**TEACHER'S NOTES**

# Walk-On Analemmatic Sundials
## Brian Albinson June 2008

**Background**

Sundials were a personal and social necessity before the middle of the $17^{th}$ Century. From the $13^{th}$ to $17^{th}$ Century mechanical verge and foliot clocks were available but only kept time to the nearest hour and they needed resetting by sundial whenever the sun shone. You can make a sundial out of almost anything that throws a shadow.
Many dial types have been devised. The ones most often seen have a sloping gnomon; these were the standard Renaissance sundial and could be found in every town and village in Europe. They are in two sub groups; horizontal dial face and vertical dial face, the one most seen is the horizontal or 'garden' dial. Vertical dials were often built over church doors to remind folk of prayer time. Both have gnomons (pointers) with a slope parallel with the Earth's axis and pointing North. These dials were probably brought back to Europe by the Crusaders in the $13^{th}$ Century. Another, less common type, is the equatorial dial with face plane parallel to the equator plane.

Many very beautiful interpretations of the various Renaissance dials were, and still are, constructed. One beautiful Equatorial dial can be seen in Vancouver on the beach at English Bay. All assumed that the apparent sun kept perfect time through the year. The **analemmatic** dial was introduced in France in the $17^{th}$ Century, and is one of the very few dials that are not of Middle East origin. Analemmatic dials have been rarities, largely because of better clocks, but also because of the difficulty in calculating the dial parameters before computers became available. They are now being constructed in many public places, particularly schools, as examples of public art.

The pendulum clock, introduced by Huygens in 1665, kept time to within a few seconds a day and made sundials obsolete. The pendulum was a technical breakthrough comparable with the transistor. The pendulum also highlighted a fundamental difference between mean time kept by clocks and sun time kept by the simple sundial. The error, caused by a combination of the elliptical orbit of the earth and the tilt of the earth's axis, is called the Equation of Time (EoT) and can be about a quarter of an hour fast or quarter of an hour slow compared with mean time.

Several methods are used to correct sundials to allow for the EoT. All use either some mechanical shifting device or some application of a graph or tables. The social need for more accurate timekeeping coincided with the introduction of the pendulum clock and the need for more accurate sundials vanished when pendulum clocks became available.

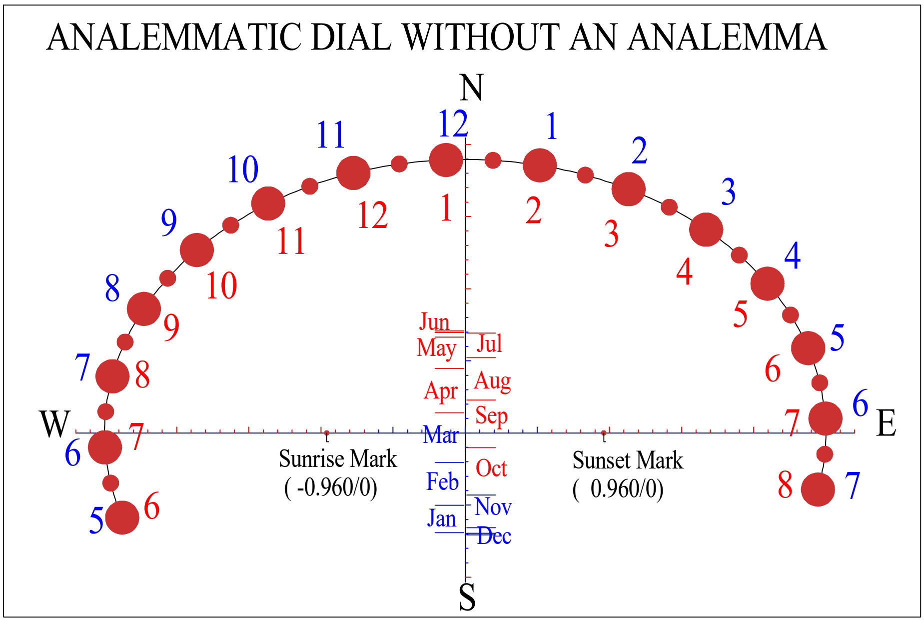
**ANALEMMATIC SUNDIALS**

The origins of this type of dial are somewhat obscure; the first known example is in the Church at Brou in France. The Church was built in 1506 but the dial was probably added in the $17^{th}$

