

Sequence 4

Technical assistance for sequence 4: improve and evaluate the precision of your measurements

In order to ease out the exchanges between the schools, all the participants in the operation have been parted into 8 groups more or less homogeneous (plus one group for the Egyptian schools). Considering the distribution in latitude of the schools in the French territory, we had to assure a minimum latitude gap in the schools in each group. That is to say whichever group you are in, we tried to associate you with a partner that has a latitude with at least 3 or 4 degrees of difference.

Why? Because a correspondent that is 4 degrees south of your town will measure an angle inferior by 4 degrees to yours on the same day. Unfortunately, your measurements being only an estimation of the real angle between the sun and the vertical. As you might know, an estimation is always imprecise. Sometimes you will measure an angle that is superior to reality, sometimes inferior. This spread, this mistake, depends both on the quality of your gnomon (length and perpendicularity of the stick), and of the quality of the setting up (horizontality of the board, drawing of the local meridian). You will have understood that your measurement should be as precise as possible.

If the mistake you are making on each measurement is around 3 to 4 degrees, it is obvious that your calculus of the perimeter of the earth will be very far from reality, since your mistake will be the distance with your partner. If your measurement is reliable by 2 degrees, it is better, but your partner having around the same precision, there is a big risk that the difference should be cancelled! As a conclusion, it is necessary for your gnomon to be sufficiently well set to allow you to carry out measurements with a precision of (at least) 1 degree.

This technical card should help you control and improve your measuring instrument in order to publish quickly measurements that are as precise as possible. Among the schools that already published measurements, some of them already meet this criterion, therefore you can all do it! We wanted to gather in this card a number of advice and ideas to help you out. Of course, these are only suggestions, and the list is not exhaustive... Don't hesitate to contact by e-mail the other schools of your group and to exchange your technical tips, that's what the discussion groups are for!

Repeated mistakes!

Every time you assemble two parts of your instrument, or that you set up your instrument before a measurement, you inexorably make little mistakes, that, put together, might well have your measurement fail. Sometimes luckily your mistakes compensate each other, and sometimes they add up and damage your results severely, it is therefore important to control every step meticulously.

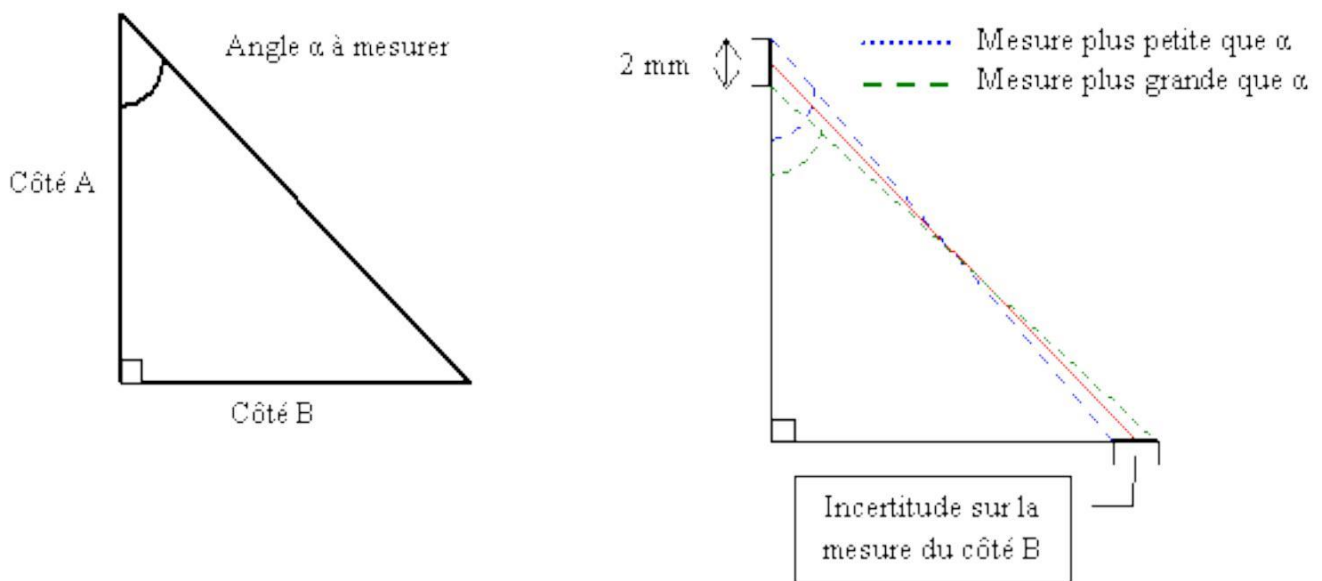
Make a list with your pupils of the different stages that lead to each measurement, from the making of the gnomon: choice and measurement of the length of the stick, fixing the stick perpendicularly to the board that is also supposed to be perfectly flat, setting up the board and checking its horizontality, drawing the meridian, locating the passage of the shadow of the stick over the meridian line, measurement of the shadow, drawing the angular sector thanks to the lengths of the shadow and of the stick, and eventually measurement of the angle.

