Practical work - 1	Solar day measurement	Primary School

- TOOLS

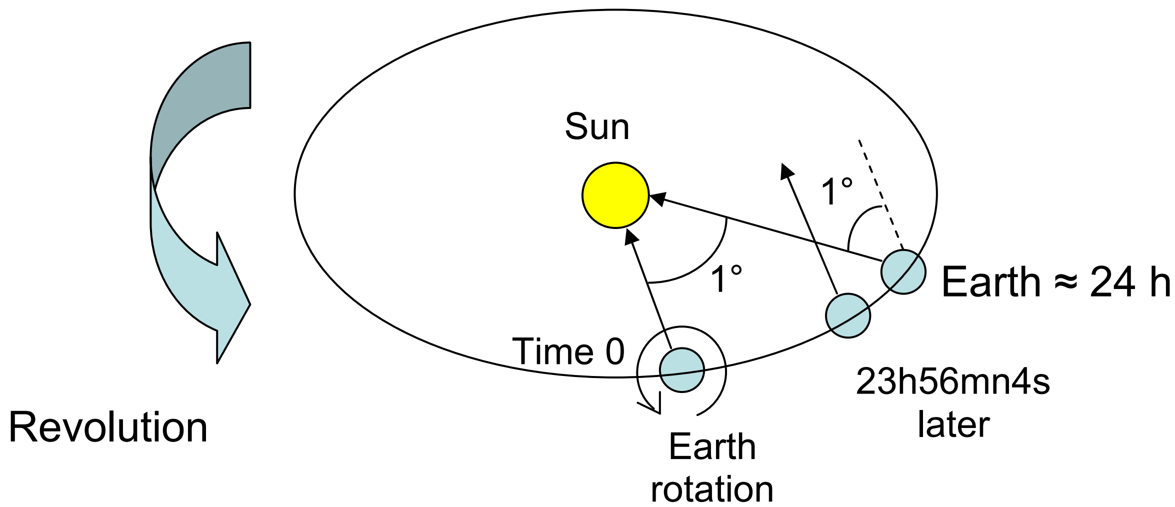
A solarscope,
A chronometer,
A measurement screen (optional),
This experience can be done inside a room southward oriented, or outside in a windless environment.

- 1 - PRINCIPLE

Earth is rotating around itself and also rotating around the Sun. The Earth has, throughout the year, a complex periodical movement. The earth revolution around the Sun determines the different stage of the year. The Earth rotation determines the different stage of the day. However there is two definition of the day :

Sidereal day (from Latin *sideris*, « star ») it lasts 23h 56mn 4s. It is the measure of the Earth's rotation. It is linked to a referential linked to distant stars.

Solar day is 24 hours. It represents the time separating two passages of the Sun at the same Meridian. Indeed if we take the Sun as a reference, Earth has to make a whole rotation to show the next day the same direction of the Sun, (see sketch bellow). This period, of approximately 24 hours, is an average. Solar Day can vary throughout seasons.
Indeed the Earth is not rotating at a constant rate along its ecliptic (plan that goes through the centre of the Sun and that includes the Earth's orbit).

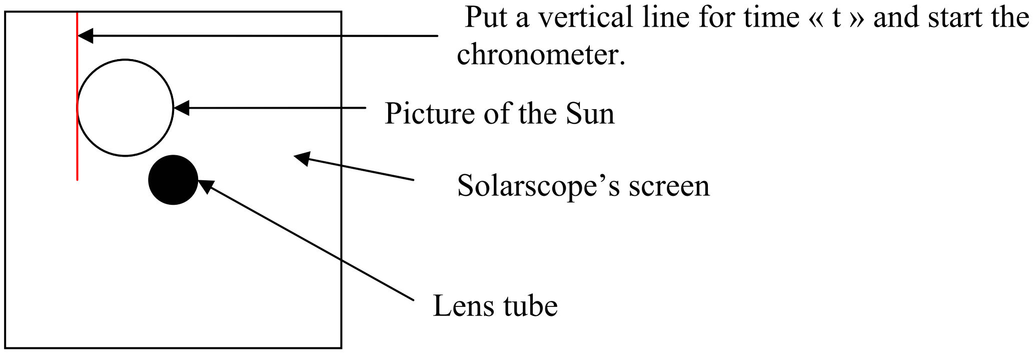


N.B : In a year (of 365 days) the Earth has a revolution of 360 ° around the Sun.
That is to say 1° degree per day.

