NEWTON'S LAW OF MOTION

OBJECTIVE:

The purpose of this experiment is to allow you to explore Newton's three laws of motion. You will verify the 1st law, the law of inertia, and you will demonstrate the 3rd law of action-reaction. You will study the 2nd law in detail by measuring the acceleration of an object when an unbalanced force acts upon it. In this experiment the unbalanced force will be supplied by the force of gravity as the object moving down an inclined plane.

METHOD:

You will use a track that provides a low-friction apparatus on which carts can be made to move. You will use photogate and computer software to measure the velocity of cart at two positions along the track. From velocity and position measurements with a level track, you can demonstrate Newton's 1st and 3rd laws.

Your study of the 2nd law will be made by inclining the track a known amount and then measuring the acceleration of the cart as it is pulled down the incline by the force of gravity. By adjusting the mass of the cart and analyzing the resulting data, you will first determine the relationship between the acceleration and force on a body. You will also be calculating a value for "g", the acceleration of the freely falling body.

APPARATUS:

Track, Two carts, Balance, Weights, Leveler, Two photogates and Computer

THEORY:

The first law of motion is that an object at rest will remain at rest and an object in motion will continue in motion with a constant velocity unless it experiences a net external force.

The second law of motion is that the acceleration of an object is directly proportional to the resultant force acting on it and inversely proportional to its mass.

$$\mathbf{F} = \mathbf{ma}$$

(A more general statement of Newton's 2nd law is that the time rate of change of momentum of a particle is equal to the resultant external force acting on the particle.
$F = d(mv)/dt$ where mv = the momentum)

The third law of motion describes the interaction of two bodies: the force on body 1 by body 2 is equal and opposite to the force exerted on body 2 by body 1, i.e..

$$\mathbf{F}_{12} = -\mathbf{F}_{21}$$

PROCEDURE:

PART 1. Computer Setup

1. Turn on the interface and then turn on the computer. Double click the icon "DataStudio". The Experiment Setup window appears.

2. Drag the "Photogate & Picket Fence" from Sensor List to Digital Channel 1 and Drag the "Photogate & Picket Fence" from Sensor List to Digital Channel 2.

   Remember: The photogate connected to Digital Channel 1 will be "Gate 1". The photogate connected to Digital Channel 2 will be "Gate 2".

3. Double click the icon "Photogate & Picket Fence" to open "Sensor Properties" window. Click Tab "Constant" and then type 0.02 m for Band Spacing. Click OK to return to Experiment Setup window. (Do this for both of them.)

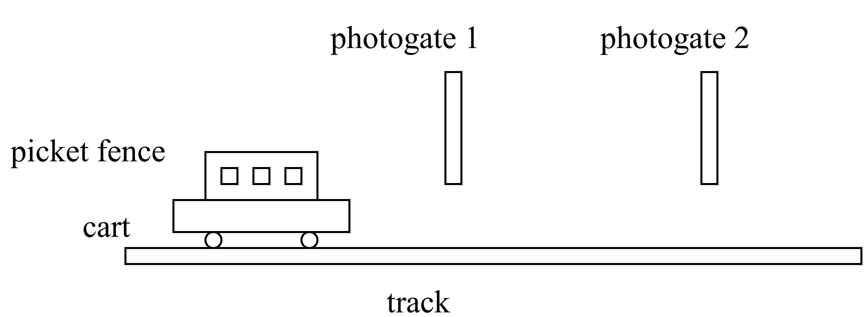
PART 2. Sensor Calibration and Equipment Setup

* You do not need to calibrate the photogate for this activity.

1. Level the track by leveler.

2. Put a picket fence in the notches at each end of the accessory tray of each cart. Use the balance to find the mass of each cart including the picket fence and record the value.

3. Adjust the height of each photogate so that as a cart moves through the photogate, the 2 cm band spacing fence on the picket fence blocks the photogate beam.



PART 3. Newton's First Law - the Law of Inertia

1. Place the cart at the end of track.

2. Click Start button to begin data recording.

3. Gently push the cart forwards other end of track.

4. Click the Stop button to end data recording, after the cart passed two photogates.

5. Using Table Display shows the velocity of the cart at Gate 1 position and Gate 2 position, by drag the recorded data from "Velocity Ch 1" to Table display and then drag the recorded data from "Velocity Ch 2" to the Table window. At the Table window, click statistic button and then choose "mean". Record the mean values, V_1 & V_2 .