You now have to admit that on every step of the way, you made a slight mistake. You can understand that the final measurement and therefore the calculus of the diameter of the earth can be very far from the reality! Let's see now a number of tips and ideas to evaluate and minimize these mistakes.

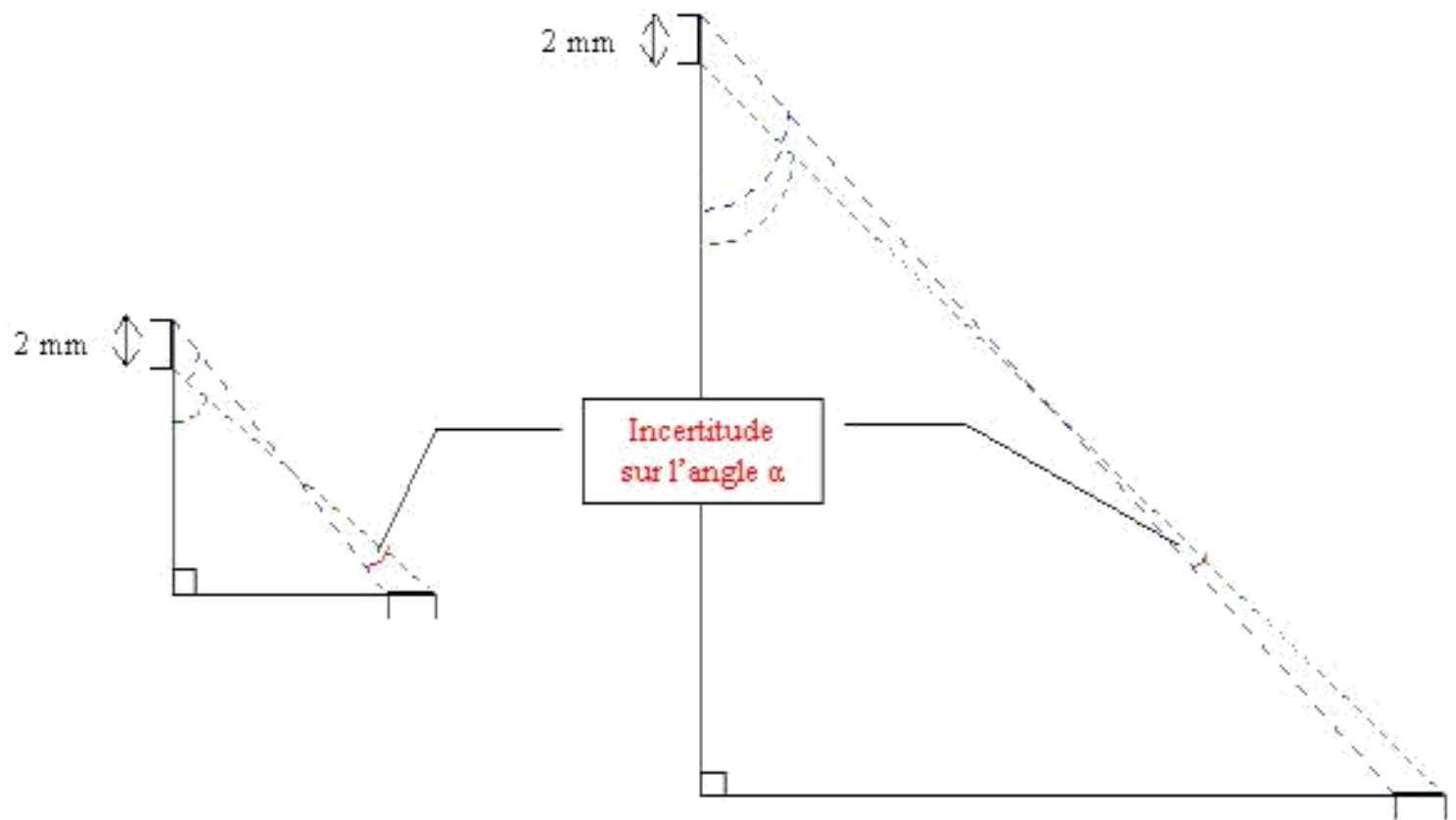
Basic rules

How to reduce to maximum the error in the measurement of an angle? By increasing as much as possible the length of the sides that you draw to measure the angle (see figure 1). Indeed, you can never know exactly the length of something, but you can measure it with a certain precision (give a double decimeter to three pupils and ask them to measure one by one the size of your desk with a precision of half a millimeter : they will surely find three different measures!).

Suppose now that you wish to measure the angle α represented on the figure 1 below from the knowledge of the length of the segments A and B. Suppose that the length of A and B have been measured with a precision of 1 mm (reasonable). The figure shows you that the uncertainties on the measures of A and B lead to one on the knowledge of the angle α itself.