***Rotation** is : when a star or a planet is spinning on itself.
***Revolution** is : a orbital periodical movement of a star or planet around another star or planet.

- 2 - MEASUREMENT

For children in primary school, the most important notion to remember is solar Day.
Thanks to a chronometer or a watch (that shows seconds) children are able to measure the time of a Solar Day and its slight changes throughout the year.



-1- Make a vertical line on the measuring screen (the Sun will touch this line on one point, it doesn't matter is the line is not completely vertical).

-**2**- In order to get a correct picture of theSun, make all adjustment necessary.

-3- Make separate groups of 2 to 4 children in order to have different results. Each group must have a watch indicating hours minutes and seconds.

-**4-** One child seated next to the Solarscope must give the starting time when the Sun touches the vertical line. Each group must write this time on a note pad, (in hours, minutes and seconds).

-5- Put those results on the board below.

-**6**- Next day, 5 minutes before the starting time, make another measurement. When the Sun touches the vertical line, note the time, (in hours, minutes and seconds). Do remember not to remove Solarscope for 24 hours. Make sure the second measurement is similar to the first one.

-**7**- Put those results in the table on page 6 fill in line 1 to 2.

-**8**- Each group must calculate the length of time, and put it in the table (page 6) form line 3.

If another class is making the same experiment at the same time, you can compare results.
To make sure children take the correct starting time, train them before the experiment.

-3- RESULTS

This experiment can make children aware on measurements and precision, and also that measurement depends on who has taken it.
There is also a whole work on Time's calculation (add, remove......).
It is important to remember that a Solar day is 24 hours (an average done on a whole year). It is due to the Earth revolution around the Sun that slightly varies throughout the year. The Earth's orbit is not a perfect circle.
We are anyway obliged to live on the same hour pattern, by having days of equal value called legal hour.

-4- EXAMPLE

	Group 1	Group 2	Group 3	Etc…
Time of the first top	11 h 07' 45''	11 h 09' 22''	11 h 04' 02''	
Time of second top (next day)	11 h 07' 39''	11 h 10' 09''	11 h 04' 13''	
Time of the day	23 h 59' 54''	24 h 00' 47''	24 h 00' 11''	
Average *	(23h 59'54''+ 24h 00'47''+ 24h 00'11'') : 3 = (71h 59' 112'') : 3 = (71 h 60' 52'') = (72 h 00' 52'') : 3 = 24 h 00' 17''			
Difference with the average (Positive value)	24 h 00' 17'' - 23 h 59' 54'' ------------------ 0 h 00' 23''	24 h 00' 47'' - 24 h 00' 17'' ------------------- 0 h 00' 30''	24 h 00' 17'' - 24 h 00' 11'' ------------------- 0 h 00' 06''	
Average of differences	(23'' + 30'' + 6'') : 3 = 59'': 3 ≈ 20 secondes			
RESULT	During the experiment the result of the calculation of the day has been : 24h00'17 with a precision of 20 seconds.			

Average * : This calculation is difficult for middle school children, teachers can make it for them, and give results, to show them who were the closest to the results.

NB: Calculation of the difference in average is for children in Grammar school.

Notice: According to the days, the picture of the Sun appears at different places.
Do remember that pictures are inverted on the Solarscope. Consequently in a period when days are growing the Sun's picture will be lower (in reality it is higher), when the days are getting shorter, the Sun's picture is higher (in reality it is lower).

Saut de section (page suivante)

Date:

Practical work - 1 : SOLAR DAY MEASUREMENT

Class :

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**	**Group 9**
Time of the first start									
Ending time (Next day) Second top									
Length of the day									
Average:									
Difference in averages									
Averages of differences:									
RESULT :									

