed pinnule and end at 220.

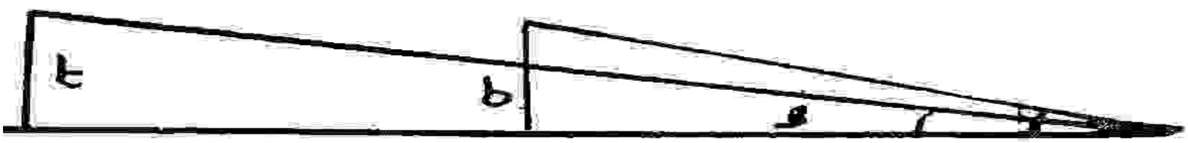
The observer must bring his eyes nearer to the hole of the fixed pinnule when he is using this instrument during the observation because the starting point of the division have to be at the top of the optic cone.

[30] There is no clear example on the direction the narrow part of the mobile pinnule will take after the ruler is placed on the canal.

The apex of this cone is inside the lens. It is because this cone includes a part (which can be observed easily) from the surface of the lens that the object is perceived with the help of this part. When the area cut off by the optic cone from the surface of the lens is really very small, so small that, the objects cannot be perceived with the eye, because the smallness of the apex angle of the optic cone, as a result of the distance between the viewer and the objects (Figure XXXVI).

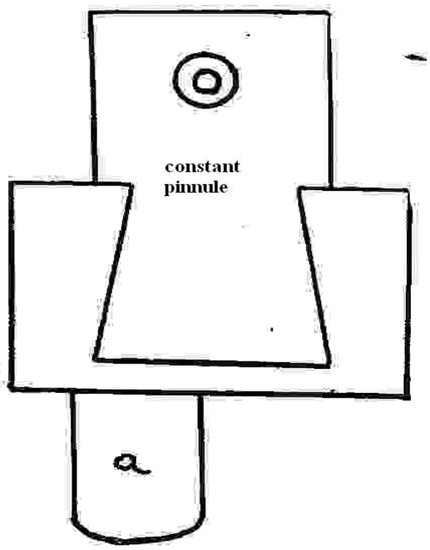


That is why, there are convenient distances for the objects, and these objects can be seen from these distances. There are so many different distances but they cannot be seen from these distances. These limits change according to the strength of the sight. For every object there is a certain distance in proportion to the eye of the observer, if the distance of the object is larger it cannot be seen but when it is nearer, the section cut off by the cone from the surface of the lens will be larger and this way it can be perceived easily (Figure XXXVII).

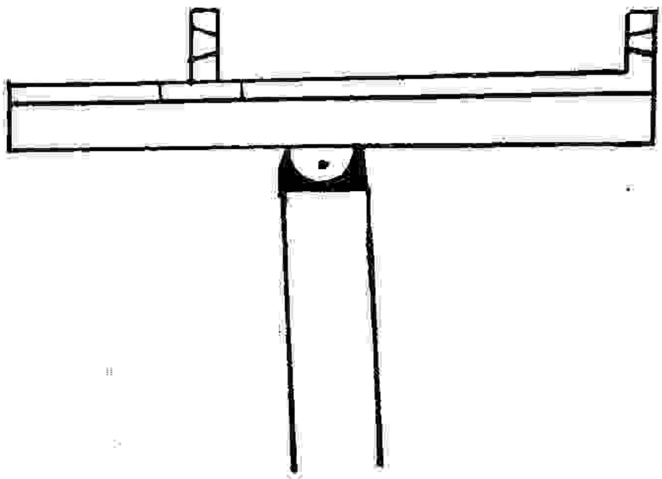


When we have terminated the completion of the instrument with great care, we fix the half of the joint to the middle point of the lower surface of the ruler, that is to say to the middle of the opposite of the surface where the canal and two pinnules are found[31] (Figure XXXVIII a).

[31] The German translation does not correspond with the manuscript. P. 67.



The upper half of the joint turns around the axis which comiacts it to the other half. One of the ends of the ruler on this axis moves upwards towards the zenith while the other end moves downwards. We fix firmly one of the apexes of the joint to the ruler and the other one to the hole over the axis (Figure XXXIX). When we want horizontal movement from the ruler, we turn the central column. When we want up and down movement then we move upward the end of the ruler, which is towards us. We can turn the instrument as much as we want and towards any direction over the axis of the joint.



During the eclipse or any other time, we bring the ruler to the direction of the moon, we keep away the pinnule from the eye once and then bring it forward until we see the whole moon. The hole on the pinnule includes all of it, the moon covers the hole and there is no excess left. We mark the distance between the mobile-pinnule and its indicator with the eye. We do the same thing for the image of the sun. We know at what distance the apparent diameter of the moon is equal to the diameter of the sun. The amount from the divisions of the ruler does not exceed 130.

In regards to the diaphragms,[32] which are mentioned before, if the eclipse is the eclipse of the sun then we use the small circle of the instrument to find the eclipsed area of the surface of the sun. In order to do this measurement, we keep at a distance (marked previously) the mobile-pinnule from the fixed pinnule. At this distance, as we have mentioned before, the hole of the mobile pinnule encircles the sun entirely. Thus, if we turn the ruler towards the sun during the eclipse and if we cover the eclipsed area with the small circle, the quantity of the eclipse will be established. In regards to the eclipse of the moon, we make with the big circle the thing that we have done with the small circle during the eclipse of the sun.

We have divided the diameter of the small circle into 12 parts with the diameter-finger. With the help of these, we can calculate the quantity of the eclipsed part of the diameter of the sun. We divide the diameter of the large circle into 31 $\frac{1}{4}$ parts with the eclipse-finger with these we can find the quantity of the eclipsed part of the diameter of the moon by the help of the section separated by the circle from the divided part.

The writer of the Almagest has mentioned these instruments as being constructed of the Porch in Alexandria. In regards to the *(dhât al-shu'batayn)* triquetrum, we will describe it in detail. We will also mention the ones that we have constructed which are more precise and firm. But again these things are best known by the Great God.

In regards to the instruments whose construction is created by us and whose missing parts are completed, some of these have been put into practice and they are found in the Great Observatory. We constructed the model of some of them. After these, we had other engagements such as: to construct a small mosque, to carry the water in large containers up to the top of the mountain and to construct a house for his Royal Majesty, God protect his supreme being. These were not my job, but your brother was forced to the jobs that he did not like to do. And your brother is not a hero.

There is also another instrument, which is called *(dhât al-rub'ayn)* instrument having two quadrants, which replaces the armillary sphere. We cast a circle from copper whose diameter is as large as it possible could be.

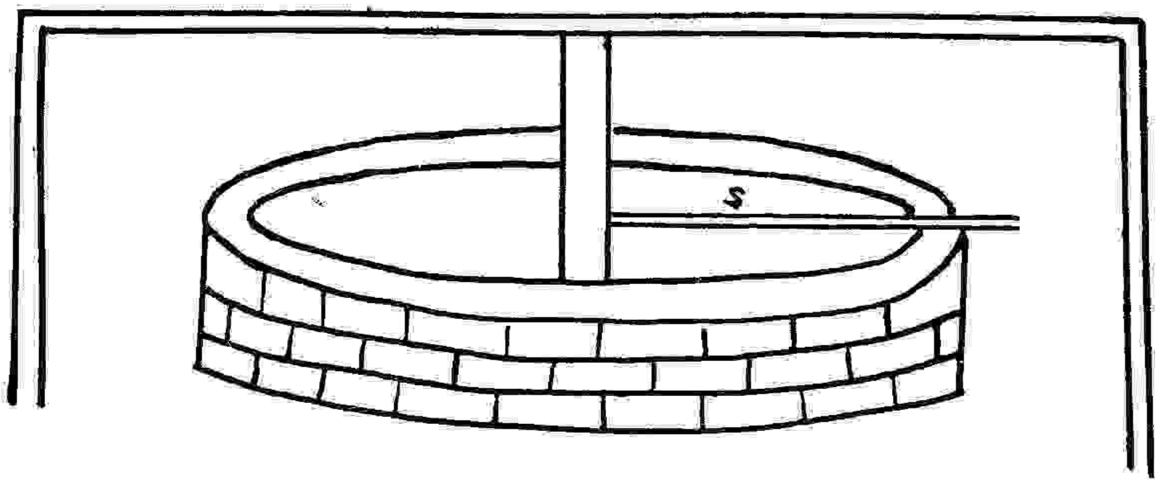
We can cast this circle in segments rather then of a single piece and connect the pieces together afterwards. It is not necessary to make it very thick because it is immobile and is placed on a circular masonry foundation and parallel to the horizon. After we finish its filing, we inter it into a section, which will reinforce it and encircle it from the outside and it will not be higher than its surface.