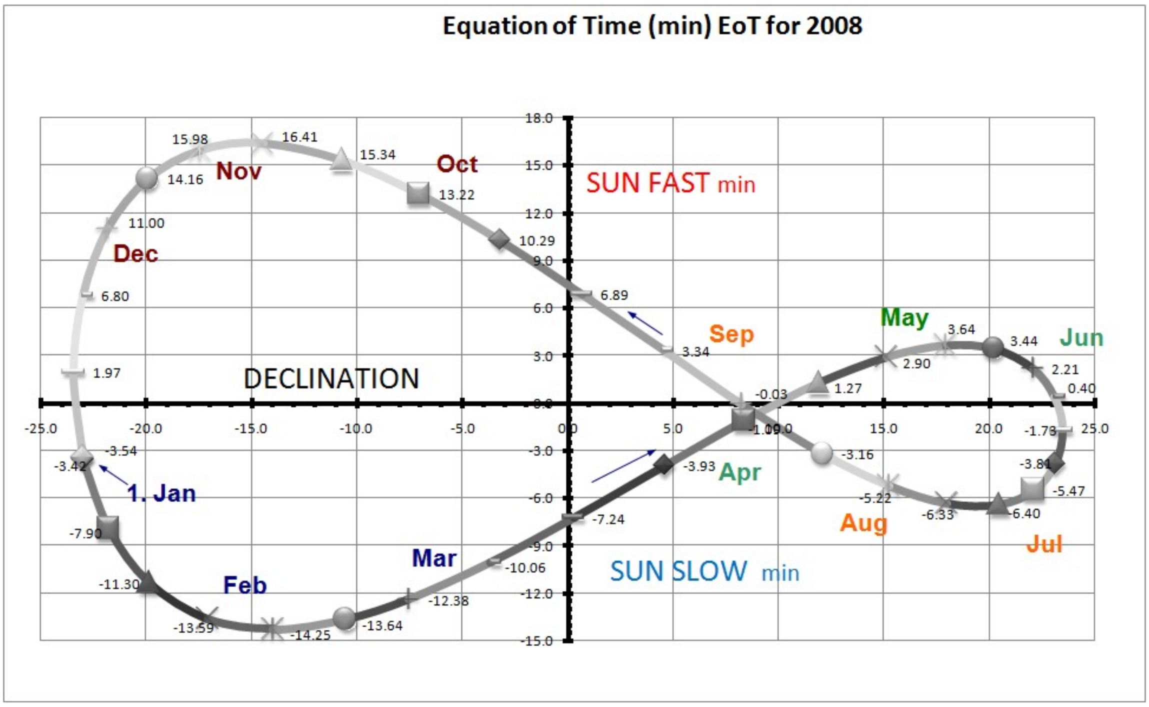
Century. The relationship between the ellipse and the pointer location is not obvious, and the concept seems to have been discovered, perhaps serendipitously, in the period 1532 to 1640. The computation was formalised and published in graphical form by a French mathematician J.J. de Lalande in 1756.

## Basic Analemmatic Sundials

The basic analemmatical sundial comprises an elliptical dial face drawn on a horizontal surface and having the hours marked on the ellipse. The shape of the ellipse depends on the latitude of the site. The minor axis of the ellipse points to the geographical North and contains the gnomon placement on a given date (the Zodiac line). The position of the gnomon is a function of the sun's declination and the latitude of the site. The major axis lies on the East-West line. Analemmatic dials can be any size. The moveable vertical gnomon, which may be a person on large dials, casts a shadow which shows the **sun time** where it intersects the ellipse. Only the direction of the shadow is needed, not its point; the gnomon can be any height which is sufficient for the shadow to indicate sun time on the dial.




**The basic analemmatic dial provides sun time,** but the apparent sun wanders away from the mean time which we use for our watches. The difference is called the Equation of Time (EoT). A graph of the EoT is shown below:

