The Sundial Primer
ZW2000 and Your Sundial

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At this point I assume that you have downloaded and set up ZW2000 on your computer. If not please read "Getting Started with ZW2000".

Initiate the program ZW2000. Figure 1 shows the ZW2000 introductory screen that appears when you start up the program.
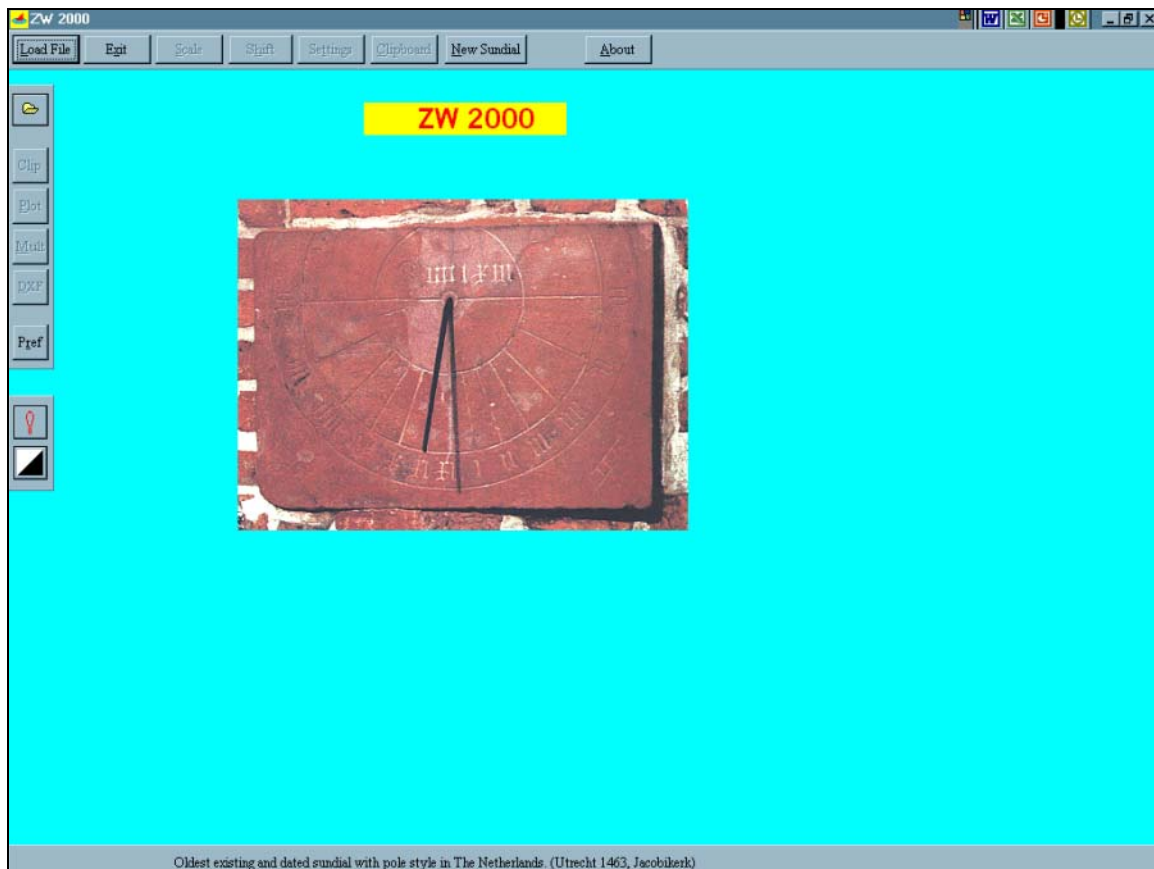

Figure 1: ZW2000 Intro Screen

The manual that comes with ZW2000 describes all the features of the program and should be read thoroughly. This document is intended to help you learn what you need to know to design three particular sundials:

1. A horizontal sundial.
2. A vertical direct south (Northern Hemisphere) or north (Southern Hemisphere) sundial.
3. A vertical declining sundial.

There are many features provided with ZW2000 but they will not all be discussed at this time. As was mentioned above, this document deals with introducing you to what you need to know to design these three sundials. Separate instruction sets describe in detail how to design the three sundials.

Select the "New Sundial" button and the screen shown in Figure 2 will be displayed. All the
data required to design a sundial are entered on this one page. This page will always contain
the data entered and options selected from the last time you worked with the program. The
page is divided into two areas. The "general layout" area is where you enter the type of
sundial you wish to decide and information about its location. This area also displays some
useful data that the program calculates. The "kind of lines" area is where you select the type
of hour lines you want displayed and whether the sundial will have analemma and declination
lines.