We take the centre out and correct the convex and the concave surfaces with the help of two concentric circles. When we come to the correction of the surface parallel to the horizon, the best way to do this is the following: after correcting the inside and the outside sections, as it is done in the previous ones, we put it in its place and fix it. We construct a canal, which will include the concave section. The surface of the circle will not be higher than the surface of the canal; on the contrary, it will be one small finger lower. In a calm day, we fill the canal with water and we scatter over the water the plant dust, which has been grinded. We

[32] The forms of the diaphragms are not clearly explained in the manuscript. They could be in form of a divided circles or a hole opened over a plate. When the circle is filled up, it covers the dark section but when it is empty, it covers the lighted section. In the manuscript, this section could have been read both ways.

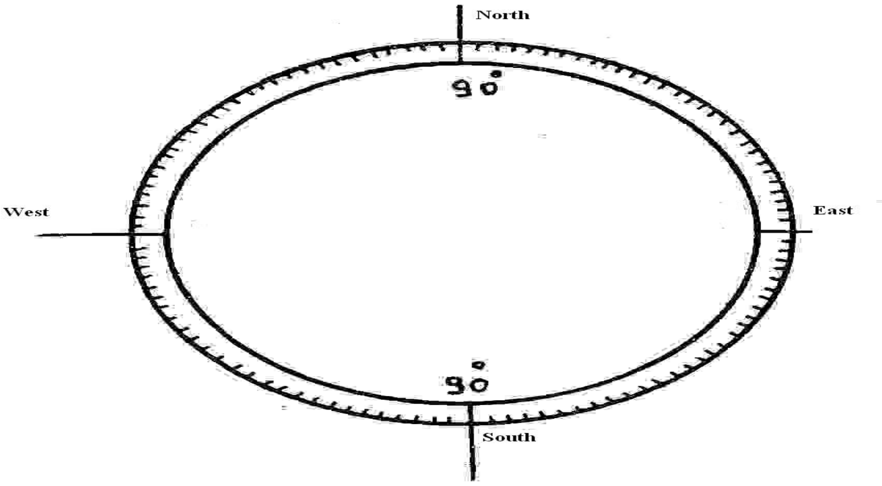
file it so that the water and the plant dust will cover it in equal quantity in every part. We rectified the bottoms of the gutters in Damascus the same way.

It is possible for us to make another levelling instrument in order to rectify its surface. For this, we set up a column at the centre of the horizontal circle and construct a handle, which will hold the column from its top (Figure XL). We set up this column in such a way that the column will not lean when it makes a complete turn; it stays in a perpendicular position, and stays in the same position making a right angle with the surface of the circle. This is easy to' handle. We open a hole at the bottom of the column and we construct a ruler or a thin stick (s) which will be fixed at this hole. Only the end of the ruler will not rest on the surface of the circle, the ruler, as a whole will rest on the column, which carries the ruler. The end of the ruler should barely touch the surface of the circle.



The sections where the ruler is higher than the surface of the circle are lower. The sections where the ruler is contact to the surface of the circle are filed until the ruler will be in equal distance from the surface of the circle or it will be in contact with it the same way all around in the complete tour of the ruler, so that the connection will fulfil the requirements. This way we will accomplish the horizontality and the filing of the surface of the circle. In this case, it will be definitely parallel to the horizon.

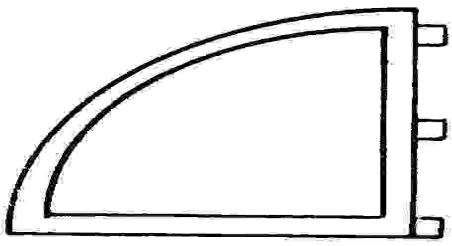
In regards to the division, we take out the meridian line, which passes from the centre dividing the circle into two, and we draw a diameter perpendicular to this, which passes through east and west points. We draw five concentric circles over the surface of the circle. We mark the small divisions between the largest circle and the one following it. The division of the degrees and the ones with five degrees are written in a way that they will start from east and west points and end at 90 degrees in south and north points. We divide the degrees into the smallest portions possible provided that these smallest portions are clear, that is to say the lines to mark these divisions do not intercept each other (Figure XLI).



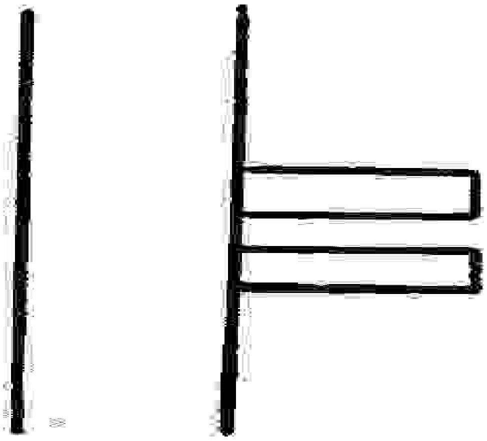
We construct two quadrants equal to each other from copper. Each of these is covered with parallel surfaces and each of these is 3 fingers of the hand wide 2,5 fingers thick. These should be • made from a circle whose circumference is equal to the circumference of the circle of the horizon. Let there be two copper radiuses for each quadrant intercepting each other perpendicularly at the centre of the quadrant, whose thickness and width are equal to the width and the thickness of the quadrant, and surfaces are parallel to each other, and cut off section is in the shape of a square.

We make additions in semicircular form near the two ends of the two diameters that we have constructed perpendicular to the surface of the circle, at the centre of the circle of the horizon and they are connected to each other. We do the same thing in the middle part also.

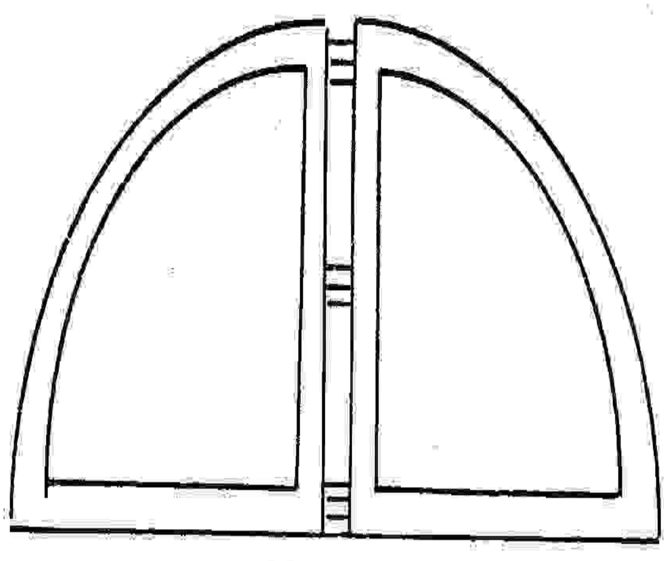
We construct two female sections (Figure XLII),



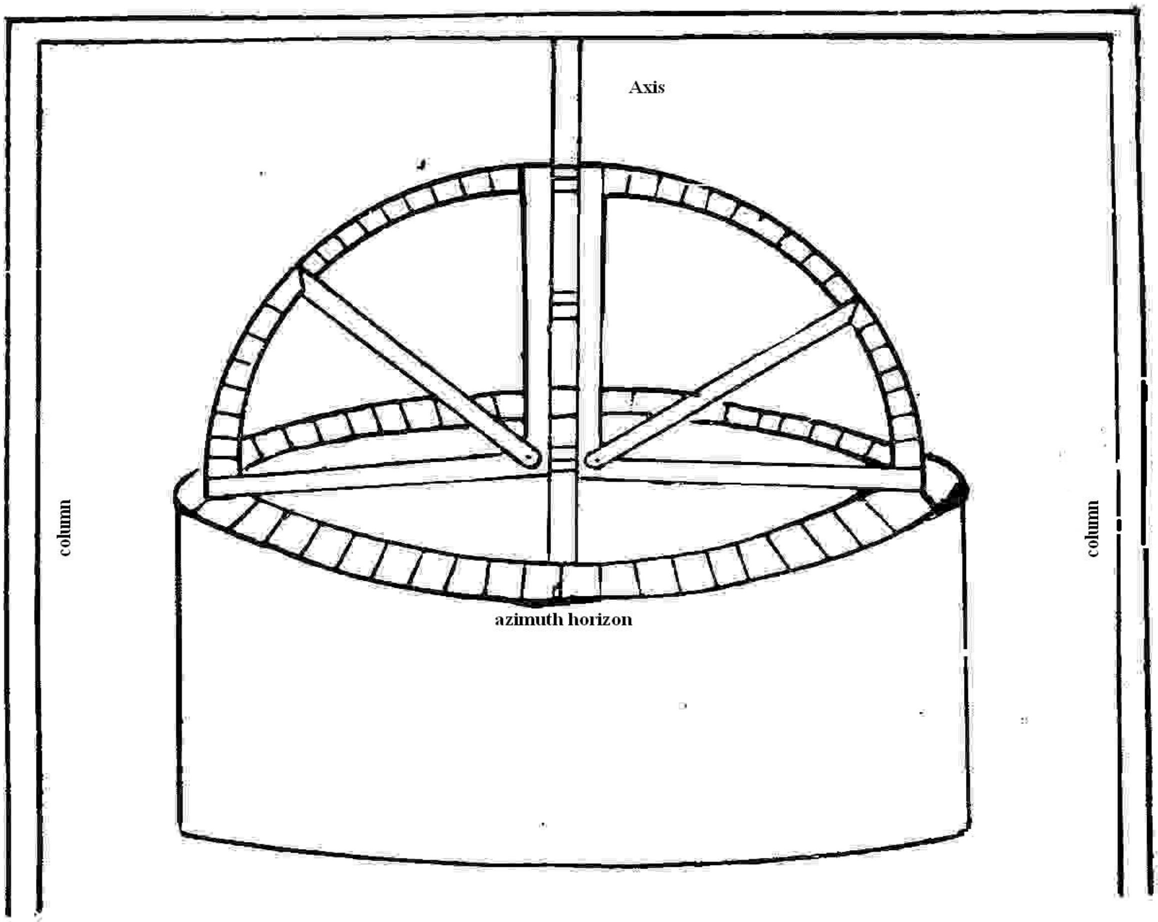
which are formed from two half parts as it is in the hinges constructed for the doors which are made in such a way that the one wing of the door coincides with the other wing when they are folded (Figure XLIII). They enter soundly into the ones facing these on the other quadrants. These additions must be resistant and sound. Either these are constructed ensemble with the radius from copper or they are made of iron and put separately into their places. They are placed in such a way that each of these turn freely inside the one opposing it (beginning from the surface of the radius) and its projection must be two fingers and the thickness one finger.



