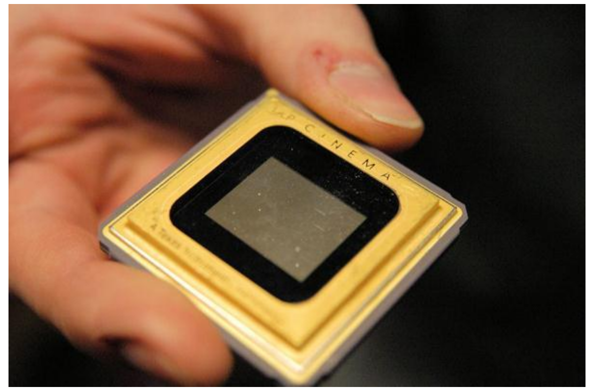
Advanced Reflections



DLP chip used in a digital projector at the Cinerama in Seattle
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The "Law of Reflection" for light beams may seem rather simple, "The angle of incidence is equal to the angle of reflection or $\Theta_i = \Theta_r$." Applying this law in practical situations, however, is often more difficult than might be expected. While the fundamental principle has been understood and used for many centuries, it remains at the heart of much cutting-edge technology. Texas Instruments, for example, manufactures a Digital Light Processing™ (DLP) module with over 750,000 micromirrors within a total area of less than 2 cm^2. Each micromirror moves independently, changing position up to 1000 times per second to reflect light and produce high-quality television and theater images.

Moving mirrors are also used in large-scale applications, for example in the processing of steel for electrical transformers. AK Steel scans a high-power Nd:YAG laser beam across rapidly moving rolls of steel to break apart the magnetic domains, thereby reducing energy losses within the transformer. Particularly when dealing with high-powered lasers, it is much more practical to move the light beam with mirrors, rather than attempting to move the laser itself.

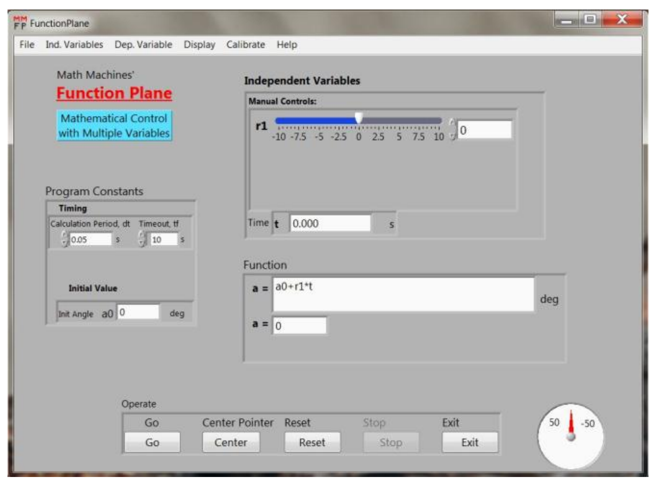
Task: Your task will be very much like the process at AK Steel. You will design and test rotation rates for a mirror to scan the beam from a stationary laser across a flat surface.

Additional Materials: Mirror attached to the Function Plane, stationary flashlight or laser pointer with support.

Math Machines Program:

Function Plane

Activity File: Reflection



1. Work with the class to identify and measure a layout which simulates the environment at AK Steel—but without the dangers and the costs associated with high-power lasers and fast-moving sheets of steel. In the space below, make a careful scale diagram of the layout, showing the location of the light source, the boundaries of the steel roll and the position of the mirror. Also measure and label the angles in degrees to show how far left and right of its center line the light beam must move to scan from one edge of the steel to the other edge.

Steel Target

2. The computer program will pivot the mirror using your inputs for the initial angular position, *a0*, and the angular speed, *r1*. The angular positions, *a* and *a0*, should be in degrees. The position of the **mirror** is zero when the normal (the perpendicular to the mirror's surface) is directed along the center line from the motor's pivot to the sheet of steal. Use the program's "Center" button to ensure the reflected beam strikes the center of the "steel" target so the normal, the incident beam and the reflected beam are along the same line.

   Positive angles indicate counterclockwise positions and negative angles indicate clockwise positions. Decide on the angular position of the **mirror** which will reflect the beam to the right edge of the steel target. Enter this value below and enter it into the computer program as "a0." Insure that the rotation rate, r1, is set to zero, then select "Go" and verify that the beam does move to the right edge of the target. Explain in words below how the orientation of the mirror's normal is related to the directions of the incident and reflected beams.

   a0 = ______________

   The mirror's normal is oriented ____

3. Decide on the angular rotation rate of the mirror which will scan the light beam from the right edge of the steel target to the left edge in 20 seconds. Test your prediction by adjusting r1 to the desired value and report the results below.

   r1 = _____________________
   Describe the results of the trial:

4. Stop the previous motion and modify the value of r1 as needed to complete each scan in 5 seconds.

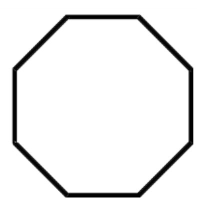
   r1 = _____________________
   Describe the results of the trial:

5. Stop the previous motion and modify the values of a0 and r1 as needed to scan from <u>left to right</u> in 5 seconds.

   a0 = _____________________

   r1 = _____________________

   Describe the results of the trial:



<u>Challenge</u>: Economical operations such as the steel processing at AK Steel require rapid, continuous movement. In these applications, it is more effective to use a set of continuously rotating mirrors, instead of a single mirror which sweeps back and forth. One possible arrangement uses eight mirrors, positioned on the edges of a rotating octagon like the one shown at right.

Design an 8-mirror system which will sweep the beam from right to left across the target, repeating the sweep 200 times per seconds. This may require moving the mirror closer to the target or further away. Your plan should specify the position of the rotating octagon and the rotational speed, r1.

