Background:

Laser cutting close up © Makalu Bachkou | Dreamstime.com

Controlled lasers are important in a large number of modern applications that include eye surgery, the cutting and processing of specialty steels and targeting enemy aircraft and satellites. The same concepts and equations which can control lasers are also used in the control of automated machine tools, elevators, subway trains, assembly lines, robots and countless other objects.

Task: Use the equations of uniformly accelerated motion to design and test mathematical functions which control the motion of a laser.

Additional Materials: Screen, dry-erase marker, meter stick, 3 toy or paper targets.

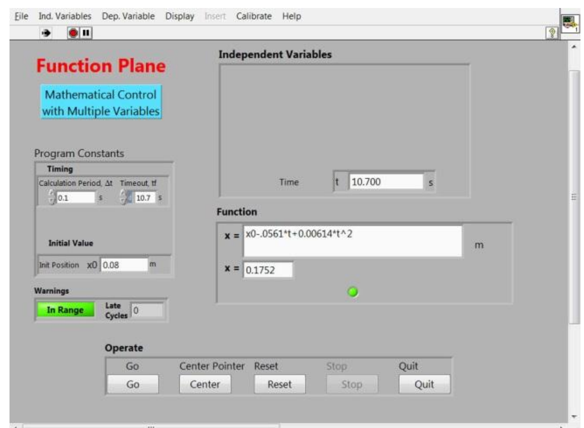
The 10-minute video, “Controlling a Laser,” provides additional instructions.

Math Machines Program:

Function Plane

Activity File: Control_a_Laser

This activity uses a Class II diode laser, similar to those used in many barcode scanners. Never look directly into the laser beam and never allow it to shine into anyone’s eyes.



Start the “Function Plane” program, select the option for no analog probes, and load the activity file, “Control_a_Laser.”

1. <u>Establish a coordinate system:</u>
   a. Use the “Center” button to identify the zero point. Lay a meter stick as shown on the front of the Function Plane with the 50-cm mark at the “zero point.” (You may want to adjust this slightly left or right to match the center of the Function Plane.) Use a dry-erase marker to show your zero point directly on the screen.
   b. Select your units. The program default is meters, but you can change this to “cm”, “mm”, “in”, or virtually any length units you like by typing over the “m” to the right of the main Function block. If you change the units for the Function block, also change the units for the initial value, x0.

   c. Using both positive and negative values, mark key points of your coordinate system (e.g., “-100 mm”) directly on the screen. (You will still use the fine divisions of your meter stick, but the numbers on the screen will correspond to the values and units used in the computer program.
   d. Experiment by typing specific values for x (e.g., “-100”) into the main function block and pressing “RUN.” Verify that the values you enter into the computer correspond as you expect with the position of the laser dot. (When you first press “RUN”, the laser should move to the position specified by x0. When you press “Start,” the laser should move to the position specified in the Function Block, which may or may not be different.)

2. You will be creating dynamic functions where x is a function of time, x = f(t). What is the “range” of possible output values for x which will keep the laser dot safely on the screen?

   x_{min} = ________________________ x_{max} = __________________________

3. Place one target at a location of your choice to the left of center and a second object at a location of your choice right of center. Using your coordinate system (including units), specify the locations of the two targets below.

   Target 1 is at _________________ Target 2 is at ________________________

Motion at Constant Velocity

4. Create a function, x = f(t), which moves the laser dot at uniform speed from target 1 to target 2 in 10 seconds. Enter this function (without units) into the Function Block. Also (a) enter the initial position as “x0”, and (b) set the “Timeout” value to 10 s so the motion will stop at that time. Test and revise your function until you achieve the desired result.

   Velocity = _______________

   x0 = _________ x = f(t) = ________________________

5. Revise your function and x0 to move the laser dot at uniform speed from <u>target 2 to target 1</u> in 10 seconds. Test and revise your function until you achieve the desired result.

   Velocity = _______________

   x0 = _________ x = f(t) = ________________________

6. Revise your function, x0 and timeout to move the laser dot at uniform speed from target 2 to target 1 in 5 seconds. Test and revise your function until you achieve the desired result.

   Velocity = ____________

   x0 = ________ x = f(t) = ____________________

7. Revise your function, x0 and timeout to move the laser dot at uniform speed from target 1 to target 2 in 20 seconds. Test and revise your function until you achieve the desired result.

   Velocity = ____________

   x0 = ________ x = f(t) = ____________________

Motion at Constant Acceleration

8. Revise your function to move the laser dot at uniform acceleration from target 1 to target 2 in 20 seconds starting from rest. Test and revise your function until you achieve the desired result. SHOW BELOW HOW YOU FOUND THE NECESSARY ACCELERATION.

   Initial Velocity = ____________________ Acceleration = ______________________

   x0 = ________ x = f(t) = ____________________

9. Revise your function to move the laser dot at uniform acceleration from target 2 to target 1 in 20 seconds starting from rest. Test and revise your function until you achieve the desired result.

   Initial Velocity = ____________________ Acceleration = ______________________

   x0 = ________ x = f(t) = ____________________

10. Revise your function to move the laser dot at uniform acceleration from target 1 to target 2 in 10 seconds starting from rest. Test and revise your function until you achieve the desired result. SHOW OR EXPLAIN BELOW HOW YOU FOUND THE ACCELERATION.

    Initial Velocity = ____________________ Acceleration = ______________________

    x0 = ________ x = f(t) = ____________________

11. Revise your function to move the laser dot at uniform acceleration from target 1 to target 2 in 10 seconds so the final velocity (at t = 10 s) is zero . Test and revise your function until you achieve the desired result. SHOW BELOW HOW YOU FOUND THE INITIAL VELOCITY.

    Initial Velocity = ____________________ Acceleration = ______________________

    x0 = ________ x = f(t) = ____________________

Three Targets

12. Place a third target roughly midway between the first 2. Revise your Timeout so the laser dot begins at target 1, moves to target 2 where it stops instantaneously before continuing on to target 3. Test and revise your function until you achieve the desired result. SHOW YOUR CALCULATIONS BELOW FOR FINDING THE REQUIRED TIMEOUT.

    Location of target 3 = ______________________________

    Initial Velocity = ________________________ Acceleration = ____________________________

    x0 = _________ x = f(t) = _________________________

    Timeout = ________________

13. Summarize your work:

    a. When does the velocity need to be positive?

    b. When does the velocity need to be negative?

    c. When does the acceleration need to be positive?

    d. When does the acceleration need to be negative?