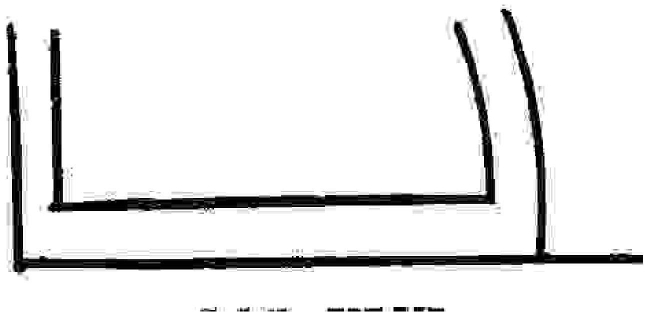
We open circular holes at their centres whose half is beside the semicircle and the other half beside the ruler, which is to say beside the perpendicular radius (Figure XLIV).



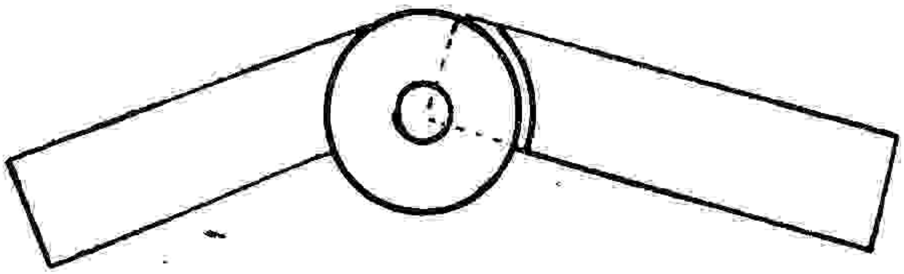
Thus, when the centres of these circles are connected to each other, they are found in a straight line, which is the intersection of the surfaces. We connect the two quadrants to each other with an iron axis, which passes from the holes of the semicircles. Half of this axis sets up inside the rulers whereas the other half sets up inside the projections beside the semicinles. This way they will form one when one of the faces of one of the quadrants coincides with the face of the others and they form a semicircle when the gap between them is kept at such a distance that the quadrants come to a straight line. In order to prevent the bending, the axis must be strong. The lower end of the axis is fixed at the centre of the horizon circle and the upper end is placed at a handle, which rests over the two cylinders fixed outside the azimuth horizon in order to prevent the movement of the quadrants. We make as exact as possible the right angle formed by the axis and the azimuth horizon (Figure XLV).



In regards to the two ends of the quadrants, these move over the inner side of the azimuth horizon. Let there be two indicators at their ends. The sharp side of these indicators must be over the surface of the quadrants, which coincide with each other (Figure XLVI). These turn over the sections of the circumference of the azimuth horizon. 1/3 of the surface of the circle from the inner side (of the azimuth horizon) is not divided for the ends of the quadrants that move.



We have to cut out two segments which are facing each other from the edges at the side of the semicircles where the two perpendicular radius project. Each of these is quarter of a cylinder that is to say one fourth of the iron axis, which connects the two quadrants (Figure XLVII). The circular forms of the holes in the semicircles are completed with these two protected sections. These two holes must be over the surfaces of the quadrants, which coincide with each other.



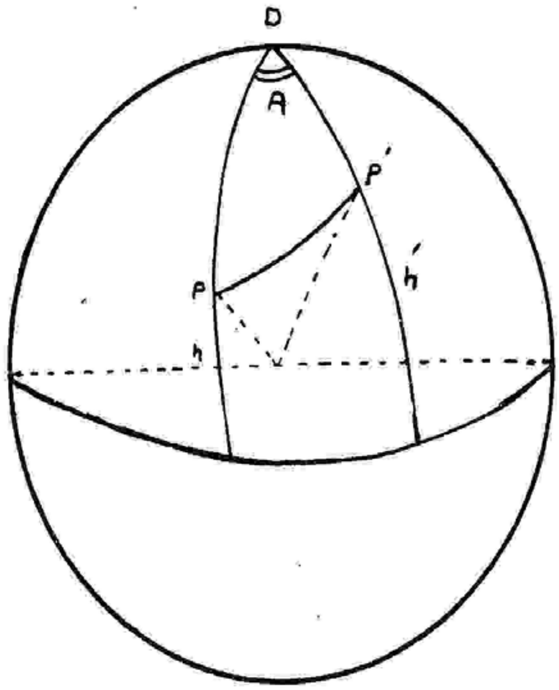
We mark the centres of the quadrants over the two other surfaces and draw four concentric circles over the quadrant. We divide into 18 equal parts the space between the smallest circle and the one following it. In here, we write the five degrees starting from the end of the quadrant which moves on the horizon and which is completed to 90 degrees on the upper end. We divide into 90 degrees the space between the second circle from the inside and the one following it and we divide into the smallest degrees possible the space between this circle and the one following it.

We fix two-iron axis in the shape of a cylinder at the centres of the quadrants. We construct two rulers from copper, which is one finger more than the sides of the quadrants that is to say than the radius, whose surfaces are parallel and which are equal to each other. We open a circular hole near the end of each of these about the radius of the axis fixed to the centre of the ruler. We cut out half of the width of the ruler from the other end. Let the width of the ruler be 3,5 fingers and the thickness 1,5 finger.[33] We fix two pinnules, which are parallel, and equal to each other over each of these, we open two holes in the shape of a truncated cone on the pinnules as is usually done. The distance of each of these pinnules must be one *dhirâ.* We add one pipe for each of these in order to connect the distance between the two holes and a segment to collect the lights on the section towards the eye. In this way, this magnificent instrument is completed.

I say that we will not be needing armillary sphere when we have this instrument. It is clear that the construction and the use of this instrument are sounder and easier. We can provide many things with the instrument that we cannot have with armillary sphere. But we have to admit that this does not mean that we do not need any calculations (only in the height we do not need calculations) when we use this instrument.

We assigned this instrument only to determine the distance between two stars; this can be any two stars whose distance is desired to be determined. This distance is the size of the arc cut off by the two straight lines that reaches the highest celestial globe starting from the centre of the universe after passing the two stars (Figure XLVIII).

[33] This part does not correspond with the German translation, P. 68.



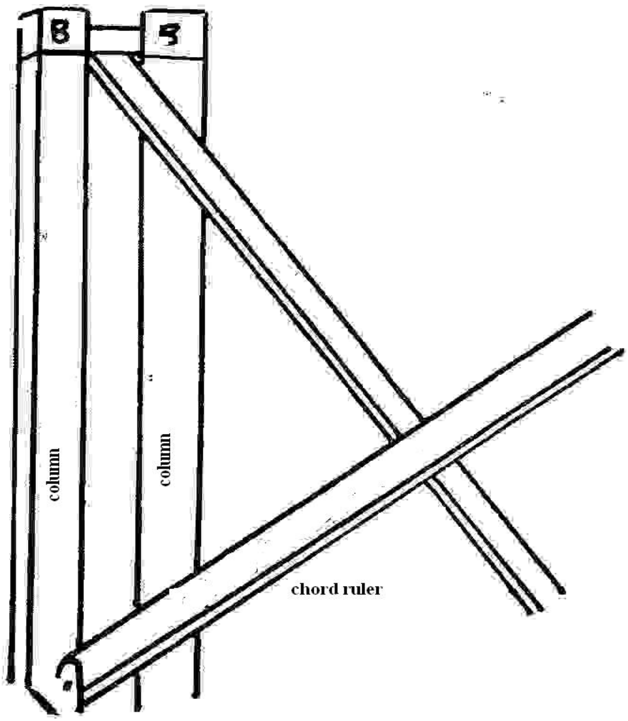
Besides, this instrument is capable of measuring the heights of the zenith and the altitudes of each of the stars. With it, we can also calculate the altitudes of the two stars at the same time.

