

Measure the Earth's Radius with a Nothing but a Stopwatch and Meter stick! (Basic Version)

HONEST! It is possible to measure the earth's radius -- armed only with a stopwatch, a meter stick and a sunset or sunrise! Keep in mind; this is a demo, not a Fermi-like laboratory investigation. That said, this will yield surprisingly 'accurate' results given the kids don't mess up on the two measurements they DO have to take.

The idea is to use a little angular knowledge and to look at a sunrise or sunset in a very peculiar way. Make sure they are together when they do this. Otherwise, they are going to get some strange looks from the old lady walking her dog in the park...

Overview: You will watch the sunset. Period. However, you will watch it twice in the same night! Huh? Well, you will watch it once in a supine position (That means lying down...) then once while standing. The amount of time the sun takes to disappear from your view is the amount of time it took it to travel YOUR height's angular displacement. Actually, the earth is rotating UNDER the sun, but same thing... Yes, this will require knowledge of angles...Not 'angels', 'angles'! Also note this also works for the *moonrise* and *moonset*.

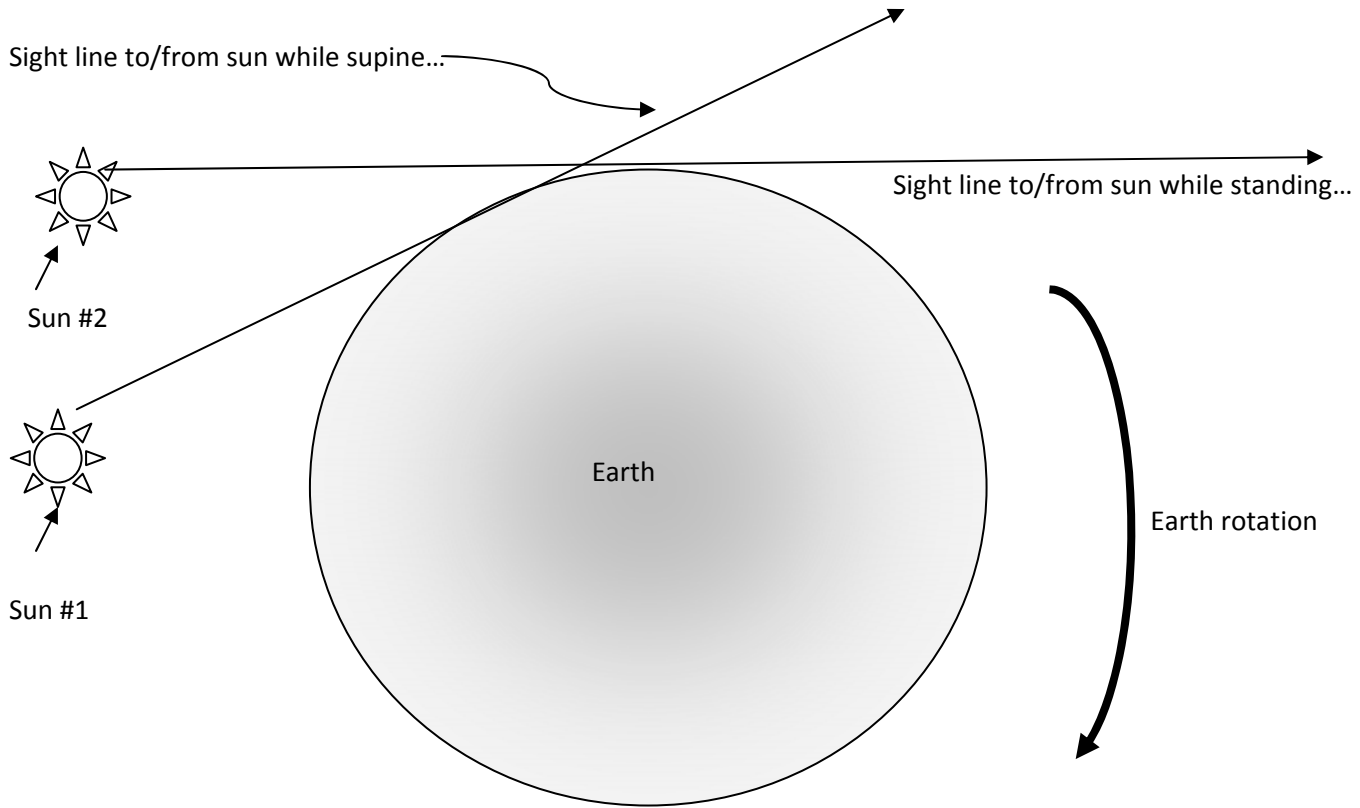
Here's the deal, Kids! (Note all directions are for sunsets. For sunrise, just do opposite; instead of standing up, lie down; blah blah blah...)