To reduce the uncertainty, now triple or quadruple the length of A and B. The uncertainty on the measurement is the same (it only depends on the way you measure : quality of the ruler and of the reading). However, the uncertainty on the angle decreases. You should be convinced by reading figure 2 : notice the extreme angles, as a consequence of the uncertainties, they show the limits that surround the angle α : here 45 degrees. This interval decreases indeed on the biggest figure (check with your protractor!). Therefore, it is your interest to use big length to measure angles.



Applications

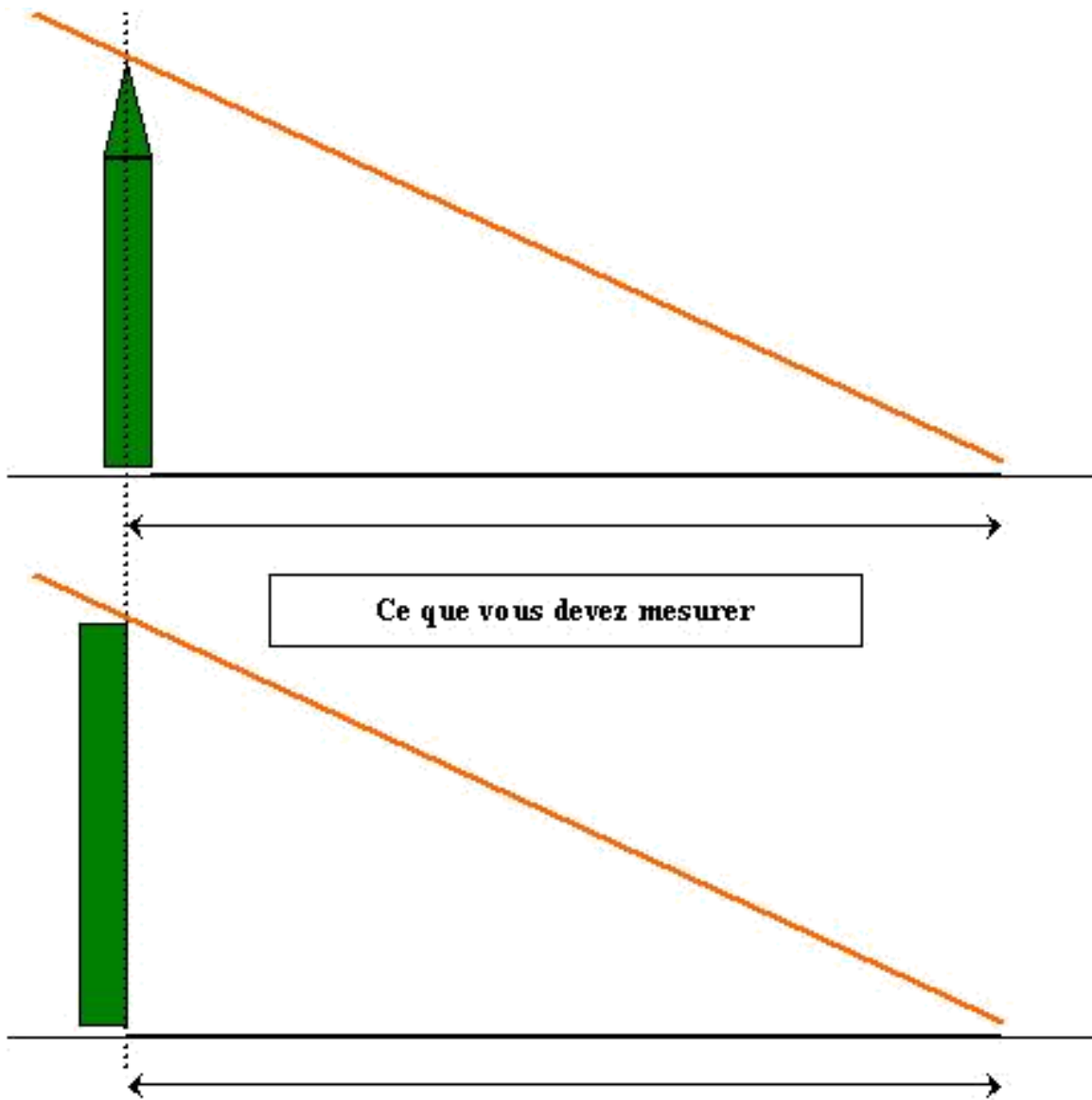
Use preferably big instruments : a square to check your gnomon is indeed perpendicular to the board.
 Beware : you have to check in two perpendicular directions to each other, that is to say turn 90 degrees around the foot of the gnomon and check again in the new direction. Indeed, the gnomon can be inclined in any direction!

