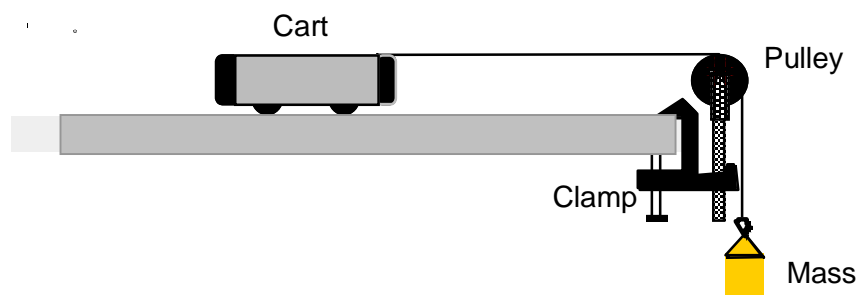# Motion With Constant Acceleration - MBL

In this experiment you will investigate the motion of a cart on a track. You will use a computer to acquire the data, and to help analyze it.

The Experiment

Constant acceleration setup

The diagram shows the basic apparatus. A cart on a track is connected to a mass that hangs over a pulley. A motion sensor at the far end of the track enables the position, velocity, and acceleration of the cart to be determined.
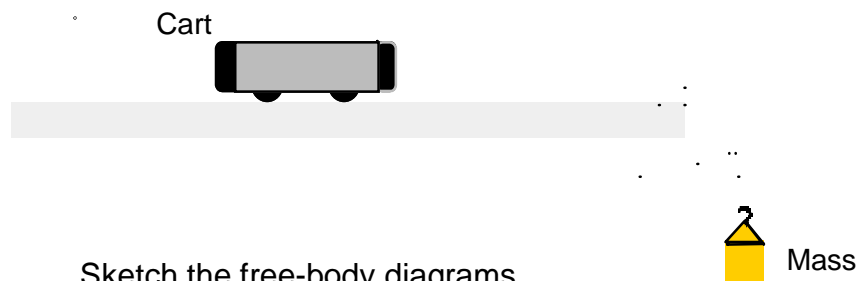
Sketch the free-body diagrams

On the diagram above, sketch the free-body diagram of the cart and of the mass. Assume that the track is horizontal, and that there is no friction between the cart and the track.

Include the free-body diagrams in your lab report. Also show how, by applying Newton's second law (the sum of the forces = ma) to each free-body diagram and combining the equations, the acceleration of the cart is given by:

$$a = \frac{mg}{m + M}$$

(1)

where M is the mass of the cart and m is the mass hanging from the string.

PROCEDURE

1. Push the cart back and forth and observe its motion. Make sure that the track is level and that the cart moves smoothly along the track.

2. Each cart has a mass of 500 g, although you should verify that for yourself. Additional masses are provided. These are also each 500 g, and fit nicely on top of the cart. Attach a piece of string to the cart, pass the string over the pulley, and hang a hooked mass from the string. Record the mass M of the cart and the mass m hanging from the string.

3. For each trial, you will obtain three graphs, showing the position, velocity, and acceleration as a function of time.

QUESTION 1. What do you expect the three graphs to look like? Sketch three graphs before taking any data to show your predictions.

4. For each trial, position the cart so the hanging mass is just below the pulley. Click ▐▶ Collect ▐, wait about a half second, and let the cart go. The computer will record data until you hit ▐ ● Stop ▐. You should wait 3 or 4 seconds after the cart stops moving before hitting ▐ ● Stop ▐.

Decide which graph to use to obtain a value for the acceleration of the cart. In theory, you could use any of the graphs to get acceleration, but you may decide that one or two of the graphs give inconsistent results:

- For the position graph, select a region of the graph by clicking-and-dragging with the mouse and then click the Curve Fit button, ▐▨▐. Select Quadratic fit from the list and click ▐ Try Fit ▐. Which value will give the acceleration? Click ▐ OK ▐ to return to the main graph.

- For the velocity graph, select a region of the graph and click the Regression button, ▐▨▐. One of the values represents the acceleration.

- For the acceleration graph, select a region of the graph and click the Statistics button, ▐▨▐.

QUESTION 2. Which graph will you use to obtain the acceleration? Why did you choose that graph?

QUESTION 3. How does the acceleration you determine from the graph compare to the theoretical value, calculated from equation (1)? You will probably find that they're close, but the agreement is not perfect. What could account for this?

5. It is possible to take a measurement to determine the effect of friction in the experiment. Record a set of data where you start with the cart near the pulley, and you give it a quick push so it moves away from the pulley. From the graphs, determine the acceleration for this motion. Compare this with the acceleration you measure for the cart moving toward the pulley. One should always be a little larger than the other – you should verify this.

To help analyze this data, start by constructing two free-body diagrams, one for the cart moving toward the pulley and one for the cart moving away. Include friction on both. What you should notice is that in one case the acceleration is smaller than the theoretical value because of friction, and in the other case it is larger because of friction. You can therefore correct for friction by averaging the two accelerations you measured above. Does this corrected value of acceleration give better agreement with the theoretical value?

6. Repeat the experiment for several combinations of M and m values. For each trial, record the values of M (the mass of the cart), m (the mass hanging from the string), the acceleration determined from your graph, and the theoretical value of the acceleration according to equation (1). Note that you should correct the experimental values for friction in every case. In other words, average the accelerations you determine for the cart moving toward the pulley and for it moving away.

QUESTIONS AND ANALYSIS

QUESTION 4. Compare your experimentally determined values of the acceleration to the theoretical values. Is there good agreement? Do you notice any systematic differences? (e.g., are the experimental values always greater than the theoretical values?)

QUESTION 5. You corrected for the effects of friction in the experiment. What are other possible sources of experimental error? Estimate how significant each source is, if possible.

QUESTION 6. By varying the two masses, the mass of the cart and of the weight hanging from the pulley, you obtained different accelerations of the cart. What is the maximum acceleration attainable by varying *m* and *M*? The minimum?