

## Concept Questions: Geometrical Optics

**Description:** These questions with selected response answers test specific concepts relating to **geometrical optics** (factors that affect the size of the umbra and penumbra, apparent and angular size of an object or image). This resource is designed to be used either as homework or in small discussions with methods such as [Peer Instruction](#), [Teaching with Clickers](#), or [CAE Think-Pair-Share](#).



Find more teaching resources at [aapt.org/Resources/NASA\\_HEAT.cfm](http://aapt.org/Resources/NASA_HEAT.cfm)

This resource was developed by B. Ambrose, X. Cid, and R. Lopez. The co-authors acknowledge useful discussions with J. Bailey, R. Vieyra, and S. Willoughby, and the support of a subcontract from the NASA Heliophysics Education Activation Team to Temple University and the AAPT under NASA Grant/Cooperative Agreement Number NNX16AR36A.

## A. Understanding the factors that affect the sizes of the umbra and penumbra

### *Requisite concepts:*

Students should be able to understand how shadows are formed by an obstacle placed between an extended light source and a viewing screen. They should recognize the effect on the shadow by changing the distance between the obstacle and the screen. The students should also be familiar with the definitions of umbra and penumbra, particularly in the context of solar eclipses.

2.1. Imagine the Sun, Earth, and Moon in the arrangement needed for a total solar eclipse to occur, *except* suppose that the Moon were *slightly farther away* from the Earth than it actually is. How, if at all, would this change affect the size of the umbra (created by the Moon) projected onto the Earth?

- The umbra would occupy a larger surface area on the Earth as compared to before.
- The umbra would occupy a smaller surface area on the Earth as compared to before.
- The umbra would occupy the same surface area on the Earth as compared to before.
- There is insufficient information to tell for sure.

**Ans. for 2.1: (b)**

2.2. Imagine the Sun, Earth, and Moon in the arrangement needed for a total solar eclipse to occur, *except* suppose that the Moon were *slightly farther away* from the Earth than it actually is. How, if at all, would this change affect the size of the penumbra (created by the Moon) projected onto the Earth?

- The penumbra would occupy a larger surface area on the Earth as compared to before.
- The penumbra would occupy a smaller surface area on the Earth as compared to before.
- The penumbra would occupy the same surface area on the Earth as compared to before.
- There is insufficient information to tell for sure.

**Ans. for 2.2: (a)**

### *Concepts tested:*

Questions 2.1 and 2.2 test whether students recognize that moving the Moon farther from the Earth will cause the penumbra of increase in size and the umbra to decrease in size.



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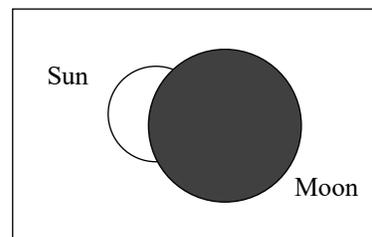
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## B. Interpreting the apparent size (or angular size) of an object or image

*Requisite concepts:*

The apparent size (or angular size) of an object is the angle subtended by the object as seen or measured at a particular observation point. For distant objects, apparent size can be treated as a ratio of the actual dimension of the object (*e.g.*, its width) to the distance to the object.

2.3. When the Moon was formed, it was much closer to the Earth than it is now. A time traveler goes to an *unknown* point in time and observes a solar eclipse, during which the Sun and Moon appear in the sky as shown in the diagram below right. What can be said about the point in time at which the time traveler arrived?



Observation of solar eclipse made by time traveler

- The time traveler arrived at a point in the distant past.
- The time traveler arrived at a point in the distant future.
- It cannot be determined from the information given.
- Trick question: The given observation is impossible for a solar eclipse, whether in the distant past or in the distant future.

*Concepts tested:*

Question 2.3 can be used to test whether students recognize that the apparent sizes of the Moon and Sun as observed on Earth are nearly identical (at least, at the present time), as well as how well they interpret a much different observation in which the apparent size of the Moon would be noticeably larger than that of the Sun. In particular, students need to understand that in this hypothetical situation, the Moon would be closer to the Earth compared to nowadays.



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