Activity P08: Newton's Second Law - Constant Force
(Force Sensor, Motion Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Newton's Laws	P08 Constant Force.DS	P11 Constant Force	P11_CONF.SWS

Equipment Needed	Qty	Equipment Needed	Qty
Economy Force Sensor (CI-6746)	1	Mass and Hanger Set (ME-8967)	1
Motion Sensor (CI-6742)	1	String (SE-8050)	1 m
Balance (SE-8723)	1	Super Pulley w/ Clamp (ME-9448A)	1
Dynamics Cart (inc. w/ Track)	1	1.2 m Track System (ME-9435A)	1

What Do You Think?

The purpose of this activity is to study Newton's Second Law. Using Newton's Second Law, what happens to an object's acceleration if the force applied to the object is increased but the object's mass remains constant?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

Newton described the relationship between acceleration, force, and mass as follows:

The acceleration of an object is directly proportional to and in the same direction as the net force, and inversely proportional to the mass of the object:

$$a = \frac{F_{net}}{m}$$

a is acceleration, F_{net} is net force, and m is mass.

Applying Newton's Second Law to the static setup used in this activity for an object accelerated by the weight of a hanging mass, neglecting friction, the acceleration of the object and hanging mass can be written as:

$$a = \frac{F_{net}}{m} = \frac{m_{hanging}g}{m_{object} + m_{hanging}}$$
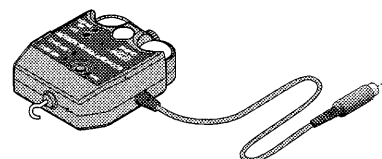
| SAFETY REMINDER	
• Do not let the cart run away from the user. Catch the cart before the cart crashes into the bumper or travels off the table.	**THINK SAFETY** **ACT SAFELY** **BE SAFE!**
• Follow directions for using equipment.	

For You To Do

For this activity, use a Motion Sensor to measure the motion of a cart that is pulled by string attached to a hanging mass that is suspended over a pulley. Use a Force Sensor mounted on the cart to measure the force that accelerates the cart. Next, use *DataStudio or ScienceWorkshop* to plot and analyze the data.

PART I: Computer Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.

2. Connect the Motion Sensor's phone plugs to Digital Channels 1 and 2 on the interface. Plug the yellow-banded (pulse) plug into Digital Channel 1 and the second plug (echo) into Digital Channel 2.

3. Connect the DIN plug of the Force Sensor to Analog Channel A.

4. Open the document titled as shown:
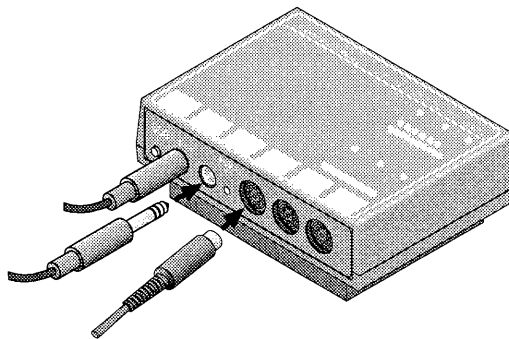
DataStudio	ScienceWorkshop (Mac)	ScienceWorkshop (Win)
P08 Constant Force.DS	P11 Constant Force	P11_CONF.SWS

*   The *DataStudio* document has a Workbook display. Read the instructions in the Workbook.

*   The *ScienceWorkshop* document has a Graph display with Velocity versus Time and a Table display of Force.

*   Data recording is set for 200 samples per second (200 Hz) for the Force Sensor.

PART II: Sensor Calibration and Equipment Setup

*   You do not need to calibrate the Motion Sensor.

*   To calibrate the Force Sensor, refer to the description in the Force Sensor Manual.

1. Place the Dynamics Track on a horizontal surface. Level the Dynamics Track by placing the Dynamics Cart on the Dynamics Track. If the cart rolls one way or the other, use the Adjustable Feet at one end of the Dynamics Track to raise or lower that end until the Dynamics Track is level and the cart does not roll one way or the other.

2. Attach a pulley to the right end of the Dynamics Track. Place the Motion Sensor at the left end of the track.

3. Use the thumbscrew included with the Force Sensor to mount the sensor onto the accessory tray of the cart.

4. Carefully measure and record the total mass of the cart and Force Sensor in the Lab Report section.

5. Place the cart on the Dynamics Track so the hook end of the Force Sensor points away from the Motion Sensor. The cart will be pulled away from the sensor. The cart must remain a minimum distance away from the sensor. The minimum distance from the sensor to its target is dependent upon the motion sensor used. Refer to the Motion Sensor Manual to determine the minimum distance. Put a mark on the Dynamics Track the minimum distance from the motion sensor (15 or 40 cm).

6. Use a string that is 10 cm longer than the length needed to reach the floor when the cart is next to the pulley. Attach one end to the Force Sensor's hook.

