M16a: Newton’s Second Law

Introduction:

One of the founding cornerstones of all of physics is Sir Isaac Newton’s three laws of motion. This current experiment focuses on a closer examination of Newton’s Second Law. Newton’s Second Law of motion describes what happens to a single body when an unbalanced force acts on it. The unbalanced (net) force causes an acceleration of the body. This experiment examines the relationship between the net force and the resulting acceleration, attempting to provide confirmation of Newton’s Second Law. A common joke among physicists is that every equation can be derived from Newton’s Second Law, which is funny because it is true in a way. Since many of the actual physical situations that physics seeks to approximate are the result of unbalanced forces acting on an object, Newton’s Second Law does present a way to derive many of the different equations one makes use of.

In order to examine the second law in its simplest form an air track will be used. This limits the possible directions of motion to only one dimension. Also the air track elevates the cart on a cushion of air which effectively reduces friction to a negligible influence. This simplifies the problem so attention can be focused on the net force and the resulting acceleration.

The experiment will be analyzed using kinematics and dynamics. The kinematical analyses will be accomplished with the aid of a computer. The computer is connected to the air track and will record time intervals as the cart accelerates. These time intervals together with the displacement will allow the computer to do a graphical analysis of the data and compute the acceleration. The dynamical analysis will be completed by applying Newton’s second law and deriving an equation for the acceleration based upon the masses involved and gravitational acceleration. For each of the different trials, the net force acting on the cart will be due to the tension in the attached string. This tension will be varied via changing the amount of mass hanging from the string’s other end.

Apparatus:

- Air Track
- Cart
- Descending masses
- Pulley System
- Computer timing system

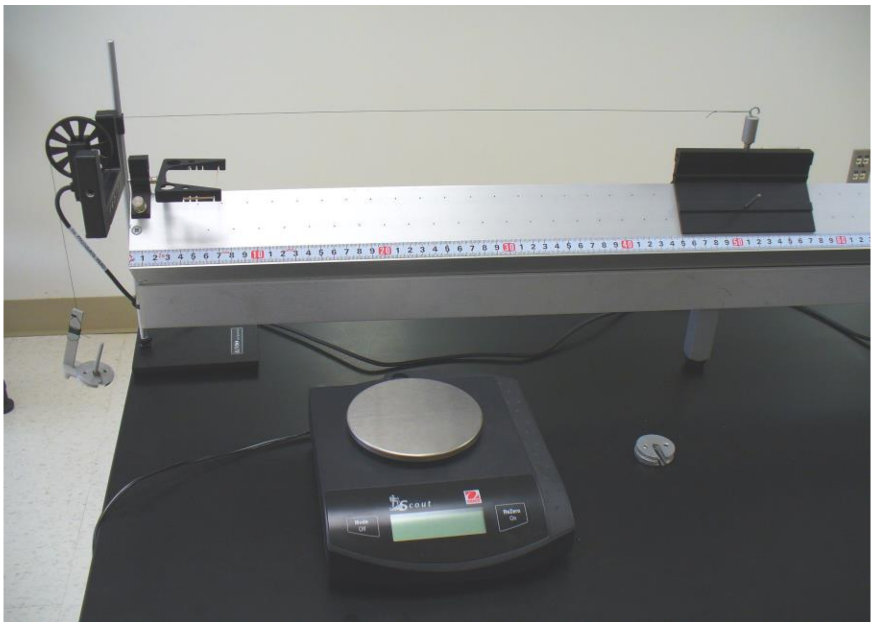

Figure 1

Discussion:

The dynamical analysis is conducted by applying Newton's second law individually to both the mass of the cart and then to the descending mass. The linking factor is the tension in the string connecting the two masses. The pulley that the string moves across is small, has very little mass and is almost frictionless; therefore the pulley's influences are going to be neglected. The cart is confined to motion in only one dimension labeled as the X-axis. The descending mass will also have motion in only one dimension labeled as the Y-axis. For simplicity call the X-axis to the right as the positive direction and the Y-axis down as the negative direction. The sum of the forces on each body would be as follows.

For the Cart:

$$\sum F_x = T = Ma$$

For the descending mass:

$$\sum F_y = T - mg = -ma$$
$$T = mg - ma$$

Combine the expressions for tension and solve for the acceleration.

$a = \dfrac{mg}{(m+M)}$	***This is the equation used to solve for the dynamical acceleration*.**

Force Diagram:

M = mass of cart

m = descending mass

F_g = force due to gravity on descending mass

a = acceleration of cart and descending mass

g = acceleration due to gravity (9.792 m/s^2)

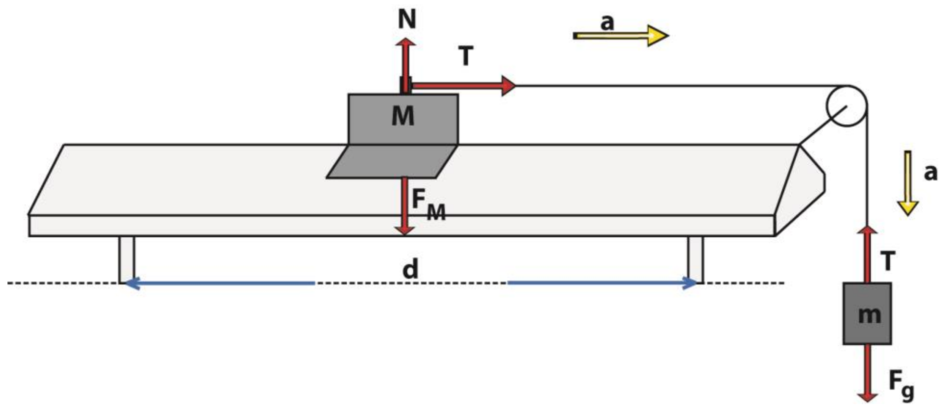

Figure 2

Procedures:

1. Measure the mass of the cart and the mass of the hanger as accurately as possible.
2. Start up the appropriate computer interface which is connected to the pulley via a photogate.
3. Make sure that the descending mass is connected with the string to the cart and is going over the pulley.
4. Using only the mass hanger, pull the cart back until the mass hanger is almost at the pulley, start the data collection, and release.
5. Stop the data collection once the descending mass hits the ground (this doesn't have to be exact).
6. Represented on the computer should be a graph with the velocity (m/s) vs. time (s). On this graph should be a linear line which ascends then may become rough. The linear portion of the graph is what should be analyzed to find the correct data. The rough part represents when the mass hit the floor. The computer should be set to a linear fit. Grab the part of the graph which needs to be analyzed by highlighting it with the left click on the mouse. Obtain the statistical slope of the line to find the kinematical acceleration and the standard deviation. **Make sure to collect at least five significant digits for the kinematical acceleration**.
7. Repeat using the other masses, adding one mass for each different trial, for 10 trials. Remember to weigh each mass along with the mass hanger and record it on the data sheet.
8. Now it is necessary to calculate the dynamical acceleration using the proper equation. The values for the dynamical acceleration (the acceleration calculated using Newton's Second Law) should compare to the values obtained for the acceleration (the actual physical resultant acceleration).
9. Using your dynamical acceleration calculate the net force on the cart.
10. Graph in excel the kinematic acceleration vs. the net force. This should result in a linear relationship.

Experiment M16a: Newton's Second Law

Student Name_______________________________________

*Lab Partner Name*__________________________________

*Lab Partner Name*__________________________________

Physics Course______________________________________

Physics Professor____________________________________

Experiment Start Date_________________________________

Lab Assistant Name	*Date*	*Time In*	*Time Out*

Experiment Stamped Completed

Data Sheet: M16a: Newton's Second Law

NAME: ______________________________ DATE: __________________

Mass of cart (kg): ____________________________

Mass of hanger (kg): ____________________________

Trial #	Total descending mass	Kinematic acceleration	Standard deviation	Dynamical Acceleration	Net Force on cart
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					