Human HET: *Challenge 2 Mirror Array*

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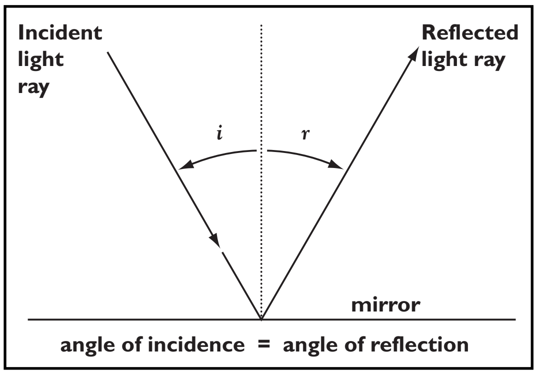
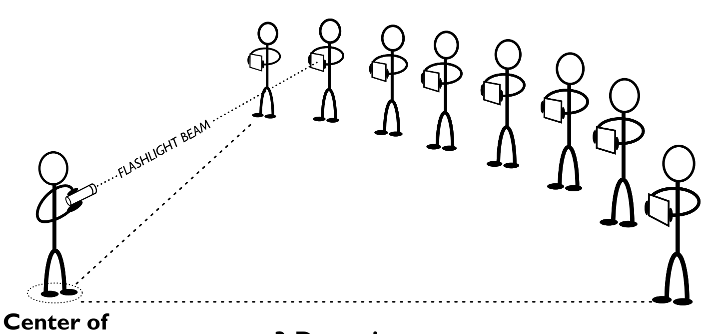
Introduction

An important characteristic of a telescope's primary mirror is its figure. Flat mirrors reflect light like a ball bouncing off a flat floor — the *incident* angle equals the *reflected* angle. But a telescope primary mirror differs from a flat mirror. A shallow bowl-shape is ground into the top side of the mirror, then coated over with a thin veneer of aluminum or silver. The same reflection rule applies, but the bowl-shape directs the reflected light rays to a point at a specified distance from the mirror, called the *focal point*. Mirror fabricators normally produce two types of telescope mirror figures — spherical and paraboloid. HET's mirror segments are spherical mirrors, meaning that each mirror is a tiny piece of the surface of a sphere, like hexagonal segments of a soccer ball. As a team, the 91 mirror segments act as one giant 10 by 11 meter mirror. Each mirror segment is the same distance from the center of curvature alignment system tower (CCAS). This is the center of the imaginary sphere of which the primary mirror is the only real part of the surface.



For the HET model, your students will form curved row(s) of mirror segments. Each student will hold a mirror and act like the truss and actuators that align the mirror. As a team, the individual mirror segments act like one big spherical mirror, just as HET's primary mirror does. This is a big job; it may be distributed among three problem-solving groups that together reach a solution.



3-D arc view

Goal

Given string, meter sticks, mirror segments, and students, form a model of HET's mirror array.

MATERIALS

1. String — at least 8 meters per group.
2. Meter stick — one per group.
3. Masking tape — one roll for the class to share.
4. Paper and pencil for each group.

Texas Essential Knowledge and Skills

Science TEKS Process Skills

- plan and implement investigative procedures (6.2, 7.2, 8.2, IPC, Physics, Astronomy)
- relationships between science and technology (8.5)

Science TEKS Concepts

- Systems (6.5, 7.5)

Math TEKS

- Geometry and spatial reasoning (6.6, 6.7, 7.8, 8.7)
- Measurement (6.8, 7.9, 8.8, 8.9)
- Underlying processes and mathematical tools (6.11, 7.13, 8.14)
- Patterns, relationships, and algebraic thinking (6.5, 7.4)

Preparation

Introduce the students to the problem by outlining the three main problems. Each problem may be assigned to a different group, but all the students should understand all three subproblems.

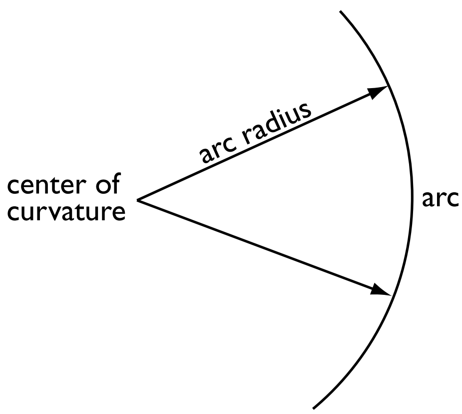
1. Form the arc: Invent a procedure that positions the mirror segments along an arc to form a mirror segment array. The students should take into account how many people will form the array along the arc they establish.

2. Estimate area requirements: Determine the work area that holds the model mirror array, then provide a maximum size for the arc, both radius and length, within the available space.

3. Arrange members of the segmented mirror array: Figure out how to neatly and efficiently arrange the segments along the arc. The members should minimize the size of the gaps between mirrors and maximize the stability.

Problem

Divide the students into three groups. Assign each group a subproblem from the list above. Groups working on these subproblems should collaborate among groups, because the solution to any one problem affects the solutions to the others. For example, if the mirror array is designed too big to fit in the work area, adjustments must be made to the configura tion of the mirror array. Another solution they may suggest is to use a larger work area, but that may not be available.



Solution

Forming the arc: One solution is to arrange the students along an arc in two or three arc-rows — one row standing, the other row(s) kneeling or sitting. Mark the center of curvature with masking tape. Set the length of the string equal to the radius of the arc. Elect a student to stand at the center of curvature holding one end of the string. Each student forming the arc in turn should take up the other end, then stand where the string becomes taut. You may want to mark out the arc on the floor with masking tape.

The students need to consider the number of mirror segments (students holding mirrors), and how much space each segment requires. This will affect the radius and length of the arc.

Hints

Applying the law of reflection to a curved surface may at first sound confusing. Normally, we think of flat mirrors. But imagine you are Phil and Phoebe Photon on a journey from a distant star who find themselves zipping toward HET's primary mirror. As they approach the mirror, the surface looks curved, or bowl shaped. But by the time Phil and Phoebe interact with the mirror surface, it looks flat. So like good photons, they obey the law of reflection and bounce away. At the point light interacts with the mirror surface, it behaves as if it has hit a tiny flat mirror tangent to the curved mirror. This is similar to that fact that as we stand on Earth's surface, it appears flat, but astronauts on the orbiting space shuttle see Earth as a sphere.