Newton's Second Law

INTRODUCTION

In your discussion of Newton's first law, you learned that when the sum of the forces acting on an object is zero, its velocity does not change. However, when a net force acts on the object, it accelerates. In this experiment, you will determine the relationship between the net force acting on an object and its acceleration.

OBJECTIVES

In this experiment, you will

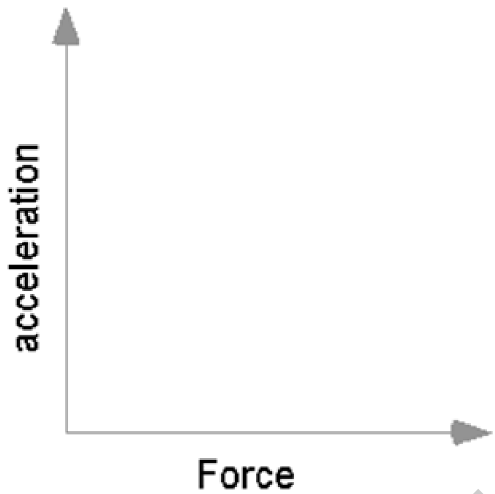
- Identify the forces acting on an object both when its change in velocity, Δv, is zero and when it is accelerating.
- Collect force, velocity, and time data as a cart is accelerated on a track.
- Use graphical methods to determine the acceleration of the cart.
- Determine the relationship between the cart's acceleration and the net force applied to it.
- Determine the effect of the mass on the relationship between acceleration and force.

MATERIALS

Graphical Analysis Pro
Go Direct Sensor Cart with force sensor hook
Vernier Dynamics Track
Vernier Ultra Pulley and Pulley Bracket
standard hooked or slotted lab masses
lightweight mass hanger and string
balance

PRE-LAB INVESTIGATION

Your instructor will show you the apparatus for this experiment. It is called a "modified Atwood's machine." A weight is connected to a cart by a string over a pulley. When the weight is allowed to fall, observe the motion of the cart. A force sensor mounted on the cart enables you to measure the force acting on the cart when it is moving. Discuss how you could determine the acceleration of the cart. Then, consider how the acceleration varies as the force applied to the cart increases. On the axes provided below, draw a sketch of the acceleration *vs*. net force graph based on your observations.



PROCEDURE

1. Prepare the cart and track for data collection.
   a. Attach an Ultra Pulley to the Pulley Bracket; then attach this assembly to one end of the Dynamics Track (see Figure 1).
   b. Attach the force sensor hook to the Go Direct Sensor Cart. Place the cart on the track so the force sensor hook is facing the pulley.
   c. Attach one end of the string to the mass hanger, thread the string over the pulley, and attach the other end of the string to the force sensor hook. Adjust the height of the pulley so the string is parallel to the surface of the track.
   d. Adjust the track to make frictional forces negligible for a cart moving towards the pulley end of the track.

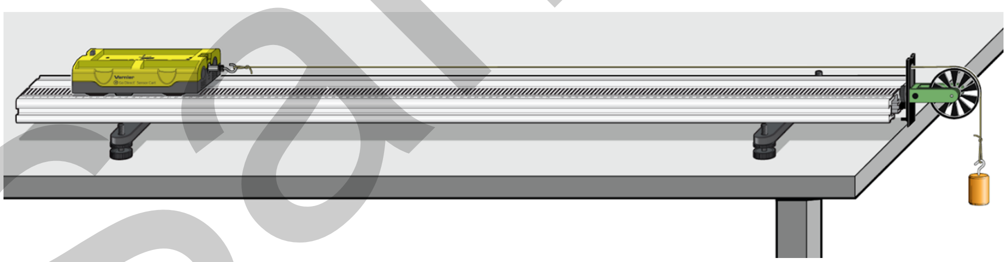


Figure 1

2. Discuss with your instructor what range of masses to use to apply the force that will accelerate the cart. Determine the total mass of your cart and any additional mass you may be instructed to use.

3. Set up data collection.
   a. Launch Graphical Analysis and connect the Go Direct Sensor Cart to your device. Change the sensor channels to use both the Position and Force sensors.
   b. You will need only graphs of force *vs*. time and velocity *vs*. time. Use View Options, ⊞, and the Plot Manager to modify the graphs as needed.

4. Disconnect the hanging mass from the force sensor, then zero both the position and force sensors.

5. Re-connect the hanging mass to the force sensor. Hold the cart so the hanging mass is about 30 cm above the floor.

6. Start data collection, then release the cart. Catch the hanging mass before it strikes the floor.

7. To determine the force acting on the cart, select the portion of the force *vs*. time graph corresponding to the interval during which the cart's velocity was changing smoothly. Manual scaling of your graph is more helpful for doing this than Autoscaling. Find the statistics for this interval.

8. To determine the acceleration of the cart, perform a linear fit on the portion of the velocity *vs*. time graph during which the velocity is changing smoothly. Be sure to record the values of force and acceleration for this hanging mass in your lab notebook.

9. Repeat Steps 5–8 until you have three trials of force *vs*. acceleration data that are reasonably consistent for that mass.

10. Increase the hanging mass and continue collecting data as described above until you have acceleration *vs*. force data for at least five different hanging masses. Save your data file.

EVALUATION OF DATA

1. To evaluate the relationship between acceleration and force, click or tap File, , and choose New Experiment. Click or tap Manual Entry.

2. Even though you investigated how acceleration responded to changes in the force, in order to facilitate your analysis of data, plot a graph of force *vs*. acceleration by entering your data into the new file.

3. If the relationship between force and acceleration appears to be linear, fit a straight line to your data. Export or print your data table and graph.

4. Write the equation that represents the relationship between the force, F, acting on the cart and the cart's acceleration, a. Be sure to record the value of the mass of the cart you determined in Procedure Step 2.

5. Write a statement that describes the relationship between the force acting on the cart and the cart's acceleration.

6. Compare your results to those obtained by others in class. What relationship appears to exist between the slope of the graph of F *vs*. a and the mass that was accelerated?

7. Assuming that the conclusion you reached in Step 6 is correct, express the SI unit of force, N, in terms of the fundamental units of mass, length, and time.

8. Write a general equation that expresses the relationship between force, mass, and acceleration.

EXTENSIONS

1. Examine the force *vs*. time graph for one of your trials. Explain why the force reading decreases as the cart is released and accelerates.

2. Suppose that you had kept the net force acting on the cart the same but varied the mass instead. Predict the shape of the graph of acceleration *vs*. mass. Your answer to the question above should suggest why it would be very difficult to perform an experiment to test your prediction. Explain.