In regards to the calculation of the distance between the two stars, we can measure their azimuths and their altitudes at the same time. We find out the difference of the azimuths of these two which are equal to the space between the two quadrants and we find out their azimuths and their altitudes. In here a triangle is formed (Figure XLVIII P P' D). The two sides of this triangle are known because they are equal to the complements of the altitudes, and the angle formed by the quadrants is established from the degrees of the azimuth horizon, which is in between the two quadrants. Thus, the base of the triangle, that is to say the arc which connects the ends of the straight lines which passes from the two stars is known.

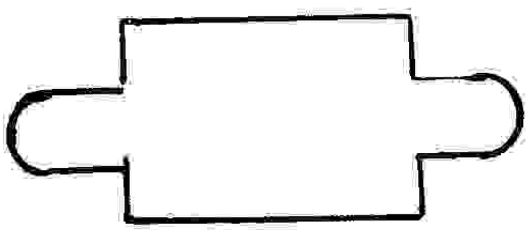
If the place in regards to the latitude and the longitude of any of the star is known, (with the help of this instrument) we can calculate the latitude of this star and also its altitude and azimuth. And from here we can calculate the degree of ascension of the ecliptic. From the observation of a star whose place is unknown, if we know the degree of ascension by marking its azimuth and altitude then we will know its place in regards to latitudes and longitudes. The most important thing that is calculated by armillary sphere is the determination of the place of the unknown star with the help of any other star the place of which is known.

However, this instrument is excellent and its construction is very easy. With this instrument, we can measure the geographical latitude in two ways: The first is from the meridian heights of the sun (in winter and in summer tropics) and the second is the meridian altitudes of the stars, which never set. It is impossible to determine such calculations with armillary sphere. We do not doubt that these are all done with the wish of the Great God.

The description of the kinds drawn from *(dhât al-shu'batayn)* triquetrum, *(dhât al-ustuvanatayn)* instrument with double column constructed for the protected Meragha Observatory are from these.[34] We set up two columns whose surface is in the shape of a square and whose height is six *dhirâᶜ* with the observatory *dhirâᶜ* for this instrument. We construct them strong enough so that they will not tremble. We fix a cap over each of these which are parallel to each other and parallel to the horizon. (Figure XLIX, B). We open two holes over these whose bottoms are round and whose depths and the largeness are equal to each other, and we try to keep them at the same level. We control the equality of their level by placing a ruler between the holes and measuring them by placing a bricklayer's plummet on them.



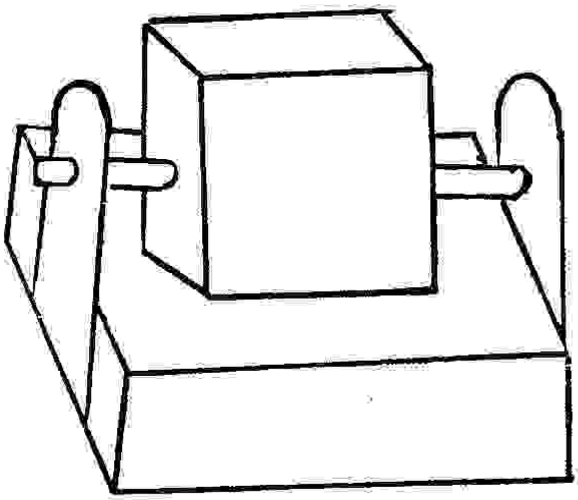
We make a rod having two round ends which will enter into the holes of the caps and its middle part between the two holes in the shape of a square, and we open a hole right in the middle (Figure L). We construct a ruler from teak tree whose faces are in the shape of a rectangle and the length $5\frac{1}{4}$ *dhirâ'* and the width of the surfaces which encircles it and which are parallel to each other is half a *dhirâ'.* We preferred this wood because it is strong and inflexible. We place one end of this ruler into the hole of the handle in such a way that they from a right angle and the face of the one will be at the same plane with the face of the other one.



[34] This part does not correspond with the German translation. Because the word *fünûn* has been read as fütûm the word. P. 85.

We draw a straight line over the face of the rod all along its length and which divides its width into two. We also divide the width of the ruler into two parts. We extend this straight line up to the straight line in the rod. Thus, we can be able to divide it into two equal parts with this extension, which is perpendicular to it. Starting from this interception point, we mark five *dhirâ* from the straight line, which divides it into two parts. This straight line is the radius of the circle drawn by the ruler about the axis of the rod from that is why we call it the radius.

We set a base at the place where the perpendicular from the centre of the axis touches the earth (Figure LI). We fix two beds over it, an iron axis whose middle is in the shape of a square with round ends, turns between these beds. We make the distance from the middle of the axis to the middle of the cut off section that is to say of the axis of the rod equal to the radius.



We construct another ruler whose surfaces are parallel to each other and the above mentioned wood and cut off section is a square. We let at one of its ends a semicircular projection (Figure LII) on which we open a hole (v) in the shape of a rectangle and as large as the thickness of the iron axis. Half of this hole will be towards the ruler and the other half will be at the fix projection. We pass the iron axis through this hole, only its two ends rest outside the ruler. Thus, the straight line, which passes all along, the middle of the thickness of the axis, is found on its upper turned surface when the ruler is placed. The length of this ruler from the socket of the axis is a little more than $\frac{1}{4}+\frac{1}{2}$ of the radius. That way its length will be almost one and a half radius. This is called the chord ruler.

We place the iron axis into the beds of the base so that the surface at the west side of the chord ruler and the surface at the east side of the ruler hanged to the rod will be on the same plane which represents the plane of the ecliptic and will touch each other. We take from the surface of the west and upper part of the ruler an amount equal to the radius starting from the middle of the iron axis, and divide it into 60 equal parts. We divide also into 25 equal parts the remaining section of the ruler. Thus the total of the divisions will be 85. We divide each division into 60 minutes. We mark these divisions, who has 5100 minutes as the total sum, on the western edge of the upper surface of the ruler and we separate these divisions from the others by a straight line, which is parallel to the edge of the ruler. We draw another straight line, which is close and parallel to the first one, and we write the complete integral divisions without fraction between these two. We write the values of the arcs suspending the chords, opposite the divisions of the chords with the help of the chord table so that it will not be necessary during the utilization of the instrument to apply to the chord table and also with the purpose to drive the values of the arcs in the chord division. And we assign to this division the area between the first and the second straight lines. These divisions start from the point near the middle of the iron axis. The ends as 85 divisions are at the other end of the ruler.[35]

We fix two pinnules, which are parallel and equal to each other on the northern surface of the ruler, which is hooked up. We bring their middle points over a straight line, which divides the ruler into two, and leave distance of one *dhirâ* with the *dhirâ* of hand between them.

When the sun comes to the meridian we pull the end of the ruler, which is hooked up, towards north until one of the pinnules shadows the other and the rays of the sun penetrates from the upper hole to the lower hole. We raise the end of the chord ruler, which stands towards us until its surface touches the end of the radius marked over the ruler which is hooked up. We find the distance of the zenith of the sun from the chord ruler, and from that, we find its altitude.

We construct a wall adjoined to the north side of the column at the east, whose heights equal to the height of the column and the lengths about five *dhirâ.* We place a quadrant at its east surface, which is just like the previous quadrant, only a little smaller, in order to measure the distance of the zenith. We construct a handle at the upper north surface, which will project towards west and place two pulleys at its end. During the utilization of the instrument, we connect the circle and the pulley with a string, which passes from the pulley to the circle, and from the circle to the pulley and which are fixed to the ends of the chord ruler and the ruler, which is hooked up. With the help of the Great God.[36]

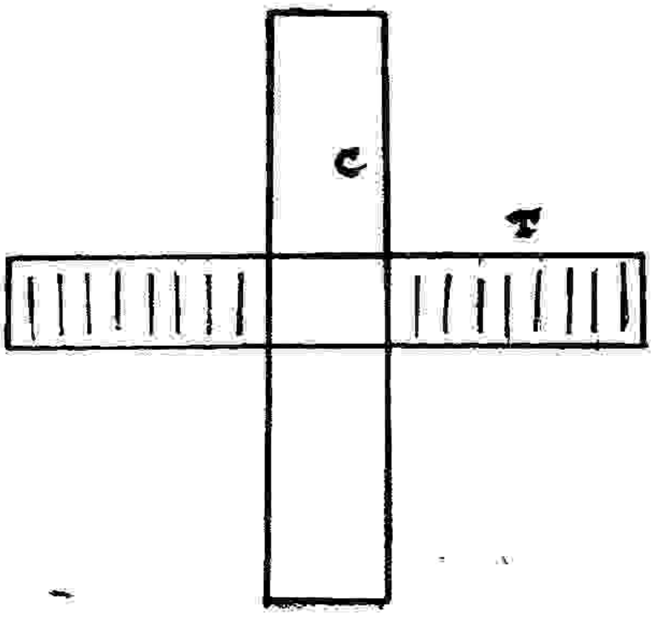
There is an instrument called *(dhât al-juyûb wa'l-samt),* the instrument having sines and azimuth we constructed for him its model, in the divinely protected Observatory. We can measure the altitudes from every direction with this instrument.