A longer gnomon will be easier to set up perpendicularly to the board, however, if longer than 20 cm, the shadow will soon become blurry, even at solar midday. Choose rather a 10 cm gnomon.

If you made a bubble leveller to control the horizontality of your board, it will be much more precise if the surface of the water is wider, according to what we explained previously.

Preferably use pencils with thin lead (like "criterium") to draw the measured lengths, that way you will reduce the mistakes in the reading of angles. As well, use big protractors to read the final angle, you will reach a higher precision in the reading.

Remark : according to the shape of your gnomon (pointy or flat at the top), you will have to measure the length of the shadow from different points of the foot, observe carefully the figure below because you would risk to make always the same mistake in your results.



Evaluate your precision yourself

To get an idea of the precision of your measurements, it is very simple, you just have to do readings every day. From one day to the next, the value of the angle of the solar rays to the vertical varies very slightly (between 0.1 and 0.2 degrees in may). It is sufficiently low a variation for you to be unable to notice it in your measurements. Therefore, carrying out three measurements three days in a row, you will have an idea of the random mistakes you make while setting your measuring instrument. You should get three measurements that are as close to each other as possible. However, you will not be able to know your mistake in relation with the real angle you are measuring.

But, don't worry, we are checking your results very precisely and we will be telling you the real precision of your readings when we interpret your results. Good luck to you all, you are almost there!

Complement :

Here is the description of the gnomon made by Alain Rouquet and his class with their protocol. This gnomon, very simple in the making, gives very good results !

“For the realization of the gnomon, nothing very original : a melaminated fibreboard set on a table and on one of the sides a wooden stick of 10 cm, with a round section (8 mm), set tight (not too much for the children to

be able to readjust it at any time) with a clamping ring for copper tube (plumbing).

For each measurement, there is someone to check the horizontality of the board and of the verticality of the gnomon, a child draws on the board the extremity of the shadow and back in class, a team is in charge of tracing the triangle and of measuring the angle. A last team goes, very excited, to the computer to publish that day's angle on the website.

By aiming directly, it is quite disappointing, the measurements are hard to obtain with precision even if the children love to observe the sun with "eclipse" sunglasses.