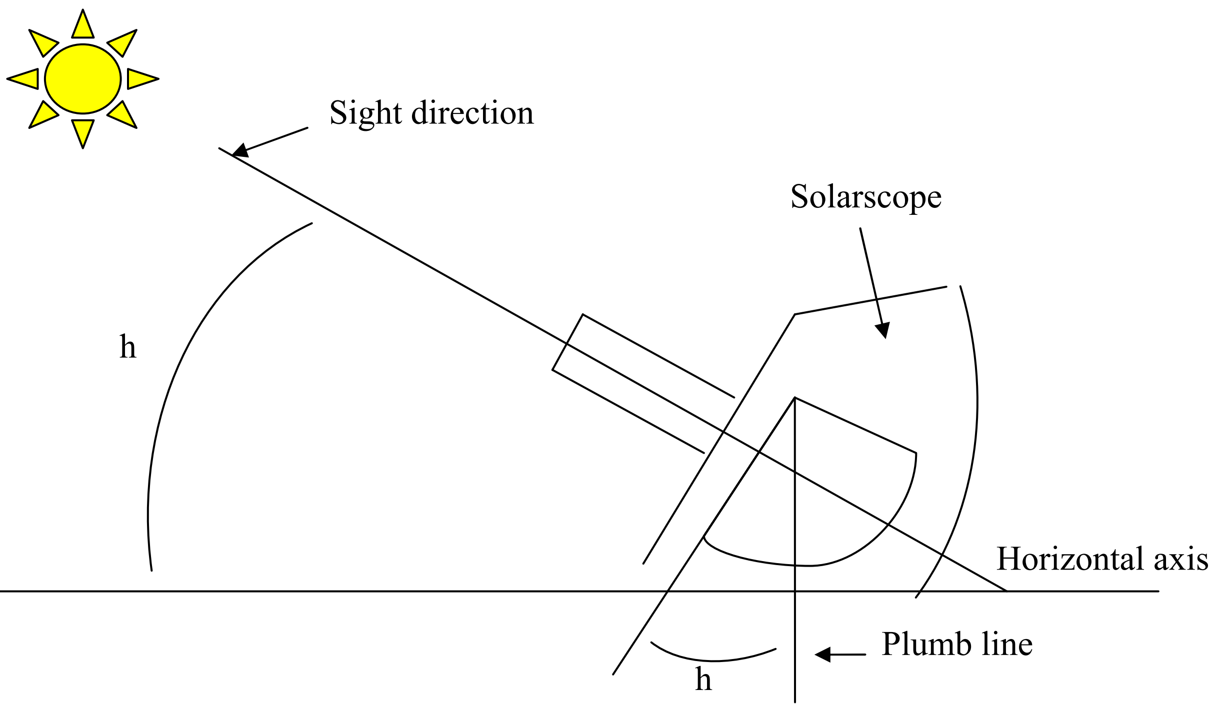
SOLARSCOPE		Level
Practical work - 2	**Solar Noon**	**Middle school**

- TOOLS

A Solarscope,
A plumb line,
A watch indicating hours, minutes, seconds,
A measurement screen.
This experience can be done inside a room southward oriented, or outside in a windless environment.

- 1 - PRINCIPLE

It is noon when the Sun is at its climax (Zenith)
It is called Solar Noon. This "real" Solar Noon corresponds to a maximum angle of sight direction called (h).
The Sun is at its peak.
If we compare it with our watch it is not showing 12:00 AM.
If you wish to measure at anytime of the day the Sun's angle (h) use:
The protractor located on the left side of the Solarscope. To put the plumb line on the protractor, follow the instructions. An angle is indicated by the plumb line, this angle compared to the horizontal is the angle of direction of sight of the lens tube.
When this angle is at its climax it's Solar Noon.
The aim of this Worksheet is to determine the difference in time between Solar Noon and Noon (legal hour).



-2 - MEASUREMENT

If we follow the Sun's path, it is hard to determine exactly the maximal angle of sight. Indeed you cannot make this experimentation for more than 15 minutes in a row.

Here are two methods we offer:

