Skills Practice Lab

IN-TEXT LAB—CBL VERSION

Force and Acceleration

OBJECTIVES

Compare the acceleration of a mass acted on by different forces.

Compare the accelerations of different masses acted on by the same force.

Examine the relationships between mass, force, acceleration, and Newton's laws of motion.

MATERIALS LIST

- balance
- calibrated masses and holder
- cord, smooth
- dynamics cart
- hooked mass, 1000 g
- LabPro® or CBL 2™ interface
- mass hanger
- meterstick
- pulley with table clamp
- rod and parallel clamp
- square of poster board, 25 cm × 25 cm
- support stand with V-jaw clamp
- tape
- TI graphing calculator with link cable
- Vernier Dual-Range Force Sensor
- Vernier motion detector

SAFETY

- Tie back long hair, secure loose clothing, and remove loose jewelry to prevent its getting caught in moving or rotating parts.
- Attach masses securely. Falling or dropped masses can cause serious injury.

Procedure

PREPARATION

1. Read the entire lab procedure, and plan the steps you will take.
2. Record your data in the data table below.

Trial	Total Mass (kg)	Accelerating Mass (kg)	Accelerating Force (N)	Time Interval (s)	Distance (m)
1					
2					
3					
4					
5					

3. Choose a location where the cart will be able to move a considerable distance without any obstacles and where you will be able to clamp the pulley to a table edge.

APPARATUS SETUP

4. Connect the LabPro® or CBL 2™ interface to the calculator with the unit-to-unit link cable. Connect the Dual-Range Force Sensor to the CH1 port on the interface, and set the switch on the sensor to 10N. Connect the motion detector to the DIG/SONIC 1 port on the interface.
5. Turn on the calculator, and start the DataMate® program. Press CLEAR to reset the program.
6. Set up the apparatus as shown in **Figure 1.** Securely tape the force sensor to the dynamics cart. Tape the poster board to the opposite end of the dynamics cart to make a flat, vertical surface. Clamp the pulley to the table edge using a table clamp, rod, and parallel clamp so that the pulley is level with the force sensor hook. Position the motion detector so that the cart will move away from it in a straight line. Securely clamp the motion detector to the ring stand. Place a piece of tape 0.5 m in front of the motion detector to serve as a starting line for the cart. (**Note: Do not pull on the force sensor.**)

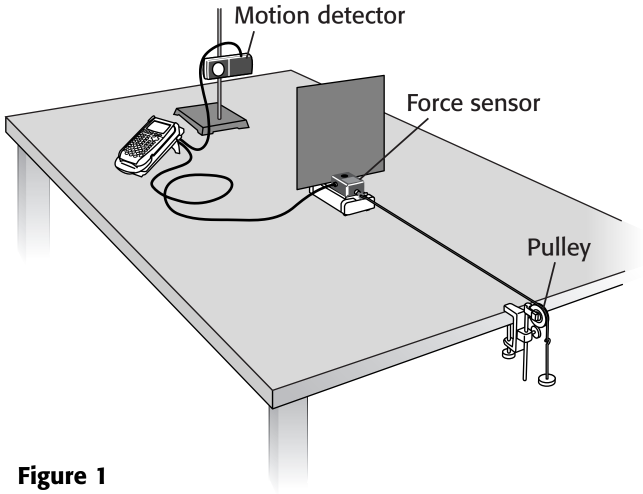

Figure 1

CONSTANT MASS WITH VARYING FORCE

7. Carefully measure the mass of the cart assembly on the platform balance, making sure that the cart does not roll or fall off the balance. Then, load it with masses equal to 0.60 kg. Lightly tape the masses to the cart to hold them in place.
8. Attach one end of the cord to a small mass hanger and the other end of the cord to the force sensor. Pass the cord over the pulley, and fasten a small mass to the end to offset the frictional force on the cart. The mass is correct when the car moves forward with a constant velocity when you give it a push. The car will have constant velocity for only a short period after it is pushed, then it will accelerate as the counterweight drops. *This counterweight should stay on the cord throughout the entire experiment.* Add the mass of the counterweight to the mass of the cart and masses, and record the sum as *Total Mass* in your data table.

9. For the first trial, remove a 0.10 kg mass from the cart, and securely fasten it to the end of the cord along with the counterweight. Record 0.10 kg as the *Accelerating Mass* in the data table.

10. Place the cart so that the poster-board end is closest to the motion detector and is lined up with the tapeline, 0.5 m in front of the motion detector. Keep the force sensor cord clear so that the cart will be able to move freely.

11. Make sure that the calculator is turned on. Make sure that the area under the falling mass is clear of obstacles. Select START to begin collecting data, and release the cart simultaneously. The motion detector will begin to click as it collects data.

12. Carefully stop the cart when the 0.10 kg mass hits the floor. Do not let the cart fall off the table.

13. When the motion detector has stopped clicking, the graph selection screen will appear on the calculator. Press ENTER to plot a graph of the force sensor reading against time. Use the arrow keys to trace along the curve. The y-value is the force in newtons; it should be fairly constant. Record this value as the *Accelerating Force* in the data table. Press ENTER to return to the graph selection screen.