That is why we need to construct a copper circle. It is better to construct the circle as big as possible. We call this the azimuth horizon. Its construction and the correction is done just like the one we mentioned above. We construct a wall in a circular shape, about 1,5 *dhirâ'* height for this instrument and fix this over it. We correct its parallelism to the horizon just like the previous one.

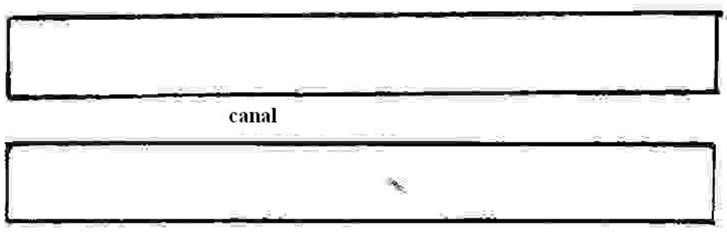
We mark over it the meridian and the east-west direction, and draw concentric circles. We write between them by twos the numbers, the degrees, and their fractions starting from east-west points and ending as 90 degrees at north-south points.

[35] This section is right in meaning but it is not a literal translation. P. 85.
[36] This part does not correspond with the German translation. P. 86.

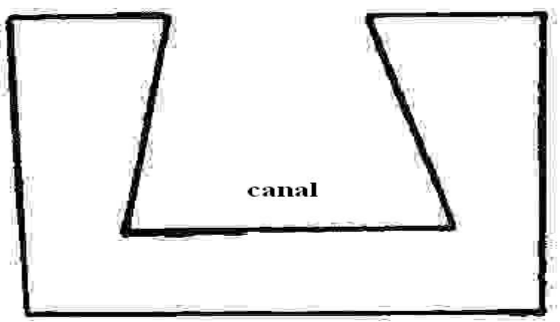
We construct a diameter from a solid wood in the shape of a rectangle whose width and thickness is 1/3 th of a *dhirâ'.* Let its two ends move on the inside edge of the azimuth horizon. We fix a traverse (t) right in the middle, perpendicular to the wooden diameter (Figure LIII, c) whose, length is about two *dhirâ'* or equal to the diameter, and the thickness 1/3 of a *dhirâ'.* We open a hole in the middle of each of these two and connect them solidly so that the traverse and the diameter make a right angle.



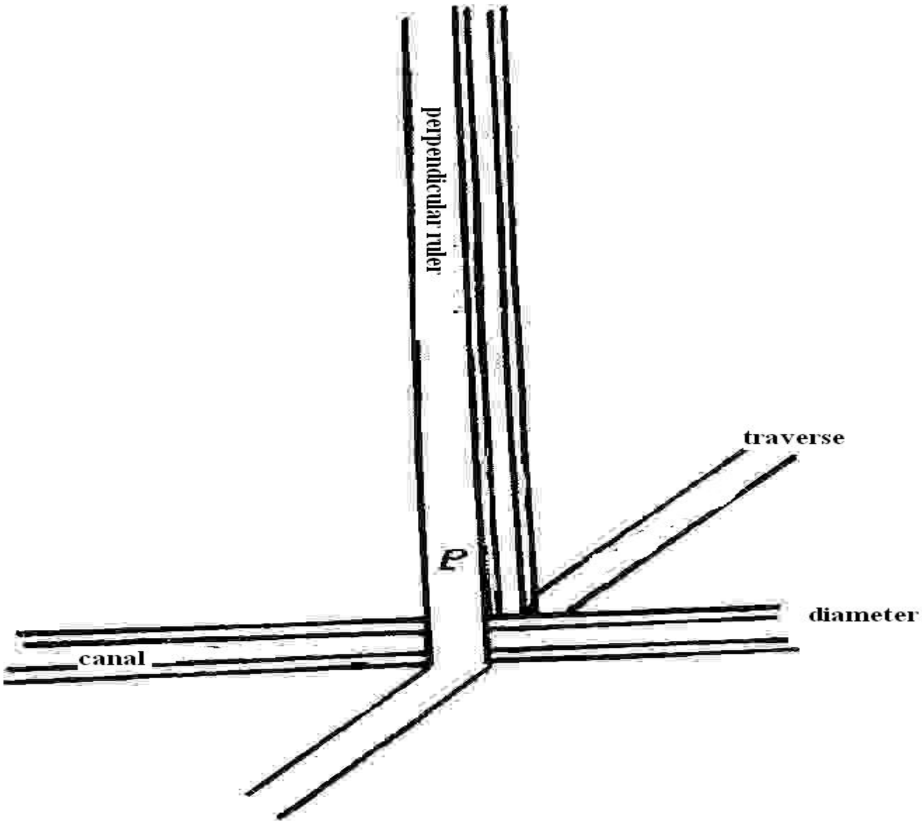
We open a canal in the middle of the diameter, all along its length, in the shape of a rectangle, parallel to the edges of the ruler and 1/6 th of a *dhirâ* wide and deep (Figure LIV).



We file the base and make it larger than the upper section (Figure LV).

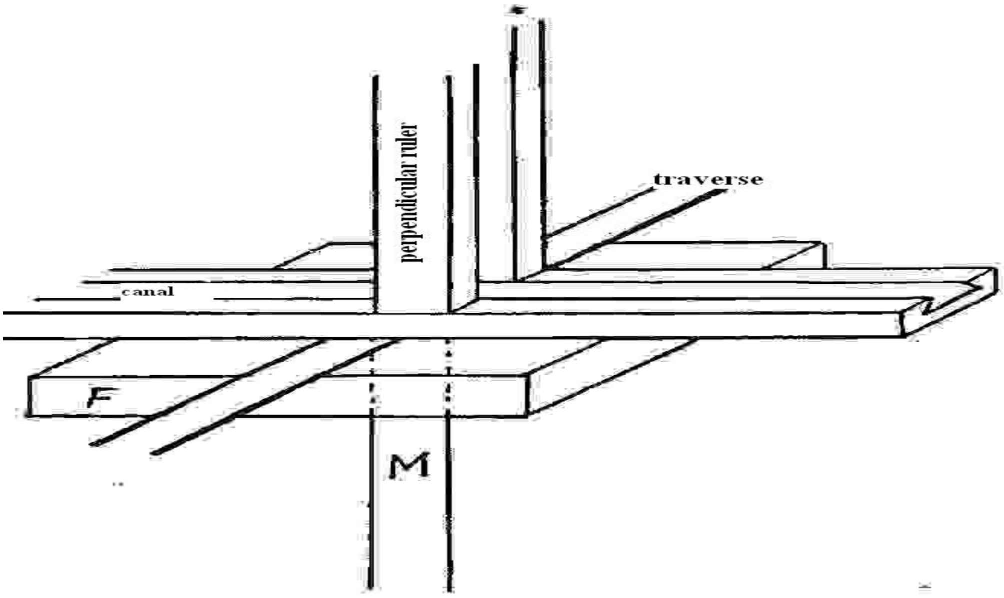


We set up two rulers in the middle of the diameter, at the two sides of the canal opened at the place, which are equal to the radius and perpendicular to the diameter and the traverse (Figure LVI, p). The cut off section of each of these must be in the shape of a square, their surfaces must be parallel to each other, they must be set up right opposite to each other, and their width must be 1/6th of a *dhirâ.* We construct a canal in the middle of each of these and all along its length whose width and depth is equal to a small finger. We set up both of these in the middle of the diameter, at the edges of the canal opened at the place. Let the canals in the ruler's face each other at the base, and the straight line between the two straight lines dividing the widths of the canals passes from the centre of the circle. We connect the distance between the upper sections with an iron axis, which holds them together.

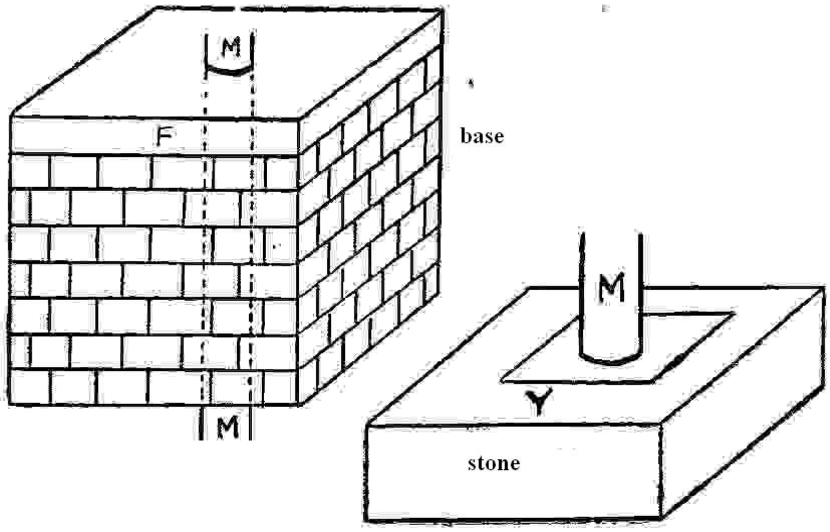


We construct three supports for each of these in order to protect them and prevent any defect in their perpendicular position. One of these supports comes from the end of the traverse and meets its 1/3 th starting from the lower section of the ruler; the other two supports come out from the middle of the diameter and meet its 1/3 th starting from the lower section of the ruler, likewise the same operation is done for the other ruler.

