Total solar eclipse

WHEN: On August 21, 2017, the moon will appear to totally cover the sun= total solar eclipse. The totality (the time when the moon seems to totally covers the sun) will be seen in many places in the United States. The path of totality is the gray and dotted path shown below.

August 21, 2017

WHERE:

People who are located in regions that are not along the gray dotted path will see partial solar eclipses. For instance in Virginia Beach, VA, residents will see about 86% of the sun obscured by the moon. People in Boston, MA will see about 63% of the Sun obscured. Here’s an interactive NASA map where you can locate what percentage of the total eclipse you will be able to see where you live


WHY:

1. The moon is much smaller than the sun. Why do you think that it will appear to cover the entire sun?

Both the earth and the moon have elliptical orbits. Surely there are times in their orbits when the moon is farther or closer to the earth and the earth is farther or closer to the sun?

2. How might that make a difference in how much sun is blocked by the moon?
One way to figure out how much of the sun will be covered by the moon is to consider the angular diameter\(^1\) of each of these celestial bodies.

Below is my diagram of how angular diameter is measured. (I have my eye looking at the moon.)

The angle, \(\theta\), is called the angular diameter\(^1\).

There are a couple of ways to figure out the angular diameter of a heavenly body (or any distant object).

- **With your arm extended**: If you extend your hand to its full length, you can use your fingers to estimate angular diameters.
  - Stretch your thumb and little finger as far from each other as you can. The span from tip to tip is about 25 degrees.
  - Clench your fist at arms length, and hold it with the back of your hand facing you. The width is about 10 degrees.
  - Hold your three middle fingers together; they span about 5 degrees.
  - The width of your little finger at arm’s length is 1 degree.

Measurements that are smaller than 1 degree are expressed in arc-minutes, or “minutes of arc”. There are 60 arc-minutes in one degree; so 1 arc-minute is 1/60 degree.

- **With trigonometry**
  We’ve created a little diagram and gathered some data to help you calculate, with trig, the angular diameter of the moon as seen from the earth.

<table>
<thead>
<tr>
<th>Distance from earth to moon</th>
<th>Distance from earth to sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>On average = 238,855 miles</td>
<td>On average = 92.96 million miles</td>
</tr>
<tr>
<td>At apogee = 252,088 miles</td>
<td>At apogee = 94,505,901 miles - (farthest from the sun)</td>
</tr>
<tr>
<td>At perigee = 225,623 miles</td>
<td>At perigee = 91,404,322 miles - (closest to sun)</td>
</tr>
<tr>
<td>On average = 384,400 km</td>
<td>On average = 149,600,000 km</td>
</tr>
<tr>
<td>At apogee = 405,696 km</td>
<td>At apogee - in early July and is about 152 million km</td>
</tr>
<tr>
<td>At perigee = 363,104 km</td>
<td>At perigee = 147,098,074 km</td>
</tr>
</tbody>
</table>

The distances from earth to the sun and moon vary depending on where our positions are in our elliptical orbits.

3. Use our drawings to try to find the value of the angular diameter of the moon from earth. Don’t worry if you can’t do the trig yet, you can use the extended arm method.
We looked up the actual angular diameter range of the moon as seen from earth. The apparent size of the moon from earth has a range of from 29' 20" arc-min to 34' 6" arc-min. Since an arch-min is 1/60th of a degree then our previous calculation of 1/2 degree is pretty close.

The moon is closest to the earth at its perigee (place in its elliptical orbit where the distance between the two bodies is the closest). The apogee is when the earth and moon are at their farthest.

3. Which angle $29^\circ 20'$ or $34^\circ 6'$ is probably at the moon's perigee to the earth? Please explain.

The earth is closest to the sun in early January. The range of apparent size of the sun is between $31^\circ 31'$ and $32^\circ 33'$.

4. Which of those two angular diameters do you think occurs in early January when earth is at its closest to the sun.

5. As a summary point, do objects appear larger when they are closer or further away?

Of the planets and moons in our solar system, which do you think could possibly pass between earth and the sun? Please explain.

Here's a picture of Mercury's transit across the Sun on May 9, 2016. Mercury looks pretty small doesn't it?

![Mercury Transit](image)

When Mercury is between Earth and the Sun the event is called a transit. When the moon is between the Earth and the Sun the event is called an Eclipse.

6. Why do you suppose these two events are called different occurrences? Aren't they both a heavenly body traveling between earth and the sun as seen from the earth? Please explain.
Actually there are different kinds of solar eclipses.

• A partial eclipse = When the moon is not aligned perfectly between the center of the sun and the center of the earth.
• A total eclipse like the event that will occur on August 21, 2017.
• An annular eclipse.

7. Try to roughly sketch the following situation. Draw the moon at its furthest from the earth, near its apogee with the angular diameter of the moon = 29.95 arc-min. At the same time, draw the sun during an eclipse with the angular diameter of the sun = 31 arc-min.

8. What might you see of this eclipse from the earth?

This phenomenon is called an annular eclipse.

9. Have you ever seen an annular eclipse?

Just a few more questions:

10. How much greater is the diameter of the sun than the diameter of the moon?

11. How much greater is the average distance to the sun from the earth as compared to the average distance of the moon to the earth?

12. What do you notice about the value of those two ratios?

13. Do you think this has something to do with why when the moon crosses between earth and the sun it is called a total eclipse, or an annular eclipse instead of a transit? Please explain.
Remember don’t look directly at the sun!

You can use special “eclipse glasses” or hand-held solar viewers. These are not the same as sunglasses.

Cameras, binoculars, or telescopes offer no protection unless they have a solar filter attached to the large end. Older solar filters were attached to the eyepiece of the telescope but they have proved inadequate.

Another way to observe the eclipse is through a pinhole projection that lets you see indirectly the progress of an eclipse.

There are also projection telescopes and projection binoculars that allow you to safely view the eclipse on a white surface that shows the projection of the instrument.

1Angular diameter is also called angular size, apparent diameter, or apparent size

Sources: [https://www.knowitall.org/sites/default/files/Path_of_Totality-ilovepdf-compressed.pdf](https://www.knowitall.org/sites/default/files/Path_of_Totality-ilovepdf-compressed.pdf)
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