14. Press the down arrow key once, and then press ENTER to display a graph of the distance in meters against time. Use the arrow keys to trace along the curve. On the far left and the far right, the flat portion of the curve represents the positions of the cart before and after its motion. The middle section of the curve represents the motion of the cart. Choose a point on the curve near the beginning of this middle section (but not the beginning point itself), and choose another point near the end.

15. Find the difference between the y-values of these two points, and record it as the *Distance* for *Trial 1* in your data table. Find the difference between the x-values for these two readings to find the time elapsed between measurements. Record this as the *Time Interval* for *Trial 1* in your DATA TABLE. Press ENTER to return to the graph selection screen.

a. Press the down arrow key once, and then press ENTER to display a graph of the velocity in m/s against time. Press ENTER to return to the graph selection screen.

b. Press the down arrow key once, and then press ENTER to display a graph of the acceleration in m/s^2 against time. Press ENTER to return to the graph selection screen. Select MAIN SCREEN to return to the main screen.

16. Replace the 0.10 kg mass in the cart. Remove the 0.20 kg mass from the cart, and attach it securely to the end of the cord. Repeat the procedure for *Trial 2.*

17. Leave the 0.20 kg mass on the end of the cord, and attach the 0.10 kg mass from the cart securely to the end of the cord. Repeat the procedure for *Trial 3.*

CONSTANT FORCE WITH VARYING MASS

18. For the two trials in this part of the experiment, keep 0.30 kg and the counterweight on the cord. Be sure to include this mass when recording the total mass for these trials.

19. Add a 0.50 kg mass to the cart. Tape the mass to the cart to keep it in place. Run the experiment and record the total mass, accelerating mass, accelerating force, distance, and time under *Trial 4* in your data table.

20. Tape a 1.00 kg mass to the cart, and repeat the procedure. Record the data under *Trial 5* in your data table.

21. Clean up your work area. Put equipment away safely so that it is ready to be used again.

Analysis

1. **Analyzing Data** Calculate the *Accelerating Force* for each trial. Use Newton's second law equation, $F = ma$, where m = *Accelerating Mass* and $a = a_g$. Compare these force values to the force value in your data table. Are they the same? Why or why not?

2. **Organizing Data** Use your values for the distance and time to find the acceleration of the cart for each trial, using the equation $\Delta x = \frac{1}{2} a \Delta t^2$ for constantly accelerated motion.

3. Constructing Graphs Using the data from *Trials 1–3*, plot a graph of the acceleration of the cart versus the time. Use a graphing calculator, computer, the graph below, or graph paper.

4. Analyzing Graphs Based on your graph from item 3, what is the relationship between the acceleration of the cart and time? Include a discussion of friction. Explain how your graph supports your answer.

5. Constructing Graphs Using the data from *Trials 3–5*, plot a graph of the total mass versus the acceleration. Use a graphing calculator, computer, the graph below, or graph paper.

6. Interpreting Graphs Based on your graph from item 5, what is the relationship between the total mass and the acceleration? Explain how your graph supports your answer.

Conclusions

7. **Evaluating Methods** Why does the mass in *Trials 1–3* remain constant even though masses are removed from the cart during the trials?

8. **Evaluating Methods** Do the carts move with the same velocity and acceleration as the accelerating masses that are dropped? If not, why not?

9. **Drawing Conclusions** Do your data support Newton's second law? Use your data and your analysis of your graphs to support your conclusions.

10. **Applying Conclusions** A team of automobile safety engineers developed a new type of car and performed some test crashes to find out whether the car is safe. The engineers tested the new car by involving it in a series of different types of accidents. For each test, the engineers applied a known force to the car and measured the acceleration of the car after the crash. The graph in **Figure 2** shows the acceleration of the car plotted against the applied force. Compare this with the data you collected and the graphs you made for this experiment to answer the following questions.

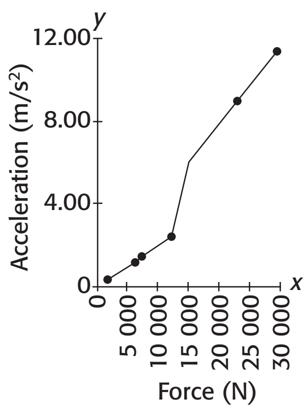

Figure 2

a. Based on the graph, what is the relationship between the acceleration of the new car and the force of the collision?

b. Does this graph support Newton's second law? Use your analysis of this graph to support your conclusions.

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c. Do the data from the crash tests meet your expectations based on this lab? Explain what you think may have happened to affect the results. If you were on the engineering team, how would you find out whether your results were in error?

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Extensions

11. Designing Experiments How would your results be affected if you used the mass of the cart and its contents instead of the total mass? Predict what would happen if you performed *Trials 1–3* again, keeping the mass of the cart and its contents constant while varying the accelerating mass. If there is time and your teacher approves your plan, go into the lab and try it. Plot your data using a graphing calculator, computer, or graph paper.