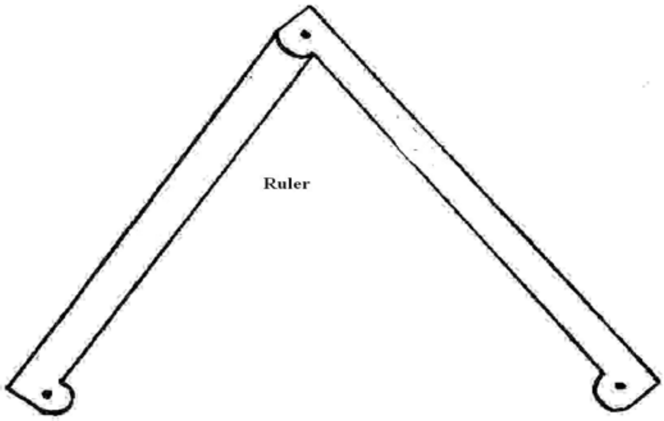
We construct an iron axis at the centre of the azimuth horizon, below the traverse; it is connected firmly and has a length of l/5th of a *dhirâ* (Figure LVII, M). We construct a part (F) from wood in the shape of a square below the traverse whose edge is equal to not less than two *dhirâ*. We open a hole in the middle so that the axis can turn there. We file its surface so that the traverse can turn over it easily.



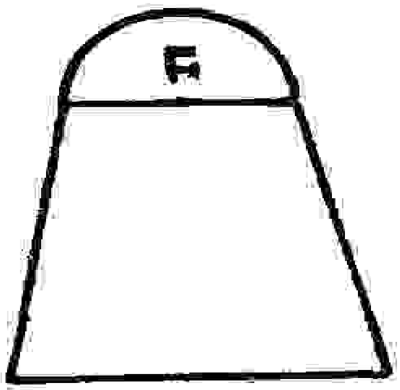
We construct a base to place the instrument. The hole mentioned above must continue in the middle of the base also (Figure LVIII). At the bottom of the base, there is a stone (Y) whose surface in touch with bottom of the hole is in the shape of a rectangle. Inside this hole there must be a bar which is perforated (in circular shape) in the middle. We place firmly this iron bar into the hole of the stone. This hole is constructed in such a way that the bottom end of the axis can turn, and the instrument will not be shaken when we turn the diameter and the two rulers.



We construct two other rulers in the shape of squares, l/6 th of a *dhirâ* in width and the length of each is equal to the radius. Let there be additions at both ends of each of these in the shape of a circle and let its height from the surface of the ruler be equal to 2/3 th of the width of the ruler. These additions must be at both ends of its surfaces. To connect the rulers to each other, we connect the semicircles at the ends of the rulers with an iron axis (Figure LIX). The middle of this iron axis is found in the intersection point of the surfaces. Thus, we have the shape of a pair of compasses. When they come together the surface of the one coincides with the surface of the other. And when the two ends are pulled away from each other they are opened. We call these the measuring rulers. The two ends of this axis must project out as much as the depths of the hollows opened in the rulers. The thickness of their cut off sections must be equal to the width of the hollows so that it will move up and down without shaking.[37]

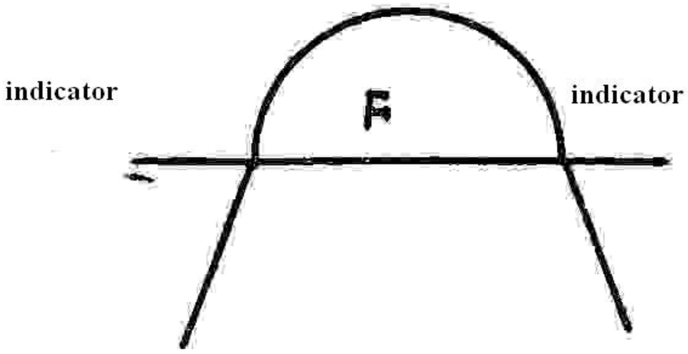


We construct two parts from wood or copper in the shape of the hollow in the diameter, whose cut off sections are in the shape of rectangles and the length of each is a span (Figure LX).

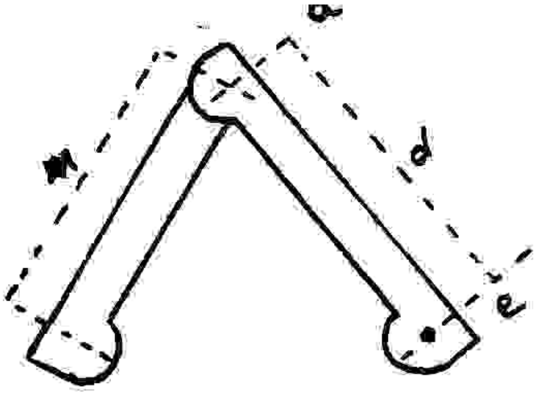


Let there be additions at the ends of these in the shape of semicircles (F). The lower section must be wider than the upper section so that it can fill the hollow. Thus, they can move there without shaking. We open a hole at the centre of the semicircles, which are at the ends of these parts. In the same way, we open holes in the semicircles, which are at the ends of the rulers. We connect each part to the ends of the rulers with an iron axis. At both ends of these sections, there must be a sharp and projected indicator, which marks the divisions at both sides of the diameter and moves over the both sides of the canal in the diameter (Figure LXIII).

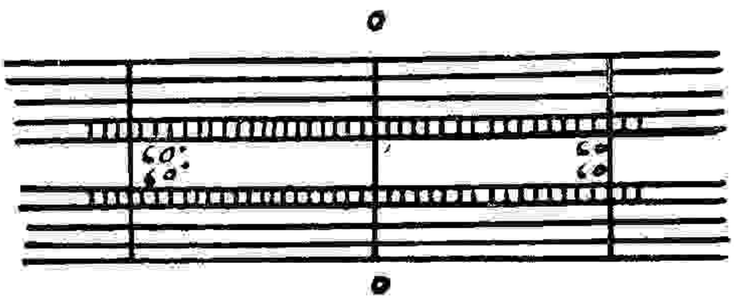
[37] In the German translation at this section, there are some missing parts. P. 90.



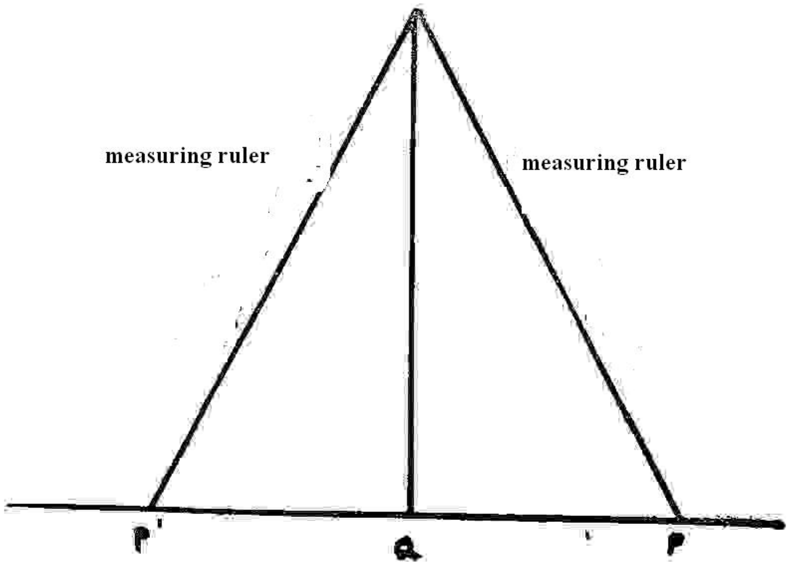
All the surfaces of the measuring rulers must be equal, in such a way that the distance between the centres of the two semicircles of the one must be equal to the distance between the centres (m) of the other (Figure LXII, d).



When the construction is completed, we take out a part equal to the distance between the two straight lines (ae), parallel to each other and perpendicular to the rulers passing through the centres of the semicircles as long as the measuring rulers, starting from the middle of the diameter that is to say starting from the straight line which crosses the canal in the ruler. We divide this length into 60 divisions and divide each division into smaller parts. We separate with straight lines the distance between the divisions and the five degrees all along the diameter and parallel to the edges of the canal in the middle of the diameter (Figure LXI). The division starts from the middle of the diameter and terminates at both ends.



