

## Task:

Use the equations of uniformly accelerated motion to design and test mathematical functions that control the motion of the LACI Smart Cart in specified ways.

## Background:

Physicists and mathematicians often focus their attention on *describing and analyzing motion*, and they have achieved dramatic successes that include Galileo's Law of Falling Bodies and Kepler's Laws of Planetary Motion. This type of analysis continues to be important today in investigations of fluid dynamics, the expansion of the universe and more. Engineers and technicians, however, typically face a different sort of challenge. They often need to *control* motions, not just to understand how things move in nature.



Drone with the Gift  
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## Materials:

LACI Smart Cart, track, computer with SensorDAQ or myDAQ interface, cable, 1 or more meter sticks.

The 4-minute video, "[LACI Smart Cart](#)," provides additional guidance.

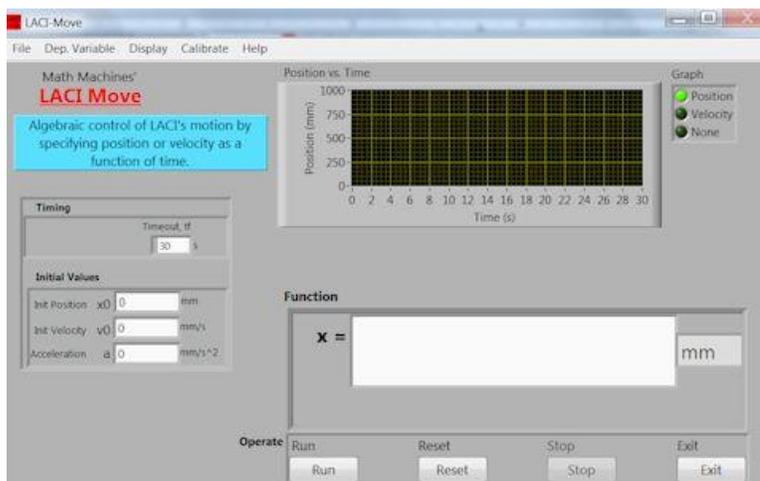
## Math Machines Program: Function Plane

Activity File: LACI-Move

1) Start the "LACI-Move" program. No activity setup file is needed.

2) Establish a coordinate system:

- a. Put LACI at the location you consider to be "zero" and place 1 or more meter sticks for use in measuring other positive (and perhaps negative) positions.
- b. Determine the range of possible values for  $x$  which will keep LACI's wheels on the track.  
 $X_{\min} = \underline{\hspace{2cm}}$   
 $X_{\max} = \underline{\hspace{2cm}}$
- c. Use the LACI-Move menu to select Display/Initial Values, as shown at right.



## Motion at Constant Velocity

- 1) Create a function,  $x = f(t)$ , which moves LACI at uniform speed from one end of your track to the other at LACI a speed of about 100 mm/s. Enter this function (without units) into the Function block.<sup>1</sup> Also set the "Timeout" value,  $t_f$ , so that LACI will actually stop before falling off the track, and set  $x_0$  to match the starting point for your motion. Test and revise your function until you achieve the desired result.

$$x_0 = \underline{\hspace{2cm}} \quad \text{Velocity} = \underline{\hspace{2cm}} \quad \text{Timeout} = \underline{\hspace{2cm}}$$

$$x = f(t) = \underline{\hspace{4cm}}$$

- 2) Revise your function as needed to make LACI move in the opposite direction back to its starting point.

$$x_0 = \underline{\hspace{2cm}} \quad \text{Velocity} = \underline{\hspace{2cm}} \quad \text{Timeout} = \underline{\hspace{2cm}}$$

$$x = f(t) = \underline{\hspace{4cm}}$$

- 3) Use LACI-Move's menu "Run/Piecewise Defined" to select 2 segments, each with a duration equal to the timeout values you used above. Combine steps 1 and 2 into a piecewise defined motion.<sup>2</sup> Note that the value of "t" continues to increase throughout this motion. To make the value of time start over at zero when the second segment begins, use "ts" as the independent variable in your second function.

$$\text{Segment 0:} \quad x_0 = \underline{\hspace{1cm}} \quad \text{Segment duration} = \underline{\hspace{1cm}} \quad x = f(t) = \underline{\hspace{3cm}}$$

$$\text{Segment 1:} \quad \text{Segment duration} = \underline{\hspace{1cm}} \quad x = f(ts) = \underline{\hspace{3cm}}$$

Test your motion. Is this actually an example of "Motion at Constant Velocity"? Justify your answer below.

## Motion at Constant Acceleration

- 4) Exit the piecewise defined mode by clicking again on Run/Piecewise Defined. Design and test a SINGLE function,  $x = f(t)$ , which will make LACI move from one end of its track to the other AND BACK AGAIN, beginning with an initial speed of 100 mm/s. Justify your function using the equations of uniformly accelerate motion in the space below.

$$x_0 = \underline{\hspace{2cm}} \quad \text{acceleration} = \underline{\hspace{2cm}} \quad \text{Timeout} = \underline{\hspace{2cm}}$$

$$x = f(t) = \underline{\hspace{4cm}}$$

- 5) Modify the function above,  $x = f(t)$ , so LACI begins with an initial speed of 125 mm/s and returns to the initial position without falling off either end of the track. Justify your function using the equations of uniformly accelerate motion in the space below.

$$x_0 = \underline{\hspace{2cm}} \quad \text{acceleration} = \underline{\hspace{2cm}} \quad \text{Timeout} = \underline{\hspace{2cm}}$$

$$x = f(t) = \underline{\hspace{4cm}}$$

<sup>1</sup> Multiplication must be entered with a "\*" symbol. "100t", for example, should be entered as "100\*t".

<sup>2</sup> The value of "x0" need only be entered for the first segment. The final value of x for the first segment automatically becomes the initial value for the next segment.

- 6) Modify the function above,  $x = f(t)$ , to reverse LACI's motion so it begins at the opposite end of the track and returns to that same position. Explain how your new function is different from the previous one and justify the changes you made.

$x_0 =$  \_\_\_\_\_ acceleration = \_\_\_\_\_ Timeout = \_\_\_\_\_

$x = f(t) =$  \_\_\_\_\_

- 7) Use the "Dep. Variable" menu option to make *velocity* the dependent variable. Design and test a function for velocity,  $v = f(t)$ , to match precisely the motion in the step above. Justify your function using the equations of uniformly accelerate motion in the space below.

$v_0 =$  \_\_\_\_\_ acceleration = \_\_\_\_\_ Timeout = \_\_\_\_\_

$v = f(t) =$  \_\_\_\_\_

- 8) Compare and contrast the motion in steps 6 and 7 with the motion in step 3. Engineers or technicians planning the motion of trains, elevators and other transportation systems need to consider both speed and comfort. Which of these motions completed the round trip in the least time? Which motion is likely to be more comfortable for passengers?
- 9) CHALLENGE: Design, test and explain a 5-segment motion which avoids sudden starts and stops while still completing the round trip as quickly as reasonable. The motion should be smooth enough that LACI can carry a load without damage.<sup>3</sup>

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<sup>3</sup> An appropriate load might be a *Jenga* block standing on end, similar to that shown in the video, "[LACI Smart Cart.](#)"