Analemmatic Sundial

Safety Precautions
- NEVER look directly at the Sun!

Vocabulary
- analemmatic sundial - horizontal sundial that has a vertical gnomon and hour markers positioned in an elliptical pattern
- aphelion - the point in a planet's orbit when it is farthest from the Sun
- autumnal equinox - the point at which the Sun's path crosses the celestial equator moving from north to south
- declination - the angular distance of a point north or south of the celestial equator
- ellipse - a regular oval shape
- equinox - the time and date at which the sun crosses the celestial equator
- gnomon - the projecting piece on a sundial that shows the time by the position of its shadow
- latitude - the angular distance of a place north or south of the Earth's equator
- perihelion - the point in a planet's orbit when it is closest to the Sun
- solar declination - the angle made between a ray of the Sun, when extended to the center of the Earth
- spring equinox – the point at which the Sun's path crosses the celestial equator moving from south to north
- solstice – the time and date at which the Sun reaches its highest or lowest point in the sky at noon
- summer solstice - the solstice that marks the onset of summer
- winter solstice - the solstice that marks the onset of winter

Materials and Equipment
- large tarp
- packing or other transparent tape
- white computer paper, for hour and date indicators
- meter stick
- scissors
- Excel spreadsheet: http://denisemeeks.com/hawaii_science/activities/ast/analemmatic_sundial_activity_calculator.xls

Construction
Follow the instructions listed on http://denisemeeks.com/hawaii_science/activities/ast/analemmatic_sundial_activity_calculator.xls

To construct an *analemmatic sundial* we need to know:
1. the size of the *ellipse* (how big is our tarp?)
2. the *latitude* of its location (where are we going to use our sundial?)
3. the *declination* of the Sun (we can look this up on the Internet).

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Questions

1. Why does this sundial have an oval shape?
2. Will an analemmatic sundial provide the correct time?
3. If you stand on a date other than today's date, will the analemmatic sundial provide the correct time?
4. If we used this sundial at different latitudes, for example in Tucson, Arizona (32^0N), San Francisco, California (38^0N), Anchorage, Alaska (61^0N), or Svalbard, Norway (78^0N), would it provide the correct time?
5. The Earth is farther from the Sun during northern hemisphere summer, and closer to the Sun during northern hemisphere winter. Why are temperatures higher during northern hemisphere summer than during the northern hemisphere winter even though the Earth is farther from the Sun?

Research

Analemmatic sundials are a type of horizontal sundial that has a vertical *gnomon* (you) and hour markers positioned in an elliptical pattern.

Analemmatic sundials mark *solar time* rather than *clock time*, but since our sundial is adjustable, we can adjust it to provide the correct clock time.

When designing an analemmatic sundial we need to know at approximately what latitude it will be used. This sundial is designed for use in Hawai'i, at a latitude of 20^0N (the N means north), so it will work at latitudes close to 20^0N, but won't provide accurate times if we use it at latitudes much higher or lower than 20^0N.

The Earth orbits the Sun approximately once every 365.25 days. Its distance from the Sun changes because the Earth's orbit is an ellipse, not a circle. When the Earth is farthest from the Sun its orbital speed is slower than when it is close to the Sun. The elliptical shape of Earth's orbit and its changing orbital speed are responsible for the elliptical shape of the sundial.

The Earth is tilted at 23.5^0 from the plane of its orbit. In the summer, the northern hemisphere is tilted *toward* the Sun, which means that the northern hemisphere is warmer than the southern hemisphere. The Earth is *farthest* from the Sun on July 4.

In the winter, the northern hemisphere is tilted *away from* the Sun, which means that the northern hemisphere is cooler than the southern hemisphere. The Earth is *closest* to the Sun on January 4.