In regards to the axis, which connects the ends of the measuring rulers to the ends of parts, they give us the sine of their complement of the altitude (Figure LXIV, ap). We construct two equal pinnules over the widths of the measuring rulers. We perforate them as we have always done before. It is quite clear that there will remain at both ends a part, which is not divided if each of the measuring rulers are equal to the radius.



During the time of the observation, the rays of the sun must pass through the holes of the pinnules and the indicators at the ends of the measuring rulers must be at equal distances.

In regards to the semicircles, which project from the surfaces of the rulers, and the parts, which are connected to their ends, instead of these we can use an iron joint or a copper hinge. By getting enfolded up to their halves into the ends of these rulers they become the axis upon which the rulers are turned. Thus, their construction is more solid and easier.[38]

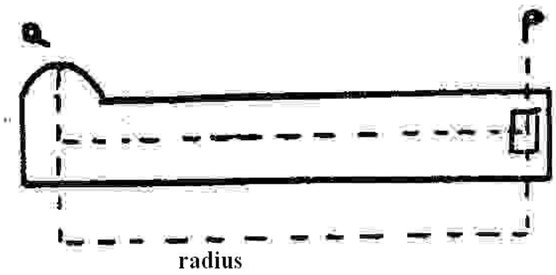
One of the instruments whose model we constructed in the observatory is *dhât al-jaib wa'l-sahm.* With this instrument, we can obtain the azimuth.

For this instrument, we construct an azimuth horizon, a diameter, a traverse in the middle of the diameter, an iron axis upon which the instrument turns a circular base and a support to hold these. These are done exactly the way we have done before.

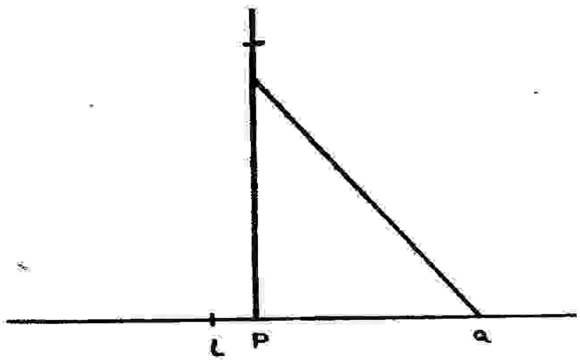
We construct two rulers (for each of these) whose thickness and the width is l/6 th of a *dhirâ*, the surfaces in the shape of a rectangle, and whose length is equal to the radius. We construct annexes in the semicircular shape, which becomes an iron project at their ends, in other words handles that are enfolded into the surface of the rulers up to their halves and connect the two rulers with an iron axis. Their construction is exactly the same as the ones constructed in the measuring rulers. Only they do not need annexes. We place one of these rulers into the canal opened on the diameter. The situation in here is the same as in the parts mentioned before because the lower part of the ruler and the hollow is wide and the upper part is narrow. We must fill up the canal with the same dimension and its upper surface must be at the same level with the upper surface of the diameter. We call this *dhât al-sahm* and the second the *radius.* We open a rectangular hole in the middle of the width of the second one. We construct an axis for that hole in the shape of a plate whose ends are in the shape of a cylinder and which is perpendicular to the surface

[38] In the German translation this section is translated in summary, P. 92.

of the diameter.[39] The two ends of the axis move inside the hollows opened on the perpendicular rulers so that we can protect its position between the two rulers during the up and down movement of the diameter. We put a sign over the main support (the straight line which is parallel to the edges of the ruler and which divides the surface from the middle) which passes through the centre of the axis, which connects the two rulers, and over this end of the *radius.* The distance between the sign and the axis is equal to the radius (Figure LXV, ap). The same way we put signs on the surfaces of the columns starting from the big diameter, their heights are equal to the radius. Each of these three parts is divided into 60 equal parts and each of these also are divided into smaller parts. We divide the ruler buried into the canal of the ruler into the same equal parts. In here, the starting point is the middle of the iron axis, which connects it to the radius.



We can calculate the sine of the complement of the arc of the altitude from the section left between the surface of the column and the axis (Figure LXVI, ap); and from the rest we can calculate the versed sine of the arc of the altitude.

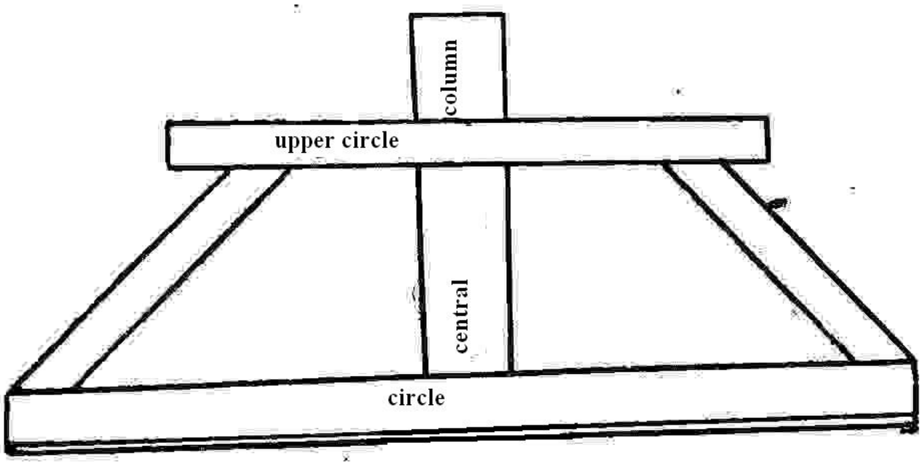


We place two pinnules, which will divide the width along the length into two parts, on the surface of the radius opposite the surface, which is towards the columns. We do not need to repeat ourselves here because the operation has been mentioned many times before. We calculate the sine of the arc of the altitude from the interception of the columns with the radius. There are many proves which verify each other in this instrument.

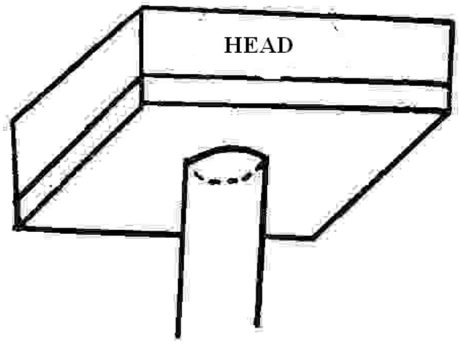
In the year 650, 1 constructed another instrument for his Royal Highness Mansur, ruler of Hims in the City of Damascus; I constructed this instrument in the presence of the Wazîr Najm al-Din-al Lubudî and he called it *(aid al-Kâmil)* perfect instrument. This is another kind of this same instrument, which helps us to calculate all altitudes and azimuths.

[39] This part does not correspond with the German translation. P. 94.

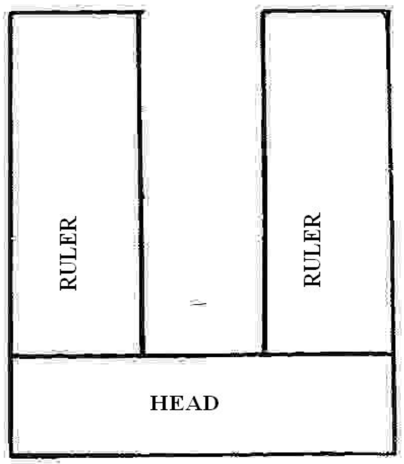
That is why we construct a base just like the one mentioned in the mobile-pinnule. Only its base is wider and its height is higher. Instead of its cross shape there, we construct the base as a very large circle with two diameters from wood which intercept each other in right angles (Figure LXVII). We attach the upper circle with eight solid supports.



We fix the base parallel to the horizon, and take out the meridian and the east-west line and we divide them into smaller parts as usual. We call this the azimuth horizon. We place a column over this circle (p). The bottom end of the column turns in the centre of the circle, and its section, which projects over the upper circle, is 1/3th of a *dhirâ.* We are careful to place it over the base in a vertical position. In regards to the top end, the section, which turns inside the upper circle, is in a cylindrical shape. The section above the circle is in a square shape whose side is not less than l/4th of a *dhirâ'.* We place a square shaped head whose width is 1/2 of a *dhirâ'* and the length l/3 th of a *dhirâ'* over this square shaped section. We strengthen the connection with nails (Figure LXVIII). We construct it in such a way that the upper surface of the circle exactly touches to the surface of the lower part of the head. This is done in such a way that the head turns over the surface of the circle without shaking. We construct a handle over it in case we need to turn the axis.