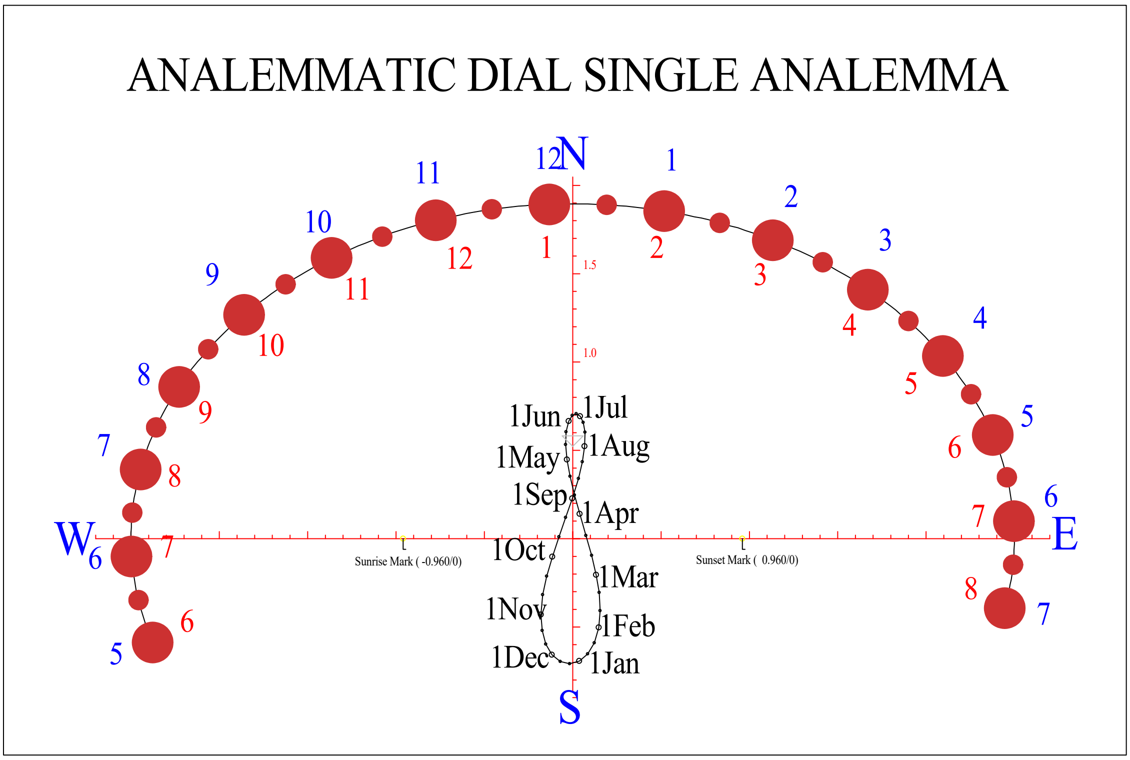



The maximum values are about 17 minutes fast in late Fall and 15 minutes slow in early spring. In February the sun is slow, so we need to nudge the shadow forward in time. In October the sun is fast so we need to nudge the shadow back a bit in time. The shifts required are shown in the graph of the EoT and when this is plotted for the whole year against the declination of the sun the resulting figure looks like a figure '8' and is called an **analemma**.

## ANALEMMATIC DIAL WITH SINGLE ANALEMMA

To find **mean time** from our dial we need to apply the EoT to the **sun time**. This can be done in two ways, by providing some form of direct correction such as an analemma on the dial itself or by reading the sun time and then applying a correction for the EoT from tables or graphs. One '8' analemma can be scribed on the zodiac (central) axis of the dial to give approximate mean time directly.

Note: The entire dial is called an analemmatic dial, with or without the figure '8' analemma.




