Angular Size and the Earth-Moon System

A NASA camera aboard the Deep Space Climate Observatory (DSCOVR) satellite captured a unique view of the moon as it moved in front of the sunlit side of Earth last month. The series of test images shows the fully illuminated "dark side" of the moon that is never visible from Earth. The images were captured by NASA's Earth Polychromatic Imaging Camera (EPIC), a four megapixel CCD camera and telescope on the DSCOVR satellite orbiting 1.6 million kilometers (1 million miles) from Earth.

Over several decades, NASA has accumulated many images of our Earth and Moon from space taken from many vantage points across the solar system.

This unretouched picture was taken by the Galileo spacecraft on its journey to Saturn from a distance of 6.2 million kilometers. We see the 350,000-kilometer separation between them dramatically foreshortened.

Below we see a photo from China's *Chang'e* 5-T1 spacecraft from a distance of 200,000 km from Earth as it is about to loop around the moon on its way back to Earth.

These pictures illustrate how our perspectives on the sizes of objects in the solar system change with our distances from them. When two objects are involved at the same time, such as for Earth and the moon, we can get an endless number of odd-looking photos that conceal the true sizes and distances between the objects. This is especially important when we are trying to identify likely places for total solar eclipses. Although most humans are forever confined to the surface of Earth, our satellites and spacecraft can be placed in many different locations where 'total solar eclipses' can be arranged.

All photographs register the angular sizes of objects and not their true linear dimensions. Angular size is a simple geometric effect produced by the combination of the actual size of an object and its distance from the observer as the formula below demonstrates:

$$\text{Angular size in degrees} = 57.29 \; \frac{\text{Diameter of object in kilometers}}{\text{Distance to object in kilometers}}$$

Problem 1 - If you were on the surface of the moon looking at Earth, the distance is 384,000 km and Earth's diameter is 12,700 km. What is the angular diameter of Earth in the lunar sky?

Problem 2 – If you were standing on Earth and our moon had a diameter of 3,500 km at the same distance, how large would it appear?

When we take compound pictures of two or more objects in the same camera field, this angular size phenomenon can lead to a variety of different views of the same objects depending on the distance of the observer. A simple geometric diagram shows how this works.
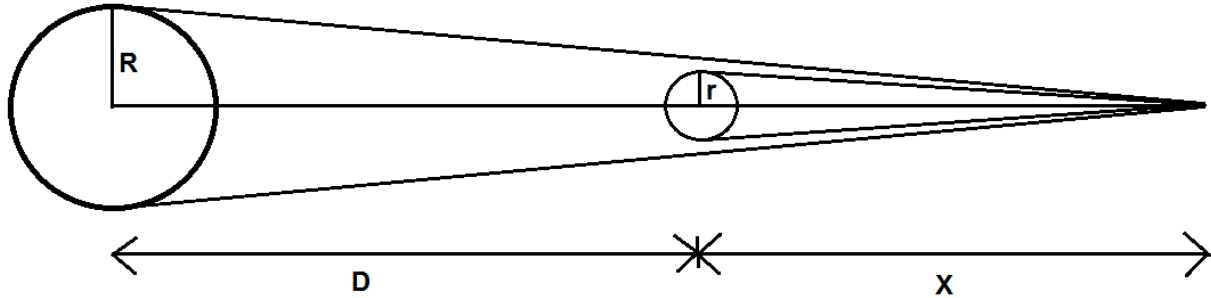
We have two objects with radii r for Object 1 and R for Object 2. The objects are separated from each other by a distance D, and the Observer or spacecraft is located a distance X from one of the objects. The angular sizes of the two bodies are given by

Object 1: $57.29 \dfrac{2r}{X}$

Object 2: $57.29 \dfrac{2R}{X + D}$

Problem 3: Write the formula that gives the ratio of the angular diameters for Object 1 compared to Object 2.

Problem 4:   From the distance to the Galileo spacecraft of 6.2 million kilometers, what is the ratio of the size of the moon (Object 1) to Earth (Object 2) in the photograph?

Problem 5: The *Chang'e* 5-T1 spacecraft was located 200,000 km from Earth and about 8,000 km from the Moon. What was the ratio of the apparent size of Earth to the moon in the photograph? What was the ratio of their apparent sizes in the phortograph?

Problem 6 - Venus and Earth have about the same diameters of 12,700 km, and the diameter of the sun is 1.4 million km. During the transit of Venus across the face of the sun in 2012, Earth was about 40 million kilometers from Venus while the Earth-sun distance was about 150 million km. On May 11, 2084, Earth will pass across the face of the sun as viewed from Mars, which is located 225 million km from the sun. A) what is the ratio of the diameter of Venus to the sun from Earth during the 2012 transit? B) What is the ratio of the diameter of Earth to the sun from Mars during the 2084 transit?

Problem 7 – As viewed from the DSCOVR spacecraft located 1.6 million km from Earth, the diameter of Earth appears to be 2.9 times larger than the moon. About how far apart would the Earth and Moon have to be to achieve this ratio?
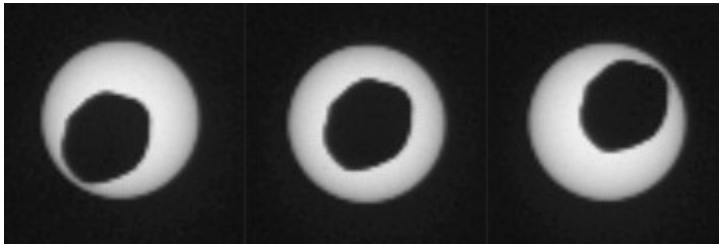
Problem 8 – From the surface of Mars, the moon Phobos has been photographed by the Curiosity rover in transit against the sun. If the diameter of Phobos is 25 km, and Mars is 225 million km from the sun, about how far was Phobos above the surface?