Newton's Second Law

INTRODUCTION

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

Vernier data-collection interface	standard hooked or slotted lab masses
Logger *Pro*	Vernier Dynamics Track
Dual-Range Force Sensor	standard cart
	Ultra Pulley and Pulley Bracket
Motion Detector	lightweight mass hanger

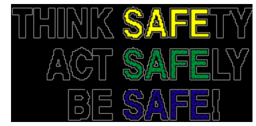
Background

The following equation is Newton's 2nd Law: $\underline{\boldsymbol{\Sigma F = ma}}$

ΣF represents the net force acting on a mass, *m*; and *a* represents the resulting acceleration.

Imagine an object in space pulled in opposite directions by two equal forces. The sum of these forces, therefore, equals zero. According to Newton's 2nd Law, the mass will not accelerate. If, however, the forces are not equal, then the object will accelerate in the same direction as the net force.
In this lab, the acceleration must be measured from a velocity-time graph. Since acceleration is defined as the change in the velocity per unit time, then the slope of the velocity-time graph equals the acceleration

Newton's First Law of motion states that if no net force acts on an object, then the velocity of the object remains unchanged. The Second Law of motion deals with what happens when a net force does act. As long as a net force acts, the velocity of an object changes - in other words, it accelerates. If more force is applied, the greater force produces a greater acceleration. Twice the force produces twice the acceleration. Often, several forces act on an object simultaneously. In such cases, it is the net force, or the vector sum of all the forces acting, that is important. Newton's second law states that the acceleration is proportional to the net force acting on the object. Newton's Second Law also states that the acceleration is inversely proportional to the mass.



SAFETY REMINDER.

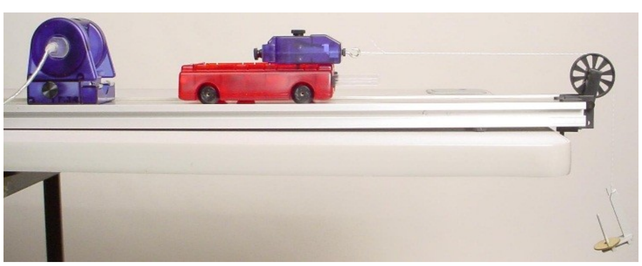
- Follow directions for using the equipment.

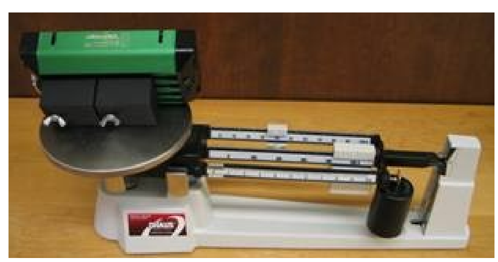
Prediction (think about the questions below before you start the experiment)

1. What happens to an object when you apply a net force to it?
2. What happens to the motion of an object if its mass changes but you keep the magnitude of the net force constant?

Setup

1. Set up the Labquest mini Interface and computer. Connect the Motion Sensor to the interface.
2. Make sure the track is levelled properly. Place the track on a horizontal surface. Level the track by placing the cart on the track. If the cart rolls one way or the other, use the leveling screw at one end of the track to raise or lower that end until the track is level and the cart does not roll one way or the other. (Note: It is very important that the track is levelled to get best results.)
3. In this experiment you will use one more sensor, it is called ***dual range force sensor***. This sensor can measure the Tension (T) that acting on the string connected to the sensor. Tension is the force on the string.There are two settings on the top of the sensor that we can use. Use the 50 N setting for this experiment.
    a. The force sensor is fixed on top of the cart. Make sure you take extreme care while handling the two sensors (Force sensor and Motion sensor). Do not drop them or hit/bang them with the cart.
4. Set up the equipment as shown in the figure (left) below.





5. The motion sensor is fixed at one end of the track.
6. Attach the pulley to the other end of the track.
7. Measure the mass of the cart and the force sensor together and record it as the total mass of the cart. Check the picture above of the measurement before you make the measurement. Place the cart on its side for wieghing as shown in the picture.
8. Attach a piece of string about 1.2 m long to a mass hanger. The mass of the hanger is 50 g. Note the mass on your lab note book and worksheet.

9. After recording the mass, place the cart and the force sensor on the track. Connect the force sensor to the interface. Open the logger Pro software, three graphs will be displayed on the screen, F-t, x-t and v-t. You only need F-t and v-t graphs for this experiment, so remove x-t graph from the display.
10. Zero the sensor's by pressing the zero on the menu bar. This step is important to get better results. Zeroing of the force sensor is done before it is connected the hanger by means of the string.
11. Set up data collection.

    a. Choose Data Collection from the Experiment menu.
    b. Reduce the length of time to 3 seconds.
12. Make sure that you have masses 50 g (1), 20 g (2), 10 g (2), 5g (2) on your table. If you do not have, check with your instructor.
13. Place the hanger on the table. Connect one end of the string to the hook on the force sensor and put the string in the pulley's groove with the mass hanger hanging down. Make sure you hold the cart, otherwise the cart will start moving towards the other end of the track.
14. Adjust the pulley up or down so the string is parallel to the track and in line with the hook on the force sensor. Otherwise, the force applied will not be horizontal and there will be large error in the measured quantities.
15. ***Make sure the cable that connects the force sensor and the interface is free to move and it does not apply any force on the cart while the cart is in motion. Also, before every measurement, make sure that the motion sensor is facing the track.***
16. Now you are ready to start the data collection.
17. Hold the cart in front of the Motion Sensor but no closer than 20 cm from the sensor. Make sure that the mass hanger is not oscillating.
18. Click collect or press the space bar and release the cart. Cart will move towards the pulley. Catch or stop the cart just before it hits the pulley. You may practice this several times before you start the actual data collection.
19. To determine the tension (T) on the string attached to the cart, select the portion of the force *vs.* time graph corresponding to the interval during which the cart's velocity was changing smoothly. Find the statistics for this interval. Manual scaling of your graph is more helpful for doing this than Autoscaling. Note down the tension in your worksheet. Mass of the hanger is 50 g.
20. To determine the acceleration of the cart from v-t graph, perform a linear fit on the portion of the velocity *vs.* time graph during which the velocity is changing smoothly.
21. Be sure to record the values of tension and acceleration for this hanging mass in your lab worksheet.

22. Repeat Steps 18–21 until you have two sets of tension *vs.* acceleration data that are reasonably consistent for that mass. Record the values of tension and accelerations in your worksheet.

23. Add one 20 g to the hanger and measure tension and acceleration. Repeat the experiment three times and note down the tension and acceleration. So for each mass of the hanger you have three data sets and you find the mean of all three for your further calculations.

24. Add another 20 g to the hanger (Hanger + 20 g + 20 g) and repeat the experiment and collect three sets of data. Find mean tension and acceleration.

25. Continue the experiment by adding another (a) 20 g and (b) 50 g. Now you have five sets of data for tension and acceleration.

26. Tabulate the mean tension and acceleration in your worksheet.

27. Calculate the theoretical tension and acceleration for each run and tabulate them on the worksheet.

28. Open another logger pro and enter the measured tension on the y-axis and acceleration as x-axis as data points. Once you start entering the data on the left, you will notice that the data is actually plotted on the graph. Once you have done with entering all data, make a linear fit to the graph and obtain the slope.

29. Write the equation that represents the relationship between the tension, T, acting on the string that's connects the cart and the cart's acceleration, *a* ***<u>for the graph you plotted in step 28</u>***.

30. Write a statement that describes the relationship between the tension and the cart's acceleration.