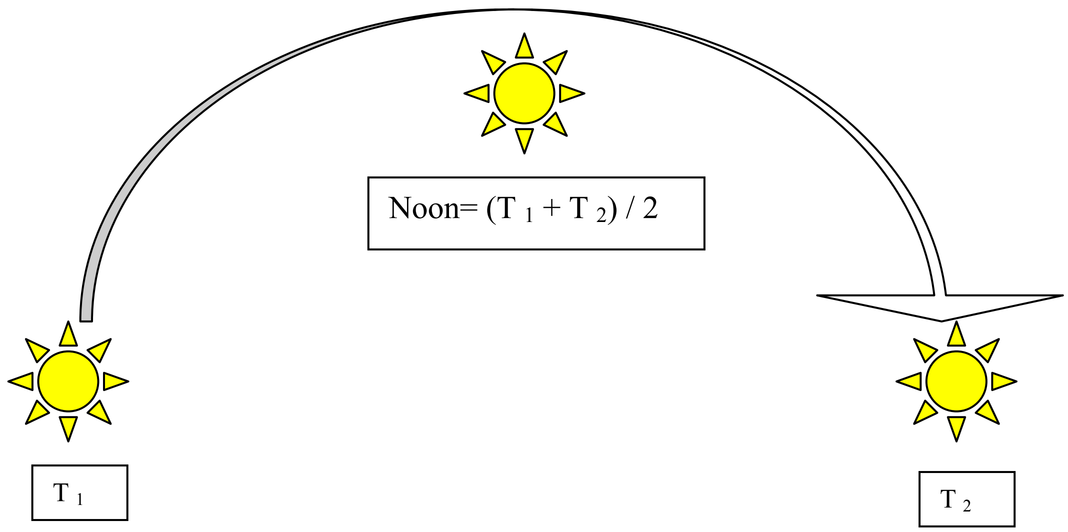
Method n°1:
Set Solarscope on a table. Make sure it is horizontal by using a spirit level.
Set a horizontal line on the Solarscope's measurement screen. (you can use a new measurement screen).
To put a horizontal line on the Solarscope it is best to do it when it is not fully assembled.

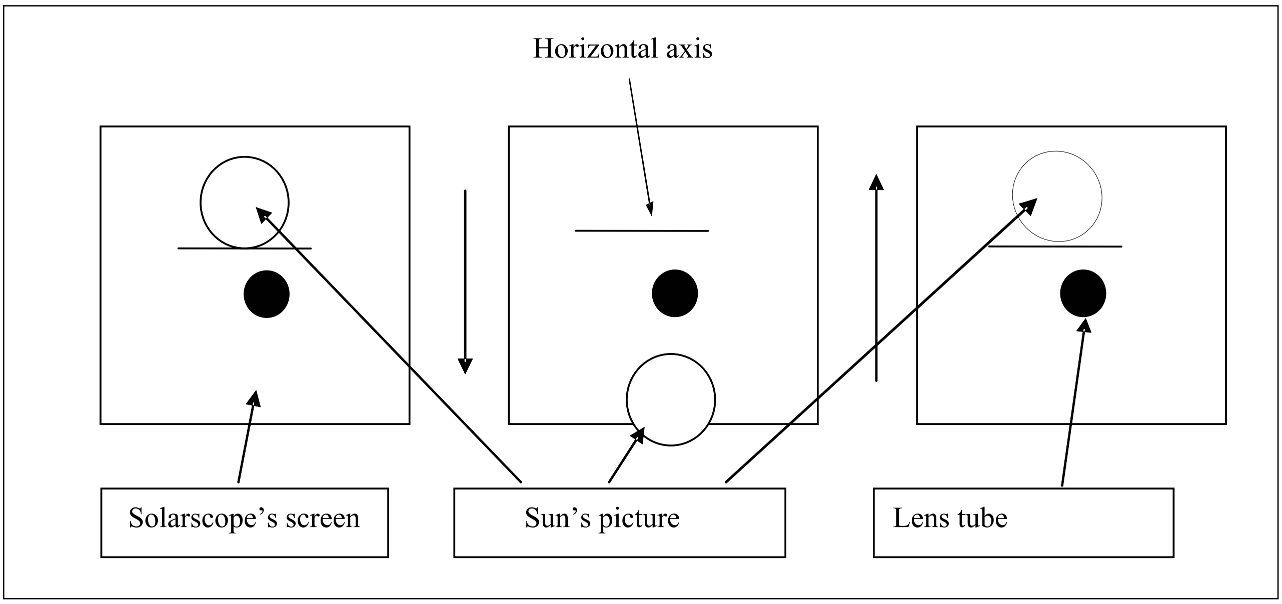
How to measure Solar Noon in 2 steps:

1/ Before Solar Noon:
Note both hours (use your watch) call it t1 and the angle (h) at that same time.
These two measurements correspond to the moment the Sun reaches the horizontal line previously drawn.

2/ After Solar Noon:
Do not modify the Solarscope's sight direction (=in declination), according to a vertical axis.
Note time t2 when the Sun's picture is reaching this horizontal line.
For this experiment adjust Solarscope only in azimuth (according to an horizontal axis).
Make sure the angle h is identical.