Figure 2: ZW2000 Data Input Screen

Before examining these areas in further detail let's select the "definitions" button. Figure 3
shows some of the definitions; as you would need to scroll down to see the rest. These
definitions are also provided in the manual. If you select the "save as defin.txt" button the
definitions will be saved as a text file in the "ZW2000" directory and then print them out. They
are very useful when you are trying to remember the range and signs of values you need to
enter. The definitions are available at the end of this document as well as the two images.
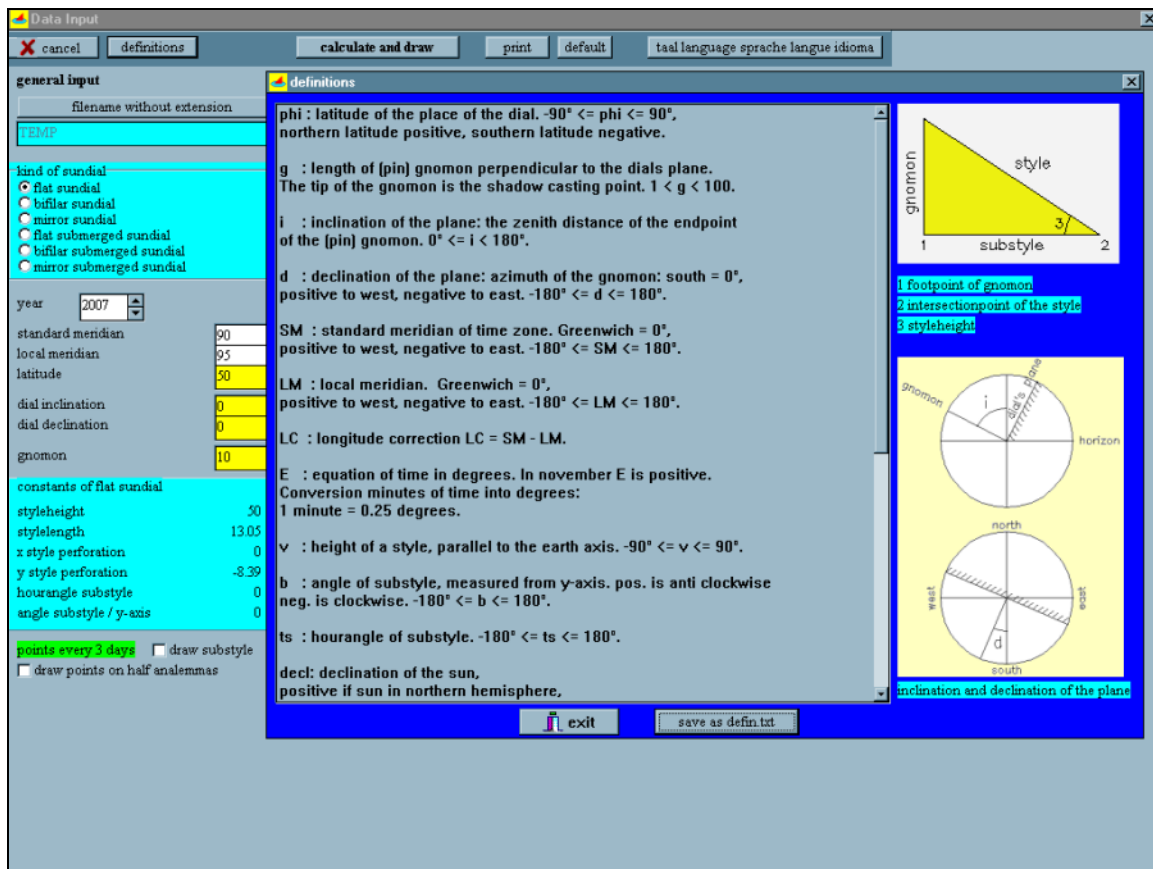
Figure 3: ZW2000 Definitions

"<u>general layout</u>"

Figure 4 shows the "general layout" area of the screen. The first item is "filename without extension" and it contains the default entry "TEMP". Select this button if you want to save the sundial under a different file name. A "Save As" window will appear where you can enter a new file name. The ZW2000 design will be saved with the name entered here and the ZW2000 "rlt" extension when the "calculate and draw" button is selected. The file name cannot be longer than 8 characters.