1. Requirement #1: You **MUST** find an unobstructed view of the sunset. Can't use it sinking over tall buildings or from the ISS. As close to the true 'horizon' as possible.
2. Lie down, get comfy, and face the horizon.
 - Make sure the horizon you choose to face is the one where the sunset will take place! Nothing messes this up faster than facing East during a sunset or West during a sunrise then having a kid come in and tell me that the sun never set last night...
 - Have a partner measure accurately the height above the ground of your eyes.
3. You will now just enjoy a typical sunset. It's USUALLY sort of safe to look at the sun during sunset with nothing more than good sunglasses since the light is dropped out by traveling through so much of the atmosphere. So enjoy. As soon as you see the very 'top' of the Sun disappear below the horizon, start the stopwatch.
 - If you are lucky, the kids will report seeing the rare 'green flash' or actually be able to witness every color.
4. Now comes the physically demanding part of this demo; stand up. Quickly.
5. Watch closely. The Sun will have miraculously reappeared above the horizon! It's magic!
6. As soon as the 'top' of the Sun disappears again, stop the stopwatch. This will be just a matter of seconds, so accuracy and observation are important.
7. Have your partner measure accurately the height above the ground of your eyes.
 - The difference between the height measured in step #2 above and this 'change in height' is the 'h' you need in the calculations later.
8. Go have a beer. (You may want to leave this step out of your class directions...)

The time it takes for the Sun to disappear-reappear-then-disappear-again is related to the angle through which the Earth has rotated between these disappearances. By measuring the time **accurately**, you can calculate the angle **accurately**. Here is a great time to introduce the idea of accuracy in measurement; If the kid is off by 10%, the radius is off by lots%...) The proportion used is simple:

