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 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.



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:

$$a = \frac{mg}{m+M} \tag{1}$$

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.

- 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.
- 5. Use either the position graph or the velocity graph to find the cart's acceleration.

QUESTION 2: 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?

6. 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 one of the graphs, determine the acceleration for the motion when the cart is moving away from the pulley. 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 consider the two free-body diagrams from the pre-lab, one for the cart moving toward the pulley and one for the cart moving away. What you should see is that in one case the acceleration is smaller than expected because of friction, and in the other case it is larger because of friction. You can correct for friction by averaging the two accelerations you measured above.

QUESTION 3: Does this corrected value of acceleration give better agreement with the theoretical value?

7. 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 3.** 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 4.** 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 5.** 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?