The next item is the "kind of sundial" that will be designed. These instructions will only be dealing with a "flat sundial" and that is what should be selected. You can read the ZW2000 manual to learn more about the other selections.

Figure 4: ZW2000 – "general layout"

The next section requires the selection and entry of a variety of information used to design a sundial. This is where the definitions will be useful. Let's review them.

year:

The year is used to calculate the Equation of Time required for the design of some sundials, for example a sundial that has an analemma on the hour lines. Any year from 1900 to 2200 can be entered but choose one in future and in the middle of a leap year period. This will provide a more average calculation.

standard meridian:

This is the standard meridian of the time zone where the sundial is located, where Greenwich is equal to 0°. Positive to the west and negative to the east with a range of -180° <= SM <= 180°. The value will usually be 0° or ± 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, or 180°.

local meridian

This is the longitude where the sundial is located, where Greenwich is equal to 0°. Positive to the west and negative to the east with a range of -180° <= LM <= 180°.

latitude

This is the latitude where the sundial is located. Latitudes in the Northern Hemisphere are positive and latitudes in the Southern Hemisphere are negative with a range of -90° <= phi <= 90°.

dial inclination

If the sundial does not lie on the horizontal or vertical plane it is an inclined sundial. ZW2000 **does not** use the inclination of the dial plate but rather the inclination of a pin gnomon from zenith. Study the image in the definitions section carefully. The inclination range is 0° <= i < 180°.

The following are the two "dial inclination" values that will be used in the designs that will be considered:

- 0°   - horizontal sundial
- 90°   - vertical sundial

dial declination

If the sundial does not lie in one of the cardinal directions, which include north, south, east and west it is a declining sundial. South is a declination of 0°. If the pole gnomon is rotated to the west the declination is positive and if the pole gnomon is rotated to the east the declination is negative. Study the image in the definitions section carefully. The declination range is -180° <= d <= 180°

The "dial declination" is normally used when designing a vertical declining sundial. It is equal to the declination of the wall where the sundial will be located as long as the signs are maintained as defined above.

gnomon

This is the length of the pin gnomon perpendicular to the dial's plane. The tip of the gnomon casts the shadow and this length is used to determine the position of the analemma and declination lines when they are displayed on the sundial. The range for this length is 0 to 100.

This length defines the position of a "nodus" that is used to calculate the position of date and declination lines.

Check out the "Sundial Configuration Table" for information regarding a number of sundials and the entries required to design them.

Converting Degrees/Minutes/Seconds to Decimal Degrees

The standard meridian, local meridian and latitude must be entered in decimal format. The local meridian is usually a whole number. The conversion is made as follows:

Decimal Degrees = Degrees + [Minutes + (Seconds / 60)] / 60

Example: 95° 52' 31" or 95 Degrees 52 Minutes 31 Seconds
Decimal Degrees = 95 + [52 + (31/60)] / 60 = 95 + [52 + 0.5167] / 60 = 95 + 52.5167 / 60 =
                    95 + 0.8753 = 95.8753°

Maintain at least 4 decimal places for accuracy. The reason for this can be demonstrated by converting the decimal degrees back to degrees, minutes and seconds.

0.8753 x 60 = 52.518 minutes and 0.518 x 60 = 31.08 seconds

or 95° 52' 31.08" that is very close to what we started with.

The next section or "constants of flat sundial" displays data the program calculates and may be used in certain circumstances. What is displayed here depends upon the "kind of sundial" selected to be designed. Because of the data entered to create Figure 2 this section is not complete for a flat sundial but it is in Figure 3. The information displayed for a "flat sundial" will be discussed here, as this is what we will be designing.

styleheight

This is the angle the style makes relative to the dial plate. Study the image in the definitions section.

stylelength

This is the length the style on a triangular gnomon. It casts the line shadow used to tell the time. Study the image in the definitions section.

x style perforation

This is the x co-ordinate of the intersection point of the style and sub-style on the dial plate. This is relative to the co-ordinates of the foot point of the gnomon that is defined to be 0,0. Study the image in the definitions section.

For horizontal and vertical direct north /south sundials this value is 0.

y style perforation

This is the y co-ordinate of the intersection point of the style and sub-style on the dial plate. This is relative to the co-ordinates of the foot point of the gnomon that is defined to be 0,0. Study the image in the definitions section.

hourangle substyle

This is the hour angle of the sub-style and has a range of -180° <= ts <= 180°.

