

# Force and Acceleration

Newton's second law states that any net external force applied to a mass causes the mass to accelerate according to the equation  $\mathbf{F} = m\mathbf{a}$ . Because of frictional forces, experience does not always seem to support this. For example, when you are driving a car, you must apply a constant force to keep the car moving with a constant velocity. In the absence of friction, the car would continue to move with a constant velocity after the force was removed. The continued application of force would cause the car to accelerate.

In this lab, you will study the motion of a dynamics cart pulled by the weight of masses falling from a table to the floor. The cart is set up so that any applied force will cause it to move with a constant velocity. In the first part of the experiment, the total mass will remain constant while the force acting on the cart will be different for each trial. In the second part, the force acting on the cart will remain constant, but the total mass will change for each trial.

## OBJECTIVES

**Compare** the accelerations 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
- C-clamp
- calibrated masses and holder
- cord
- dynamics cart
- hooked mass, 1000 g
- mass hanger
- masking tape
- meterstick
- pulley with table clamp
- recording timer and tape
- stopwatch

## SAFETY



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

**Force and Acceleration *continued***

**Procedure**

**PREPARATION**

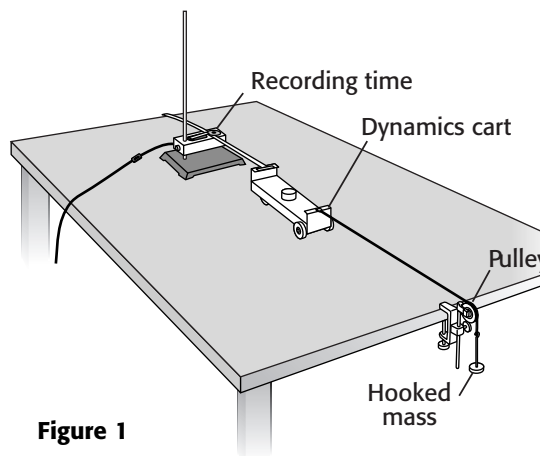
1. Read the entire lab procedure, and plan the steps you will take.
2. Record your data in the data table below.

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. Set up the apparatus as shown in **Figure 1**. Clamp the pulley to the edge of the table so that it is level with the top of the cart. Clamp the recording timer to a ring stand or to the edge of the table to hold it in place. If the timer is clamped to the table, leave 0.5 m between the timer and the initial position of the cart. Insert the carbon disk into the timer, and thread the tape through the guides under the disk. When your teacher approves your setup, plug the timer into a wall outlet.



**Figure 1**

5. If you have not used the recording timer before, check with your teacher for instructions. Calibrate the recording timer with the stopwatch or use the previously determined value for the timer's period.
6. Record the value for the timer's period at the top of the data table.
7. Fasten the timing tape to one end of the cart.

**Force and Acceleration** *continued*

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**CONSTANT MASS WITH VARYING FORCE**

8. 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 the cart with masses equal to 0.60 kg. Lightly tape the masses to the cart to hold them in place. Add these masses to the mass of the cart and record the total.
9. Attach one end of the cord to a small mass hanger and the other end of the cord to the cart. Pass the cord over the pulley and fasten a small mass to the end to offset the frictional force on the cart. You have chosen the correct mass if the cart moves forward with a constant velocity when you give it a push. *This counterweight should stay on the string 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.
10. For the first trial, remove a 0.10 kg mass from the cart, and securely fasten it to the end of the string along with the counterweight. Record 0.10 kg as the *Accelerating Mass* in the data table.
11. Hold the cart by holding the tape behind the timer. Make sure the area under the falling mass is clear of obstacles. Start the timer and release the tape simultaneously.
12. Carefully stop the cart when the 0.10 kg mass hits the floor, and then stop the timer. ***Do not let the cart fall off the table.***
13. Remove the tape and label it with the trial number.
14. Use a meterstick to measure the distance the weights fell. Record the *Distance* in your data table.
15. On the tape, measure this distance starting from the first clear dot. Mark the end of this distance. Count the number of dots between the first dot and this mark.
16. Calculate and record the *Time Interval* represented by the number of dots. Fasten a new timing tape to the end of the cart.
17. Replace the 0.10 kg mass in the cart. Remove 0.20 kg from the cart and attach it securely to the end of the cord. Repeat the procedure, label the tape, and record the results in your data table as *Trial 2*.
18. 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, label the tape, and record the results in your data table as *Trial 3*.

**CONSTANT FORCE WITH VARYING MASS**

19. For the two trials in this part of the experiment, keep 0.30 kg and the counterweight on the string. Be sure to include this mass when recording the total mass for these three trials.
20. Add 0.50 kg 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.

**Force and Acceleration** *continued*

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- 21. Tape 1.00 kg to the cart and repeat the procedure. Record the data under *Trial 5* in your data table.
- 22. Clean up your work area. Put equipment away as instructed.

**Analysis**

- 1. **Analyzing Data** Calculate the *Accelerating Force* for each trial. Use Newton’s second law equation,  $\mathbf{F} = m\mathbf{a}$ , where  $m = \textit{Accelerating Mass}$  and  $a = a_g$ . Enter these values in your data table.
- 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, 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.

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**Force and Acceleration** *continued*

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**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, 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.

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### 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?

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

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**Force and Acceleration** *continued*

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

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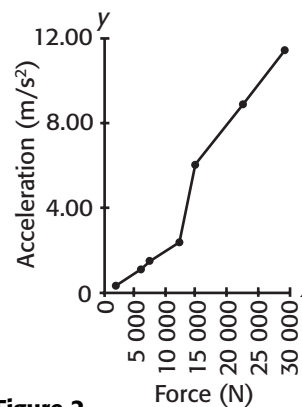


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**10. Applying Conclusions** A team of automobile safety engineers developed a new type of car and performed some test crashes to find out whether the car is safe. The engineers tested the new car by involving it in a series of different types of accidents. 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?

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

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**Force and Acceleration** *continued*

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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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**Extension**

- 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.