Solar Noon is the average of both measurements: $(t_1 + t_2) / 2$.





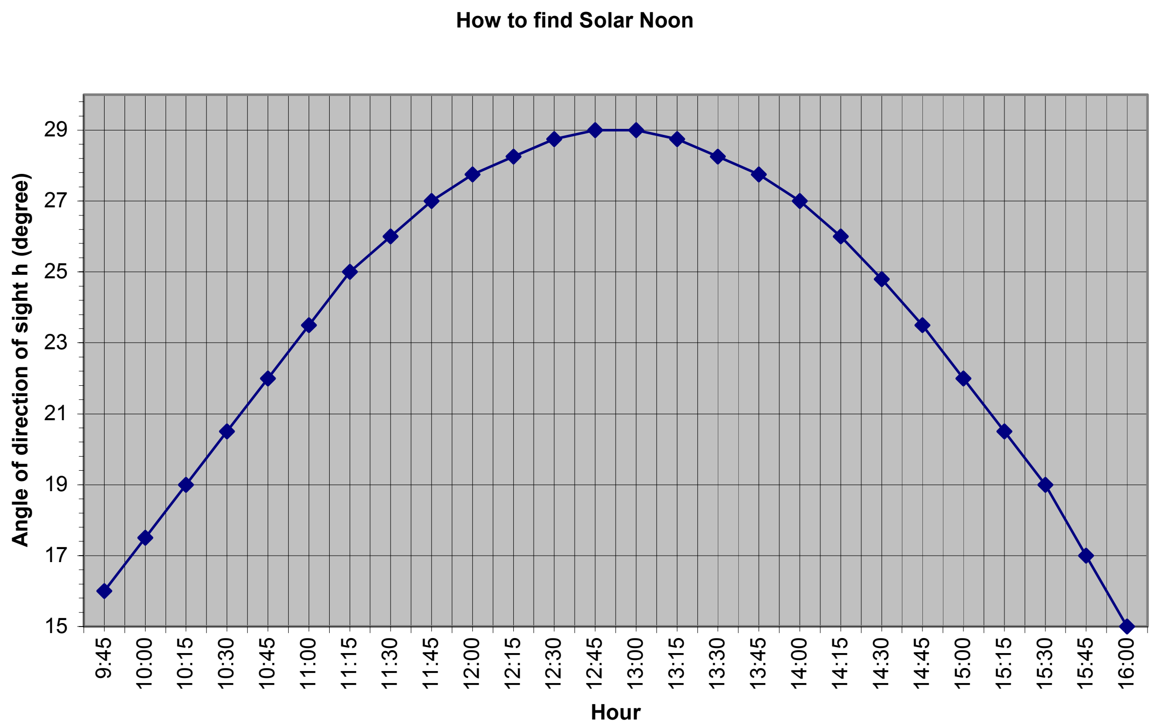
You need to constantly adjust Solarscope on a horizontal axis. This will help to keep the Sun's picture on the screen. If more than 30 minutes are elapsed between t_1 and Solar Noon then the Sun will disappear from the screen in azimuth, (according to a vertical). In this case do not change the angle of sight direction, but wait until the Sun reappears into the screen, by adjusting the Solarscope on a horizontal axis.

Notice: On the Solarscope pictures are inverted. For instance when the Sun is rising, its picture on the screen is falling. When the Sun is going from East to West it is the contrary on the screen.
If you watch at the screen it is easy to see if the Sun is rising or falling before or after Solar Noon.

Method n°2

Note the angle of sight direction on the Solarscope (you can read this angle on the protractor, indicated by a plumb line), according to the time indicated by your watch. Make at least 2 to 3 measurements in the morning and in the afternoon. Different groups can make these measurements at the same time.
Draw a curve and find Solar Noon by graphic interpolation (when the Sun is at its maximum = Solar Noon).

It is best to measure the angle of sight direction every half an hour or at least every hour.
h : corresponds to the time when a picture of the Sun and the lens tube are mixed, (on the measurement screen). The graph below represents measurements done on the 27th of January, under latitude 43°07'11''. In theory Solar Noon is at 12h48 mn AM, on the graph it is at 12h50 mn AM.