**Use of Walk-On Analemmatic Dials**

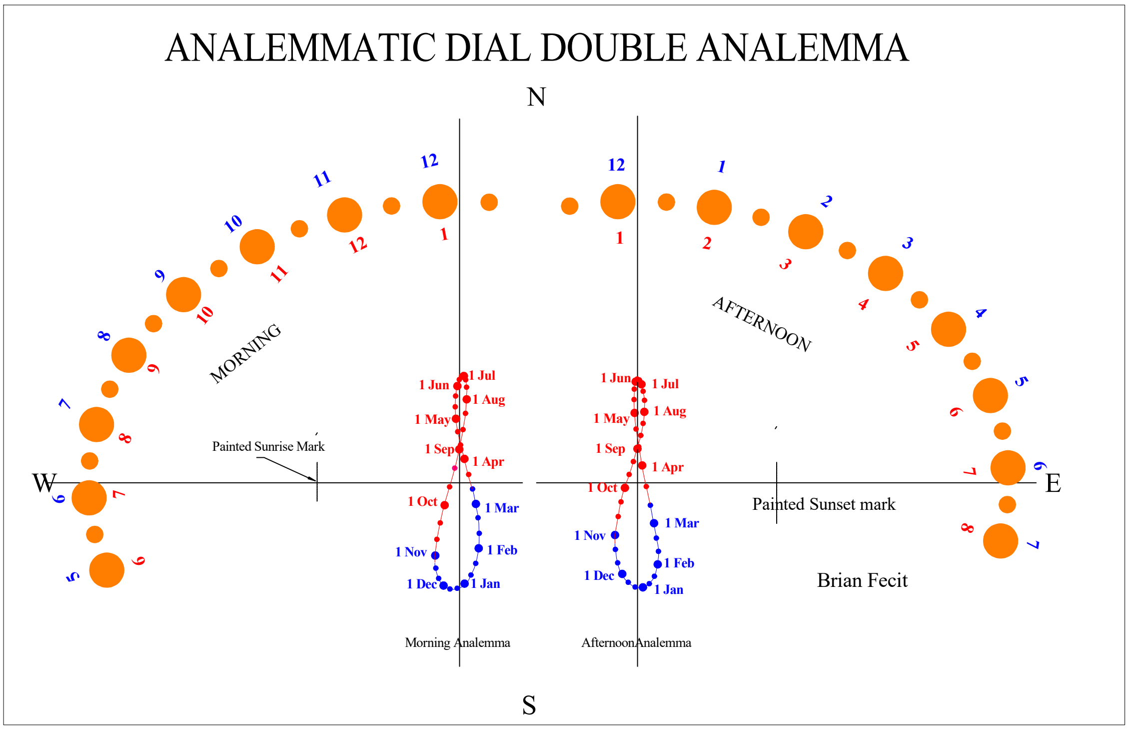
Single analemma Walk-On analemmatic dials have one ‘8’ analemma superimposed on the zodiac axis and are capable of giving approximate mean time by direct use of the figure ‘8’ analemma. The dial is marked with both Pacific Standard Time and Pacific Daylight Saving Time. The size of the dial is a compromise, too large a dial and the person’s shadow never reaches the ellipse, too small a dial and the shadow overwhelms the ellipse. School Walk-On dials generally use a 2.5m semi major axis for the ellipse.

Stand on the ‘8’ analemma with heels together on the correct date and with your back to the sun. The mean time will be shown approximately on the dial by your shadow. The single analemma dial used in this way has inherent errors which vary by the time of day and the time of year. The errors during school hours are less than +-5 minutes for the whole year (within the accuracy of reading a human shadow) ; but can be up to 16 minutes in the early morning and late afternoon.

The figure of eight shape is not only a beautiful decoration but could encourage an inquiring mind to look further into the movements within the solar system.

## ANALEMMATIC DIALS WITH DOUBLE ANALEMMAS

To get almost perfect results for automatic correction for the equation of time using an analemma, the Walk-On dial has to be split into two halves, one on the left for morning with a morning analemma and one on the right with an afternoon analemma for the afternoon.




The computations are quite complex. Only one dial with double analemmas is recorded in the literature, in the Du Pont family gardens at Longwood Gardens near Philadelphia. It was built in the 1930s and uses an accurate moveable pointer. The designer spent 10 years crawling after the Sun's shadow to get the design. Before computers it was impracticable to do this theoretically. The average deviation for a double analemma dial designed by computer is about 32 seconds of time. Double analemma dials have been recently made at the Simon Fraser University, Seycove High School and currently Highlands Elementary School.

The additional work in constructing the double analemmas is not great. If there is adequate voluntary support for construction I would recommend the double analemma; it gives accurate mean time readings for the whole day and it adds an additional element of interest.

**Sunrise and Sunset**
The time of Sunrise and Sunset on any day can be read very approximately directly off the dial. Stand on the analemma at the date required and look directly over the Sunrise or Sunset mark, the time of the event will be shown very approximately on the dial.

**Adjustment for Time Zone.**

The centre of the Pacific Time Zone is 120 degrees or 8 hours West of Greenwich. The Longitude of North Vancouver is about 123.06 degrees West of Greenwich, the difference of 3.1 degrees ( or 3.1x4=12.4 minutes) has to be allowed for on the dial face by moving the hour marks 12.4 minutes early. This can be done automatically in the 'ALEMA'software.

**General**
The objective is to create a beautiful interpretation of the motion of our solar system, not to create an accurate timekeeper. Even though the parameters are rigidly fixed there is an infinite possibility of artistic presentation and interpretation.

An example of a beautiful single analemmatic dial is: