Experiment 4
NEWTON’S SECOND LAW

EQUIPMENT
1 acrylic picket fence
1 connecting string
1 photogate
1 dynamics car
Newton’s 2nd Law Program
1/2 kg and 1 kg masses for cart
1 table edge pulley
1 set of masses
1 triple beam balance
1 295g MADD added to balance

INTRODUCTION

Figure 1

The purpose of this experiment is to examine the motion of an object under the influence of a uniform, or constant, force and to observe the effects of inertia on the motion.

Galileo discovered that objects change their state of motion when acted on by an external force, the velocity of the object changes at a constant rate. Galileo’s studies did not adequately explain the relationship between the inertial mass of an object and the force causing the motion. A century after Galileo’s discoveries, Isaac Newton was able to explain the relationship between force, mass and acceleration. Newton stated that the acceleration, or rate of change of velocity, is directly proportional to the unbalanced force acting on the object and inversely proportional to the mass of the object. This relationship can be expressed as:

\[ \text{acceleration} = \frac{\text{force}}{\text{mass}} \quad \text{or} \quad a = \frac{F}{m} \]

In this experiment you will observe the acceleration of a small cart pulled by a constant force. The force to move the cart is provided by the weight of a suspended mass attached to the cart by a string as shown in Figure 1.

Figure 2

The motion and acceleration of the cart is in the direction of the applied force as shown in Figure 2. You will use a “picket fence” like the one in Figure 3 to communicate the passing of the cart to the computer. The picket fence is constructed so that it has alternating opaque and clear bands. When you pass the picket fence through the photogate, the dark bands will block the light. The computer program, along with the photogate, makes it possible to measure the time between the breaks in the light that are caused by the opaque bands of the picket fence. Since the distance between the bands is known by the software, the velocity of the picket fence at any point is easily calculated.

Figure 3

After the cart passes through the photogate, the variation of the position, velocity, and acceleration of the cart with respect to time will be graphed. The acceleration of the cart can be determined from the acceleration versus time graph or by calculating the slope of the velocity versus time graph. The slope of the graph of velocity versus time is the acceleration of the cart. If the acceleration is constant, the slope is constant and a straight line can be drawn through the points. Any object undergoing motion caused by a uniform force has constant acceleration. The object’s
velocity is changing but the rate of change of velocity is constant.
The experiment will be repeated several times, first by varying the mass of the cart and then by varying the force pulling the cart. From the graph obtained for each run, you will investigate the change in the acceleration of the cart when the mass of the cart and the force pulling the cart are varied.

PROCEDURE

A. Acceleration
1. Measure and record the combined mass of the dynamics cart and the picket fence.
2. Set up the equipment as shown in Figure 1.
3. Place the picket fence in the holder on the car and position the cart ahead of the photogate so that the photogate is not blocked. One partner should prevent the cart from moving while the other places a mass (100g) on the suspended weight pan.
4. Load the NEWTON’S 2nd LAW setup.
5. Press COLLECT and release the cart and allow it to pass through the photogate so that the computer can collect acceleration data. Do not allow the cart to fall to the floor.
6. Once the cart has passed through the gate press STOP to stop the timer routine. The computer will then display the graph.
7. Print the graphs after setting the following options:
   File→Print Options→Names, Title, \[M_1=\] ______\[M_2=\] ______
8. File→Print screen

B. Variation of Mass
9. Add 500g. Repeat steps 5-8 in part A.
10. Add 500g.
11. Again repeat steps 5-8 in part A.

C. Variation of Force
12. Remove all additional masses added to the cart in part B.
13. Increase the value of the suspended mass by adding 50g. This will increase the force pulling the cart.
14. Repeat steps 5-8 in part A.
15. Increase the suspended mass by another 50g.
16. Again repeat steps 5-8 of part A.
Experiment 4
DATA SHEET

Name: _____________________________

Section: ___________________________

QUESTIONS
1. From your velocity versus time graphs, can you conclude that the acceleration of the cart was constant in each case? State your reasons.

2. When the mass of the cart was increased and the suspended mass held constant, what happened to the magnitude of the acceleration? Why?

3. When the suspended mass was increased and the mass of the cart held constant what happened to the magnitude of the acceleration? Why?

4. Relate the results of your experiment to the statement of Newton’s second law.

5. If a cart has a weight of 10 N and is pulled by a constant 20 N force, what is the resulting acceleration? HINT: You must distinguish between mass and weight.