For horizontal and vertical direct north /south sundials this value is 0. This value is non-zero for a vertical declining sundial.

angle substyle / y-axis

This is the angle the sub-style makes relative to the positive y-axis and has a range of -180° <= b <= 180°. The angle is measured anti clockwise if it is positive and clockwise if it negative.

For horizontal and vertical direct north /south sundials this value is 0. This value is important when designing a vertical declining sundial as it defines the position of the gnomon.

The final section has three selections that can be made. It is important to note that any selection made in this are will be reset after "calculate and draw" is selected. You must re-select these items if they are to apply for the next design.

points every 3 days

This can be toggled to "points every 1 day" and determines whether the points for lines and curves are calculated every day or every 3 days.

draw substyle

Selecting this item will result in drawing the sub-style on the sundial. This is not required for horizontal and vertical direct sundials as the sub-style lies of the y-axis. This should be selected when designing a vertical declining sundial. It will aid in positioning the gnomon.

draw points on half analemmas

Selecting this item will result in a window opening up when you select "calculate and draw" and you have asked for half analemma in "kind of lines". Depending upon your selection certain points will be marked on the analemma when the sundial is drawn.

"kind of lines"

Figure 5 shows the "kind of lines" area of the screen. This area allows you to select the type of hour lines and declination curves the sundial will contain. For the sundials being designed, only the following "kind of lines" will be considered.

	kind of lines			begin	end	step
A	local time			0	24	1
B	local time + full analemma			0	24	1
C	local time + half analemma 21 dec - 21 jun			0	24	1
D	local time + half analemma 21 jun - 21 dec			0	24	1
E	standard time			0	24	1
F	standard time + full analemma			0	24	1
G	standard time + half analemma 21 dec - 21 jun			0	24	1
H	standard time + half analemma 21 jun - 21 dec			0	24	1
I	sidereal time 21 dec - 21 jun			0	24	1
J	sidereal time 21 jun - 21 dec			0	24	1
K	date lines (day, month)	⦿ 1/ month	○ 1,16/ month ○ none	🟥	choose	
L	declination lines	⦿ 3 lines	○ 7 lines ○ none	🟥	choose	
M	altitude lines			0	90	10
N	azimuth lines			-180	180	22.5
O	babylonian hour lines			0	24	1
P	italian hour lines			0	24	1
Q	antique hour lines			0	12	1
R	islamic prayer lines					
S	planetary hour lines 21 dec - 21 jun			0	12	1
T	planetary hour lines 21 jun - 21 dec			0	12	1
U	ascendants 21 dec - 21 jun			0	12	1
V	ascendants 21 jun - 21 dec			0	12	1
W	astrological houses			6	12	1
X	CheckBox24					
Y	CheckBox25					
Z	CheckBox26					

Figure 5: ZW2000 – "kind of lines"

A local time

The sundial will contain hour lines that indicate local apparent or sun time.

E standard time

The sundial will contain hour lines that indicate zonal solar time. This is "local time" corrected for longitude but not the equation of time.

K date lines (month, day)

The sundial can contain a date line on either the first day of ever month or the first and sixteenth day of every month. However, if the "choose" box is selected a calendar appears

and you can choose any day of the year. This is great if you would like to include a date line for a special occasion such as a birthday or anniversary.

L declination lines

The sundial can contain declination lines based on the selection. "3 lines" will display the lines for the solstices and equinoxes. "7 lines" will display the lines for the sun's declination as it enters each sign of the 12 zodiacs. If the "choose" box is selected you can enter and declination you want to have displayed.

The hour lines can be further defined by the following entries:

begin

This is the earliest hour line that will be displayed on the sundial. Enter a value of 0 to 24 hours in decimal format. e.g. 2:30 a.m. = 2.5, 6:45 p.m. = 18.75

end

This is the latest hour line that will be displayed on the sundial. Enter a value of 0 to 24 hours in decimal format. e.g. 2:30 a.m. = 2.5, 6:45 p.m. = 18.75

step

This is the time interval between hour lines that will be displayed on the sundial. Enter a value of 0 to 24 hours in decimal format. e.g. 60 minutes = 1, 15 minutes = 0.25

To have your sundial display the maximum number of hours the "begin" and "end " values are the times of sunrise and sunset on the summer solstice at the latitude where the sundial will be located. You can use the declination lines to help you determine this. The lines can be removed if they are not needed in the final design.

Now you are ready to start your sundial design. There are three additional sets of instructions that will help you to design one of the following sundials:

1. A horizontal sundial.
2. A vertical direct south (Northern Hemisphere) or north (Southern Hemisphere) sundial.
3. A vertical declining sundial.

