INCLINED PLANE
AND
RESOLUTION OF FORCES

INTRODUCTION:

This lab activity is about resolving forces into component vectors and about balancing forces from a force transducer and an inclined plane against the force of gravity on an object. You'll also get more practice with statistical concepts, this time with fitting a linear function to a set of data.

OBJECTIVES:

The objectives of this experiment include:

1. Verifying the calibration of a Force Sensor used with the DataStudio; that is verifying that the computer systems response and output numbers are correct when known amounts of force are applied.
2. Measuring the force needed to hold an object from rolling down an inclined plane and compare the experimentally measured force with a theoretically predicted force.

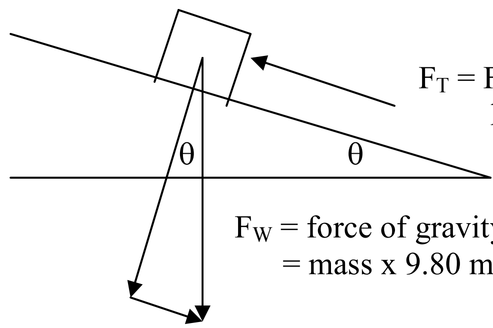
APPARATUS:

Dynamic cart; Track; Lab Stand; Masses; Meter Stick; Ruler; Balance; Force Sensor and Computer with DataStudio.

THEORY and CONCEPTS:

Forces and Units…a force has both magnitude and direction. Therefore, it must be represented as vector quantity. In the SI units system, forces are measured in units of "Newton's"; at the earth's surface, 1 kg of mass is acted on by the force of gravity ~ 9.80 N of force…from the equation $F = mg$, g is the acceleration duo to gravity.

Resolution of Forces…any vector quantity, including forces, can be represented as the vector sum of two or more other vectors. This resolution of forces into components can be done to make the calculation and measurement more convenient for certain problems. In the case of today's experiment, you'll be measuring the force that is parallel to the surface of an inclined plane that keeps the object from rolling down. If the plane were horizontal, no parallel force would be needed. In this case, the plane exerts a force perpendicular to the plane to hold the object up. If the plane were fully vertical, then the parallel force = the weight of the object.



F_T = Force of Force Sensor keeping object from rolling down

F_W = force of gravity
= mass x 9.80 m/s^2

F_P = force parallel to the plane surface
= F_W Sin θ

At equilibrium, $F_P = F_T$, two force parallel to the plane in the opposite direction must be equal.

METHOD:

In part 1, you'll apply known amounts of force to the Force Sensor using standard laboratory masses.

In part 2, you'll incline the plane and measure the force it takes to keep the cart from rolling down the plane. You'll "measure" the "force along the plane" by using your calibrated Force Sensor. You'll compare that to a value calculated from

$$F_p = F_W \text{ Sin } \theta,$$

where F_W = weight of the cart (Newton) and θ = angle of incline.

SUGGESTED PROCEDURE:

Part 1. Calibrate and Verify Force Sensor Operation

1. Start the DataStudio by double click the icon "DataStudio". The Experiment Setup window appears. Drag the Force Sensor to analog channel A.

2. Double click icon "Force Sensor" to open the "Sensor Properties" window. Select Tab "Calibration" to do sensor calibration.

   The Calibration window shows the default values (50 Newtons produces 8 Volts, -50 Newtons produces –8 Volts). The force sensor is set up so that a pull away from the sensor is a "negative" force. For example, if a 1 kilogram object is hung vertically from the hook, the force sensor measures –9.8 Newtons (since the force is downward).

- For the **High Value** calibration point, do not put any mass on the force sensor's hook, and then press the tare button on the side of the force sensor to zero the sensor. Since there is no mass on the sensor's hook, type **0** as the **High Value**. Click "Take Reading" button for High Value.

- For the **Low Value** calibration point, hang 1 kilogram mass on the sensor's hook. Type **–9.8** as **Low Value**. Click "Take Reading" button for Low Value.

- Click OK to return to the Experiment Setup window.

3. Record Data.

   a. Click **Start** to start data recording, wait few second then click **Stop**.
   b. Drag the recording data to **Table** Display.
   c. Click "Show Selected Statistics" Button on the Table window. Select "**Mean**" on Statistics Menu.
   d. Manually record the Mean value of Force.

4. Apply 0.1 kg, 0.2 kg, 0.5 kg and 1 kg to the force sensor and record the computer's result. Calculate the % difference between the applied and measured force.

Part 2. Resolution of Forces

1. Measure and record the mass of the dynamic cart.

2. Incline the track to approximately 10 degrees. Measure the base (x) and height (y) of the track to calculate the precise angle from

$$\theta = \tan^{-1}(y/x)$$

3. Place the Force Sensor in the track and press the tare button on the side of the force sensor to zero the sensor. Gently roll the cart down along the track to touch the Force Sensor's hook.

4. Record the Force Sensor output corresponding to this inclination.

5. Repeat at inclines of approximately 15 and 20 degrees.

CALCULATIONS and ANALYSIS:

1. From your data in part 1, plot the Measured Force vs. Applied Force. What is the slope of this line taken from your plot... *it should be 1.00*

2. Also, use the analytical technique explained in the appendix to find the "best fit" for a straight line to your data. Specifically, what is the value of the slope? What is the percentage difference between your graphical answer and the analytical solution for the slope?

3. From your data in part 2, calculate the component of gravitational force, F_p acting along the track from $Fp = F_w \sin \theta$, where F_w = weight of the cart (Newton's) and θ = angle of incline.

4. What is the % difference between the calculated and measured values of F_p?

SUGGESTED DATA AND CALCULATION SHEET

Part 1. Force Sensor

Added Mass (grams)	100	200	500	1000
Added Force (Newtons)	0.98	1.96	4.75	9.80
Force Sensor Reading (Newtons)	-------	-------	--------	--------

Part 2. Incline Track

Mass of cart, M = ________ (kilograms)

~ 10 degrees

	Calculated F_P	Force Sensor Reading F_p
height (y) = _____	$F_P = 9.80\times M\sin\theta$ = _________	F_P = _________
base (x) = _____		
$\theta = \tan^{-1}(y/x)$ = _____		

~ 15 degrees

height (y) = _____	$F_P = 9.80\times M\sin\theta$ = _________	F_P = _________
base (x) = _____		
$\theta = \tan^{-1}(y/x)$ = _____		

~ 20 degrees

height (y) = _____	$F_P = 9.80\times M\sin\theta$ = _________	F_P = _________
base (x) = _____		
$\theta = \tan^{-1}(y/x)$ = _____		