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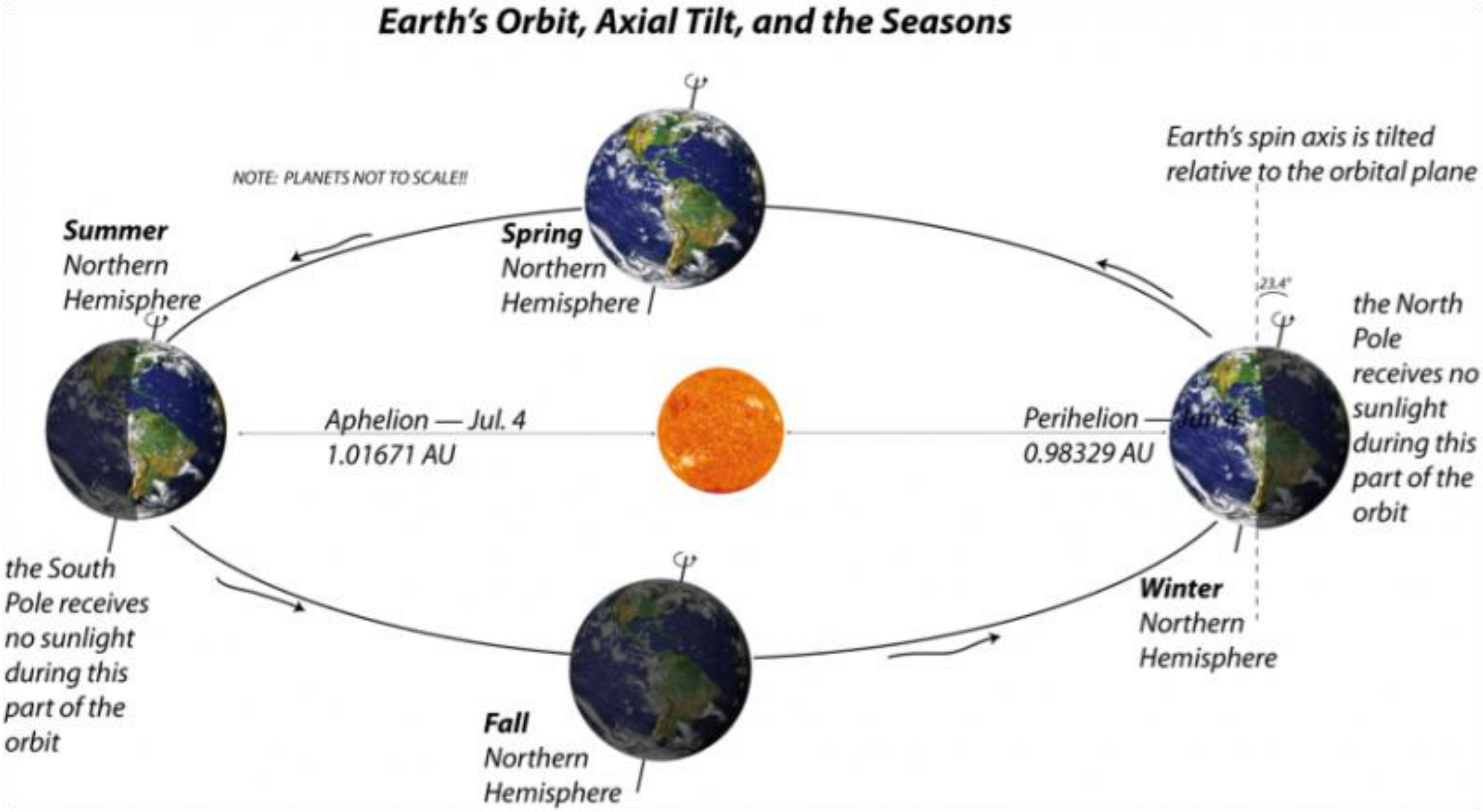

Source: https://www.e-education.psu.edu/earth103/node/1004

Hypothesis

What is your hypothesis? Be sure to include your "best guess" answers to the 5 questions above.

1.

2.

3.

4.

5.

Experiment

1. Stand on the sundial, with the back of your right foot on today's date.
2. Raise your right hand and observe where its shadow lands on the sundial.
3. Repeat this process, standing on other dates, and record where the shadow of your right hand falls.

Data and Observations

- What time was indicated by the sundial when you stood on today's date?

- What time was indicated by the sundial when you stood on the wrong date?

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Analysis

1. Explain why the sundial shape is an oval.
2. Did the analemmatic sundial provide the correct time?
3. When you stood on a date other than today's date, did the analemmatic sundial provide the correct time?
4. If we used this sundial at different latitudes, for example in Tucson, Arizona (32^0N), San Francisco, California (38^0N), Anchorage, Alaska (61^0N), or Svalbard, Norway (78^0N), will it provide the correct time?
5. Why are temperatures higher during northern hemisphere summer than during the northern hemisphere winter even though the Earth is farther from the Sun?

Conclusions

Analemmatic sundials are very accurate if they have been properly constructed for particular latitudes. They take into account both Earth's motion in orbit around the Sun, its changing distance from the Sun, and its orbital speed.