6. Repeat the data recording procedure a total of three times. What is of interest is the change in velocity from one gate to the next.

PART 4. Newton's Third Law - Action and Reaction

1. Push in the spring plunger of the Dynamics Cart, cock the spring plunger at middle position.

2. Place two carts together at the middle of the track. Position two photogates so that Gate 1 is beyond the left end of the two carts, and Gate 2 is beyond the right end of the two carts. Adjust the photogates so that the distance between Gates is a few centimeters greater than the total length of both collision carts.

3. Click the Start button to begin data recording.

4. Gently push the spring plunger release to launch the carts.

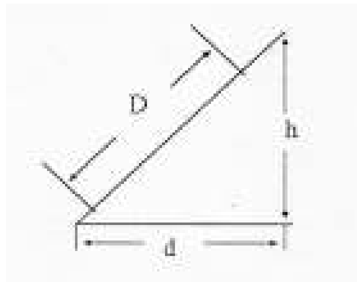
5. Click the Stop button to end data recording, after the carts passed photogate.

6. Using Table Display shows the velocity of the carts.

7. Repeat the data recording procedure a total of three times.

PART 5. Newton's Second Law - Net Forces and Acceleration

1. Incline the track. Measure h and d. Measure the distance between two photogates D.



2. Adjust the height of each photogate so that as a cart moves through the photogate, the 2 cm band spacing fence on the picket fence blocks the photogate beam.

3. Click the Start button to begin data recording.

4. Release the cart from top of the track.

5. Click the Stop button to end data recording, after the carts passed photogate.

6. Using Table Display shows the velocity of the cart at Gate 1 position and Gate 2 position. Repeat the data recording procedure a total of three times.

7. Change the mass of the cart by adding 500 g mass bar. Repeat step 3 - 6.

8. Change the mass of the cart by adding two mass bars. Repeat step 3 - 6. So that there are three different data sets.

CALCULATIONS and QUESTIONS:

From data in Part 3

1. Discuss possible sources of error that would cause the measurement of velocities to differ. Explain what Newton's 1st law predicted should have happened. How closely did your experiment verify this?

From data in Part 4

1. Multiply the mass of each cart by its velocity. Are the momenta equal? If not, why not? Explain what Newton's 3rd law predicted should have occurred if the carts were simultaneously released.

From data in Part 5

1. Calculate the angle of incline for track from $\tan\theta = h/d$.

2. For each set of velocities calculate acceleration "a" of cart, using the equation

$$V_2^2 - V_1^2 = 2aD$$

3. Group the values of acceleration "a" with each different value of mass you used. Calculate an average acceleration for each group. For example, if you used 3 different masses of carts, then calculate the three average accelerations associated with each mass.

4. For each average acceleration, calculate the force acting on the cart along the track from

$$F = ma_{avg}$$

(Note that at this step you have hypothesized that Newton's 2nd law is true. This equation is what defines the units of force. If it not true, there will not be a linear relationship between your value of F, which was calculated from the independently measured value of "a".)

5. Plot F versus m, with m being the independent variable. Is there a linear relationship between F and m? Does the graph go through the origin? Is the force acting on the mass proportional to the mass?

6. Use the average slope of the above graph to calculate a value of "g" the acceleration due to gravity. Use

$$a = g \sin\theta$$

where θ can be found from $\tan\theta = h/d$.

DATA ORGANIZATION SHEET
EXP NEWTON'S LAW of MOTION

1. Newton's 1st Law

V_1 (m/s)	V_2 (m/s)
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2. Newton's 3rd Law

V_1 (m/s)	V_2 (m/s)	$m_1 V_1$ (kg m/s)	$m_2 V_2$ (kg m/s)
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3. Newton's 2nd Law

D = ________ (m)   h = _____ (m)   d = ______ (m) θ = _____

	V_1 (m/s)	V_2 (m/s)	a (m/s^2)	$\bar{a}$ (m/s^2)	F (N)
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m = _____	-----------	-----------	-----------		
	-----------	-----------	-----------	-------	-------

	V_1 (m/s)	V_2 (m/s)	a (m/s^2)	$\bar{a}$ (m/s^2)	F (N)
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m = _____	-----------	-----------	-----------		
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	V_1 (m/s)	V_2 (m/s)	a (m/s^2)	$\bar{a}$ (m/s^2)	F (N)
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m = _____	-----------	-----------	-----------		
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