3 – RESULTS

We notice a difference in time between Solar Noon and *Noon (legal hour), it depends on what time of the year the experiment has been done. Indeed due to the complexity of Earth's rotation around the Sun: Earth's pole axis are not perpendicular to the ecliptic plan. Moreover Earth's orbit is elliptic and not circular.↔ See WS n° 6 on Time equation (Grammar and Highschool manual).

During Summer time the Sun is at its Zenith (climax) at around 01h30 PM / 02h00 PM (depending on the place of observation). So remember that sunbathing during Solar Noon (and not Noon legal hour) is of a great danger for skin.

You can also use a Gnomon to determine Solar Noon.

- 4 - SOLAR NOON (APROXIMATE VALUE) DEPENDING ON LONGITUDE AND DATE OF OBSERVATION

Date Longitude (degree)	01/01	01/02	01/03	01/04	01/05	01/06	01/07	01/08	01/09	01/10	01/11	01/12
- 5°	13h23’	13h33’	13h32’	14h24’	14h17’	14h18’	14h24’	14h26’	14h20’	14h09’	13h04’	13h10’
- 4°	13h19’	13h29’	13h28’	14h20’	14h13’	14h14’	14h20’	14h22’	14h16’	14h05’	13h00’	13h06’
- 3°	13h15’	13h25’	13h24’	14h16’	14h09’	14h10’	14h16’	14h18’	14h12’	14h01’	12h56’	13h02’
- 2°	13h11’	13h21’	13h20’	14h12’	14h05’	14h06’	14h12’	14h14’	14h08’	13h57’	12h52’	12h58’
- 1 °	13h07’	13h17’	13h16’	14h08’	14h01’	14h02’	14h08’	14h10’	14h04’	13h53’	12h48’	12h54’
0°	13h03’	13h13’	13h12’	14h04’	13h57’	13h58’	14h04’	14h06’	14h00’	13h49’	12h44’	12h50’
1°	12h59’	13h09’	13h08’	14h00’	13h53’	13h54’	14h00’	14h02’	13h56’	13h45’	12h40’	12h46’
0°	12h55’	13h05’	13h04’	13h56’	13h49’	13h50’	13h56’	13h58’	13h52’	13h41’	12h36’	12h42’
3°	12h51’	13h01’	13h00’	13h52’	13h45’	13h46’	13h52’	13h54’	13h48’	13h37’	12h32’	12h38’
4°	12h47’	12h57’	12h56’	13h48	13h41’	13h42’	13h48’	13h50’	13h44’	13h33’	12h28’	12h34’
5°	12h43’	12h53’	12h52’	13h44’	13h37’	13h38’	13h44’	13h46’	13h40’	13h29’	12h24’	12h30’
6°	12h39’	12h49’	12h48’	13h40’	13h33’	13h34’	13h40’	13h42’	13h36’	13h25’	12h20’	12h26’
7°	12h35’	12h45’	12h44’	13h36’	13h29’	13h30’	13h36’	13h38’	13h32’	13h21’	12h16’	12h22’
8°	12h31’	12h41’	12h40’	13h32’	13h25’	13h26’	13h32’	13h34’	13h28’	13h17’	12h12’	12h18’
9°	12h27’	12h37’	12h36’	13h28’	13h21’	13h22’	13h28’	13h30’	13h24’	13h13’	12h08’	12h14’

Theses figures have been found by taking into account changes of time for Summer and Winter. (Time is changed on March and October).

If you wish to know the longitude of your place of observation, go to the Geography Institute web site. (also see Worksheet – 4 for longitudes of some French cities).

To improve these figures make a proportion between dates and places.The accuracy will be of 1 to 2 minutes.

Example : Place of observation : Vannes (Brittany) on the 19th of April. Longitude: – 02°45’37’’.

On the 01/04, for a longitude of -3°, the solar noon is at14h16mn. On the 01/05, for a same longitude, the solar noon is at 14h09mn; consequently on the 19/04 solar noon is round about 14h12mn.

When longitude varies from +1°, Solar Noon put back 4 mn.
In Vannes, on the 19th of April, solar noon is round about 14h 15mn…… It is to be confirmed by experimentation !

Practical work -2 - SOLAR NOON			
Name :			
Class :			
Date :			
Longitude :			
Theorical Solar Noon :			
h (degrees)	Hour (hour, minutes)	h (degrees)	Hour (hour, minutes)