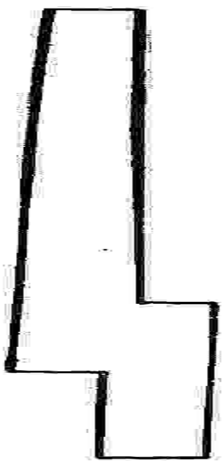


We construct three rulers from the best kind of wood, in a rectangular shape; each of these is 4 and 1/2 *dhirâ* long and 1/6th of a *dhirâ* wide. We fix the ends of two of these into the rectangular sockets of the above-mentioned head, and we make the distance between the two l/6th of a *dhirâ.* They must be perpendicular to the upper surface of the head (Figure LXIX).



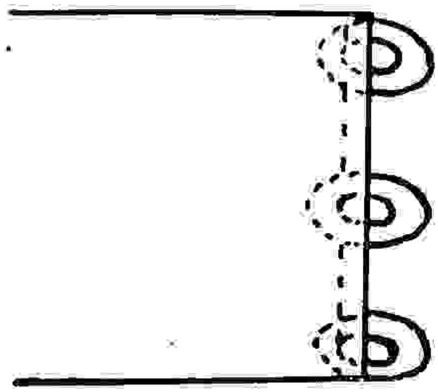
In regards to the third one, we call this the ruler, which gives us the altitudes. We divide widths of the three rulers with straight lines all along their lengths. We put a sign on the straight lines, which divide the widths of the perpendicular rulers into two, starting from the head in equal distance and nearer to the upper section; we open one hole at each of these signs opposite one another. The same way we pierce the middle of the width of the third one, and place this in between the two. We connect these three with an axis, and fix two pinnules at the middle of the width of the surface of the third one parallel to the axis. We open two holes at the same hight, dividing its widths from the middle. We make the length of the third ruler in such a way that it will be in touch with the upper surface and place it between the two straight rulers.

We construct a fourth ruler from the best kind of wood whose edges are in a rectangular form, whose length is 1,5 times of the length of the middle ruler, whose thickness is four fingers and width five fingers, we call it chord ruler. We construct an annex at its one end so that it will widen the width. Its length is 1, width 1/6 th of a *dhirâ* and the thickness is equal to the thickness of the ruler. We cut off a section from the end of the ruler connected to the annex; this section is 0,5 long and 1/6 th of a *dhirâ* wide, equal to the width of the perpendicular ruler. The surface of the chord ruler opposite the surface to which the annex is connected and the inner surface of the perpendicular ruler will be on the same plane if we coincide the surface of the width of the annex with the upper surface of the perpendicular ruler. The middle of the three turns (Figure LXX) over this plane.



We put a sign on the upper part of the straight line, which divides the width of the perpendicular ruler. We mark the length equal to the distance between this sign and the axis on the third ruler starting from the middle of the axis. We make this the radius of the circle drawn by the movement of the middle ruler over the upper axis.

We fix an iron axis about three fingers thick and 1/4 th of a *dhirâ'* long over the sign at the side and bottom of the perpendicular ruler. We construct three iron rings at the end of the annex placed on the end of the long ruler (Figure LXXI). Their halves are buried inside this annex and their widths are equal to the iron bar. They are placed side by side over the width of the annex with their centres on the surface of the chord ruler. We place the axis on which the long ruler turns inside the mentioned circles.



We divide with parallel lines thought the length of the surface of the chord ruler, which comes to the exterior when it is placed. Starting from the straight line, which passes from the centre of the iron axis, we divide the mentioned radius into 60 parts. The remaining from the end of the chord ruler is divided into 25, each being equal to the sections divided as 60 parts. Thus, we will have 85 parts. And each part is divided into smaller parts. We take the centre of the axis over which the chord ruler is turning and the side on which the perpendicular ruler is fixed as the starting point of the division. At the side of each division of the chords, we write down the value of the arcs suspending the chords. This arc is found from the chord tables. In short, this is just like it was in *(dhât al-ustuwanatayn)* the instrument with two cylinders.

When we want to measure with this instrument, we turn the handle which passes through the head. With it the instrument turns until the circle of altitudes on which the star to be measured is present, coincides with the surface of the middle ruler. We bring the ends of the middle ruler and the chord to the opposite direction of the star. We pull the end of the middle ruler until the star is seen from both pinnules. We raise it so that the divided surface of the ruler will pass through the middle ruler that is to say through the marked point of the diameter. From the divisions of the ruler we will be able to determine the chord of the angle between the two straight lines, which pass through the star and the zenith, and the arc subtending it. This is the complement of the altitude and when we subtract this from ninety the rest will be the arc of the latitude.

If the measurement of the position of the sun is being determined, it is easier because the rays of the sun penetrate through the holes of the pinnules. In regards to stars, in order to observe them clearly we construct a pipe, which connects the holes and the distance between the two pinnules. And we fix a cup like section at the end of the hole for watching.

In regards to the mounting of the instrument, we take the meridian line and place the north and south points marked over the base of the instrument on this straight line. We place the base so that its upper surface will be parallel to the horizon. We bury timbers on the ground, connect the base with strong nails to these timbers, and surround it with walls so that it will not be disturbed by the wind.

We construct a ruler whose end turns over the azimuth horizon at the lower part of the column and in perpendicular position. We calculate the azimuth with it. It is obligatory to connect the ruler to the circle of the azimuth that is to say to the surface on which the middle ruler rotates. Only the pointed end is on the opposite side towards which the chord ruler and the *radius* are directed. In such a way that, the end of the ruler and the surfaces of the chord ruler and the middle ruler which touch each other are always found on the plane of the azimuth.

Many problems, which cannot be solved by triquetrum in the Almagest, can be solved or investigated with the help of these instruments. For instance, with this we can calculate the position of an unknown star from a star whose latitude and the longitude is given. When we measure the altitude and the azimuth of any star with this instrument, we also determine its ascension. When we calculate the altitude, azimuth and the ascension of a star we can at the same time calculate its longitude and the latitude.

If this can be calculated from *dhât al-rub'eyn* the result will be more precise because the altitudes of the two will be taken at the same time. These things could be done only if the Great God wishes it.

In regards to *dhât al-shu'beteyn* in the Almagest, the results are more precise obtained with our instruments than the results obtained with this instrument. Consequently, Ptolemy says the following when explaining the construction of this instrument. We construct two rulers, their lengths are four *dhirâ'* each and the shape of their surfaces are rectangular. We divide their widths with straight lines along their lengths. We fix one of these on the base so that it will be perpendicular to the horizon. Let its surface represents the plane of the meridian. We open a circular hole along its thickness from east to west. The same way we open a hole on the straight line, which divides the width into two parts. We join them with an iron axis. The second will move freely over this axis.

We fasten a round nail on the lower end of the straight line, which divides the width of the perpendicular ruler, and attach a third ruler to this.

The distance between the lower and the upper axes will be divided into 60 parts. We put a mark on the second ruler whose distance from the upper centre will be equal to the distance between the two centres of the axes.

We fix two equal pinnules on the second one as usual and open two holes on them. The hole on the pinnule towards the eye will be narrow and the hole on the upper pinnule will be large enough so that the full moon will be seen through this hole. We make the observation when the moon comes to the meridian. We mark the section which is separated from the third ruler and which is in between the middles of the perpendicular ruler and the mobile ruler. We make the third ruler come to contact to the perpendicular ruler. The chord of the angle, which is in between the two straight lines, which divides the widths of the mobile ruler and the perpendicular ruler can be determined from the division of the third ruler opposite the mark on the perpendicular ruler. And the arc of the chord can be obtained from the tables.

The rest is known by all of us. We did not quath his article word by word but the meaning he gave is exactly given in here.

We have to point out here that for some one who has practical skill the instrument mentioned above is not precise and it has many errors and unreliable parts.

When we come to the unreliable parts, in mentioning the connection of the third one to the perpendicular ruler he does not clarify to which face the third ruler is going to be connected. If this is placed over the surface, which touches the second ruler, the thickness of the third one will go in between the two surfaces that are in touch. Thus, the triangle whose upper angle is on the axis and whose base is formed from a thin ruler cannot be at the meridian.

If it is placed on the other side of the perpendicular ruler, the thickness of the ruler will form an obstacle between the surface of the mobile ruler, which has two pinnules, and the ruler with chord divisions. Thus, it is not possible for the surfaces and the rulers, which surround the angle to be in the plane of the meridian. When the altitude is near the zenith then it will be very hard for the thin ruler to subtend the angle.

In regards to its de fee tuosity: Because of the continuous motion of the mobile ruler, the weight will pull down the axis that it is connected to. The marks and the boundaries do not keep their places.

In regards to the shortcomings, we can calculate only the culmination of the heavenly bodies. And it is necessary that this altitude must be more than 30 degrees. Since the division of the perpendicular ruler is 60 and since it is the chord of the arc of 60 degrees, the altitude when it is lower than 30 degrees, cannot be calculated with this instrument.

If they use thread instead of the thin ruler, since the tread will become longer when pulled from its end, the calculations made with it will not be precise. A person who expects exactitude from the instrument cannot depend upon a thread.

For someone who understands our critical analysis, it is clear and open that our purpose is to find the truth and not oppose someone whom we envy.