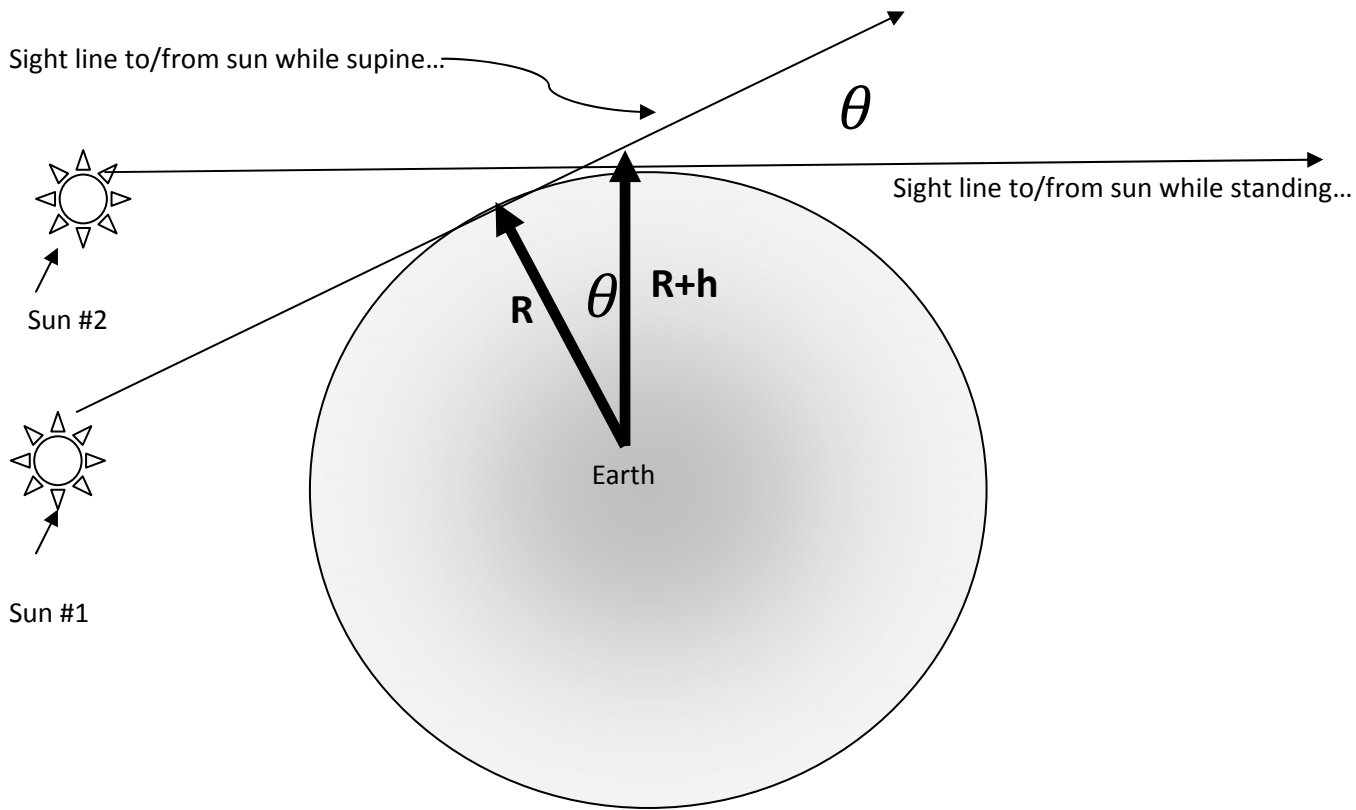
$$\frac{\Delta t}{24hrs} = \frac{\text{Angle earth moved}}{360^\circ}$$

Sound confusing and weird? Let me explain graphically. (View is from South Pole with earth rotating clockwise.)

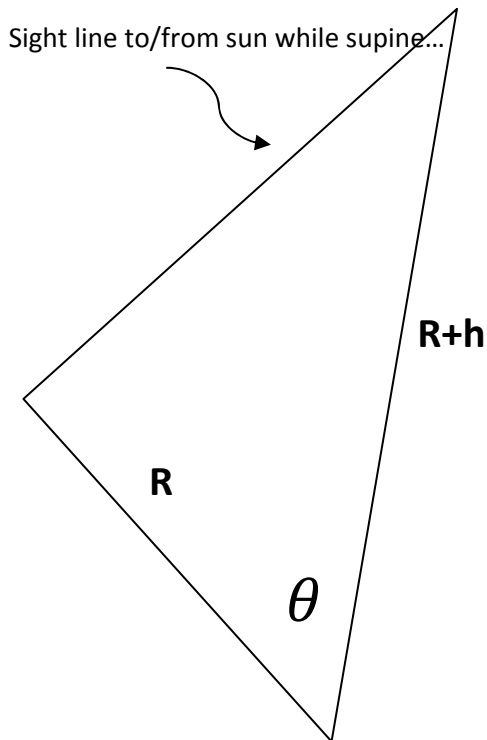


So, what's this mean? Note there is an angle between the lines of sight between the two views of the sun. This translates, through some basic geometry, to be the central angle with vertex at the center of earth. If you need the geometry behind this, contact your friendly neighborhood geometry teacher or email me. This is the 'angular displacement' of the earth during the time it took to see the 2nd sunset.

So:



So, since the “Sight line to/from sun while supine” is tangent to the earth’s surface, the angle between R and it must be 90° . Thus and forsooth, we now have a right triangle:



Basic trig:

$$R = (R + h)\cos\theta$$

Note: This is just one way to get the answer. There are many others using the same idea; using radians instead of degrees, calculating the circumference instead of the radius... All depend on your class level.

Results typically are within 15% for a regular class, within 10% for an Honors or AP class.