Science and Math (optional information)

Date	Distance from the Sun in kilometers	Solar declination in degrees
January 4 (*perihelion*)	147,099,332	-22.5
March 21 (*spring equinox*)	149,017,925	0
June 21 (*summer solstice*)	152,037,737	23.5^0
July 4 (*aphelion*)	152,096,709	22.6
September 22 (*autumnal equinox*)	150,116,093	0^0
December 22 (*winter solstice*)	147,149,612	-23.5^0

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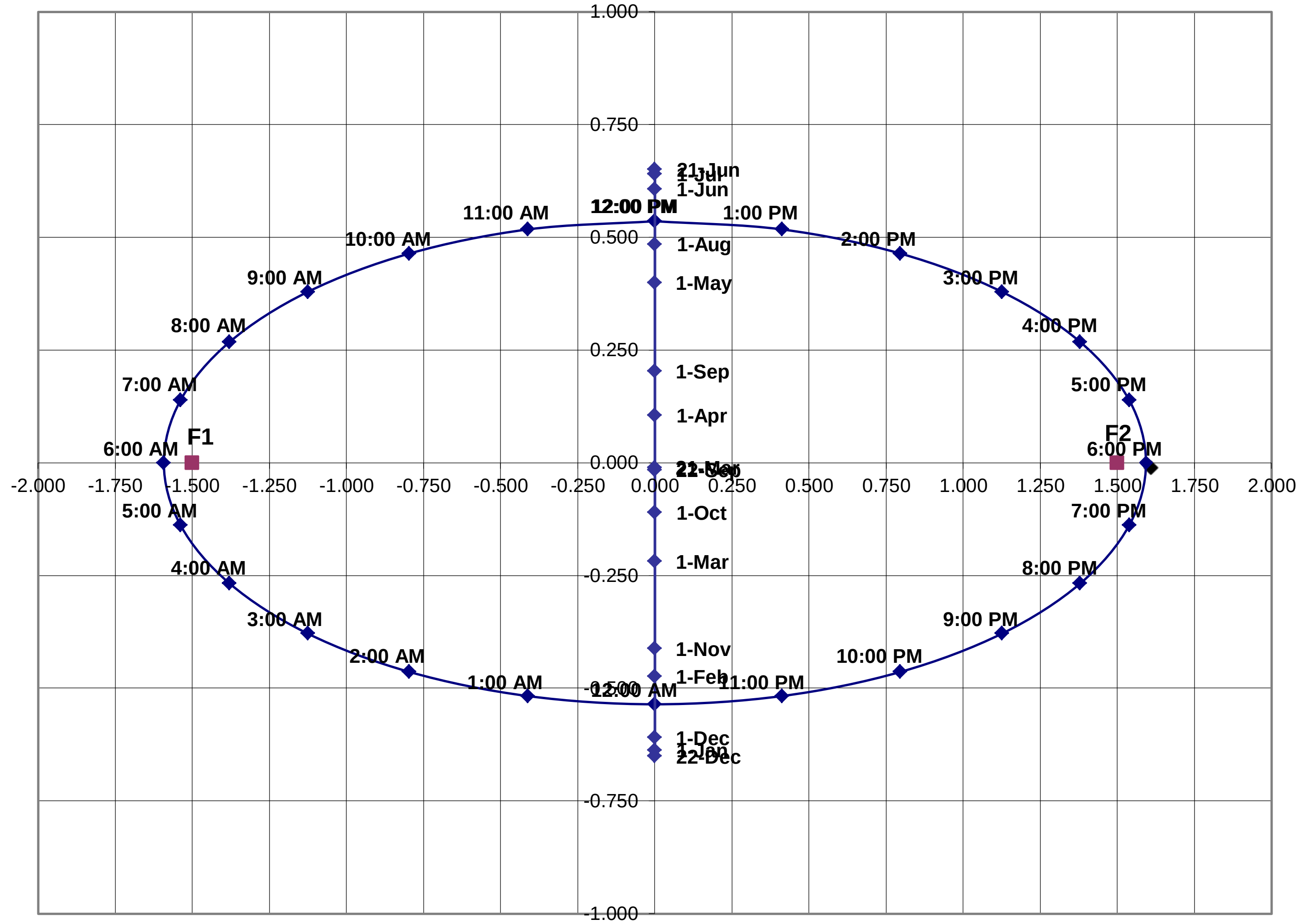
Analemmatic Sundial
Kailua-Kona, Hawai'i, 20^{0}N latitude



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