7. Add 20 or 30 grams of mass to the mass hanger.

8.   Carefully measure and record the total mass of the mass and mass hanger in the Lab Report section.

9.   Attach the mass hanger to the other end of the string, and put the string in the pulley's groove. Adjust the height of the pulley so the string is parallel to the Dynamics Track.
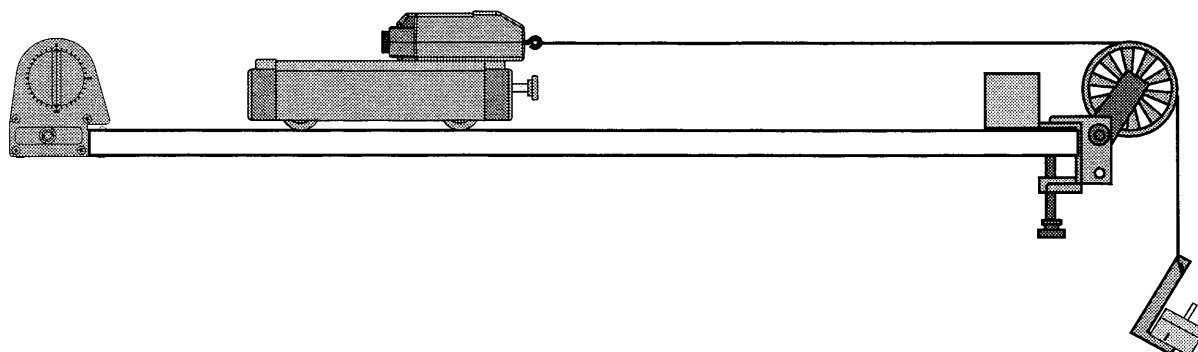

•   To fasten the string to the mass hanger, wrap the string four or five turns around the notched area of the mass hanger.

PART III: Data Recording

1.   Pull the cart toward the left end of the Dynamics Track but keep the cart at least the minimum distance from the Motion Sensor. Do not let the mass hanger bump into the pulley.

2.   Prior to each data run, support the hanging mass so that the string is not pulling on the Force Sensor. Push the tare button on the Force Sensor to zero the Force Sensor.

3.   Start recording data and then release the cart.

4.   Stop data recording before the cart reaches the pulley.

5.   Stop the cart before it collides with the pulley.

Analyzing the Data

1. Click and drag the cursor to draw a rectangle around the region of the velocity vs. time plot that shows the movement of the cart. **Result**: The area will be highlighted.
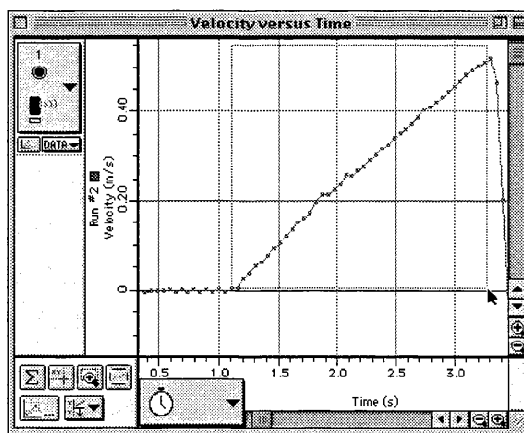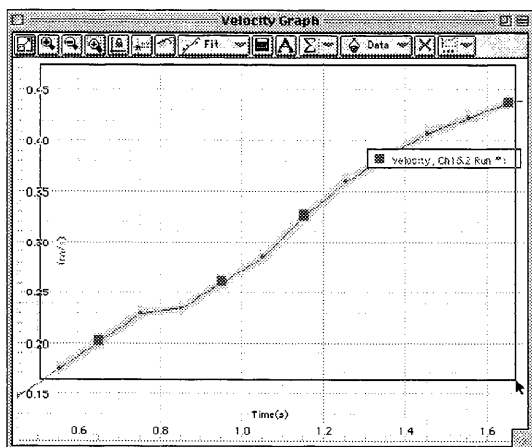
2. Select the Linear curve fit. The slope of the velocity vs. time plot is the average acceleration of the cart.

•   In *DataStudio*, click the 'Fit' menu button ( ). Select 'Linear'.

•   In *ScienceWorkshop* click the 'Statistics' button to open the Statistics area on the right side of the Graph. In the Statistics area, click the Statistics Menu button ( ). Select **Curve Fit, Linear Fit** from the Statistics Menu.

3. Record the slope of the linear fit in the Data Table in the Lab Report section.

4. Using the measured mass values, calculate and record the theoretical acceleration of the system in the Lab Report section.

5. Use the Statistics tool to find the average (mean) force from the Table display.

•   In the Force Table, click on the statistics button . Record the mean value of the force in the Data Table in the Lab Report section.

6. Using the measured mass value, calculate and record the force exerted on the cart and Force Sensor. Record the result in the Data Table.

Record your results in the Lab Report section.

Lab Report - Activity P08: Newton's Second Law – Constant Force

What Do You Think?

Using Newton's Second Law, what happens to an object's acceleration if the force applied to the object is increased but the object's mass remains constant?

Data Table

Item	Value
Mass of Cart and Sensor	
Mass of Hanger and Masses	
Acceleration (Measured)	
Acceleration (Calculated)	
Force (Mean)	
Force (Calculated)	

Questions

1. What is the percentage difference between the measured and calculated values of acceleration?

   Remember, $$\% \textbf{ difference} = \left|\frac{measured - theoretical}{theoretical}\right| \times 100\%$$

2. What is the percentage difference between the measured and calculated values of force?

3. What are some possible reasons for any differences between the measured and calculated or theoretical values?