There are two additional buttons available on the left when the sundial design is displayed. They are:

- An Analemma Shape: This will open a window where a year can be entered. Selecting "OK" button will display a graph of the Equation of Time and the sun's declination for the entered year.

- A Black & White Box: This will open a box where the latitude, dial inclination and dial declination can be entered. Selecting "OK" button will display a graph showing the times of sunrise and sunset for the entered location. A dial declination cannot be entered for a horizontal sundial, that is when the dial inclination is "0".

Happy Dialling!

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ZW2000 DEFINITIONS

phi : latitude of the place of the dial. -90° <= phi <= 90°,
northern latitude positive, southern latitude negative.

g : length of (pin) gnomon perpendicular to the dial's plane.
The tip of the gnomon is the shadow casting point. 1 < g < 100.

i : inclination of the plane: the zenith distance of the endpoint of the (pin) gnomon.
0° <= i < 180°.

d : declination of the plane: azimuth of the gnomon: south = 0°,
positive to west, negative to east. -180° <= d <= 180°.

SM : standard meridian of time zone. Greenwich = 0°,
positive to west, negative to east. -180° <= SM <= 180°.

LM : local meridian. Greenwich = 0°,
positive to west, negative to east. -180° <= LM <= 180°.

LC   : longitude correction LC = SM - LM.

E : equation of time in degrees. In November E is positive.
Conversion minutes of time into degrees:1 minute = 0.25 degrees.

v : height of a style, parallel to the earth axis. -90° <= v <= 90°.

b : angle of substyle, measured from y-axis.
pos. is anti clockwise, neg. is clockwise.
-180° <= b <= 180°.

ts : hour angle of substyle. -180° <= ts <= 180°.

decl : declination of the sun,
positive if sun in northern hemisphere, negative if sun in southern hemisphere.
-23.°5 <= decl <= 23.°5

t : hour angle of the sun: noon = 0°, positive to west, negative to east.
-180° <= t <= 180°.

x,y : coordinates of shadow point. Foot point gnomon = 0,0. x to right, y upwards.
For horizontal dial x east, y north.

dn : day number.
January first at 00:00:00 is day number 1.0, at 12:00:00 is day number 1.5.

threads   : parallel to the plane and perpendicular above 0,0 at distance height.
           If rotation = 0 thread-x parallel to x-axis, thread-y parallel to y-axis.

rotation   : angle of rotation of the threads for bifilar dial. -180 <= rotation <= 180.
           rotation positive is anti clockwise, rotation negative is clockwise

height-x, height-y : perpendicular distance from point 0,0 to threads. 1 < height < 100.

refraction index   : for water the refraction index is about 1.333.
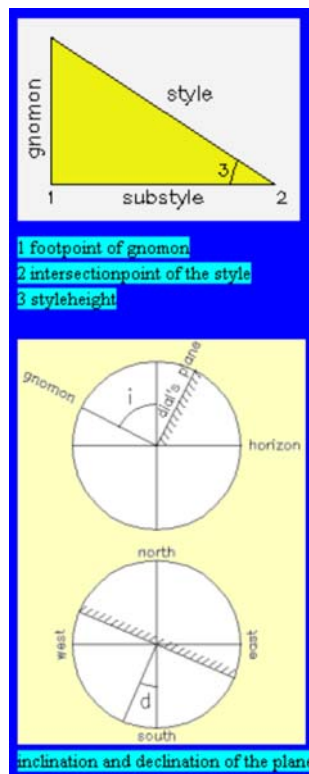
Sundial Configuration Table

Sundial Type	standard meridian	local meridian	latitude	dial inclination	dial declination
equatorial (upper face)	SM	LM	phi	90-phi	180
equatorial (lower face)	SM	LM	phi	90+phi	0
polar	SM	LM	phi	phi	0
horizontal	SM	LM	phi	0	0
vertical south (NH) vertical north (SH)	SM	LM	phi	90	0
vertical north (NH) vertical south (SH)	SM	LM	phi	90	180
vertical east	SM	LM	phi	90	-90
vertical west	SM	LM	phi	90	90
vertical declining	SM	LM	phi	90	d
inclining	SM	LM	phi	i	0
inclining/declining	SM	LM	phi	i	d

Notes:
1. NH: Northern Hemisphere, SH: Southern Hemisphere
2. SM, LM, phi, d and i are defined in the definitions section.
3. Note the inclination "i" does not refer to the slope of the dial plate but to the "gnomon" relative to zenith.