M16b: 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 varied by changing the height of the air track at one end. This change of the height, in essence making the track an incline, creates a component of gravitational force that will act down the incline apposing the force from the tension in the string.

Apparatus:

- Air Track
- Cart
- Descending mass
- Pulley System
- Computer timing system
- Stair levels to change height
- Meter stick
- Caliper

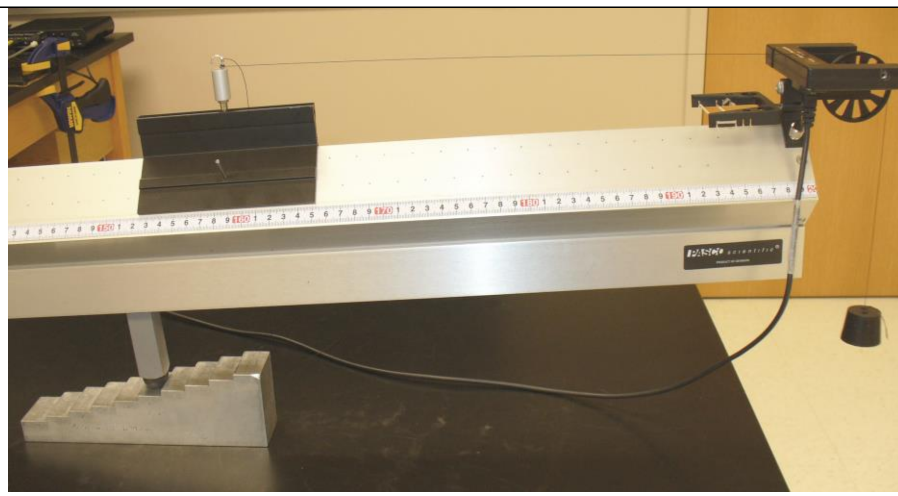


Figure 1

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 descending mass is confined to motion in only one dimension labeled as the Y-axis. The cart has motion in two directions, both the X and the Y axis, due to the fact that the air cart is being raised to heights of varying angles via the step system. The motion of the cart in the X direction is the primary dimension that needs to be analyzed and is assumed parallel to the track. 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:

$$\sum F_x = T - Mg\sin\theta = Ma$$
$$T = Mg\sin\theta + Ma$$

For the descending mass:

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

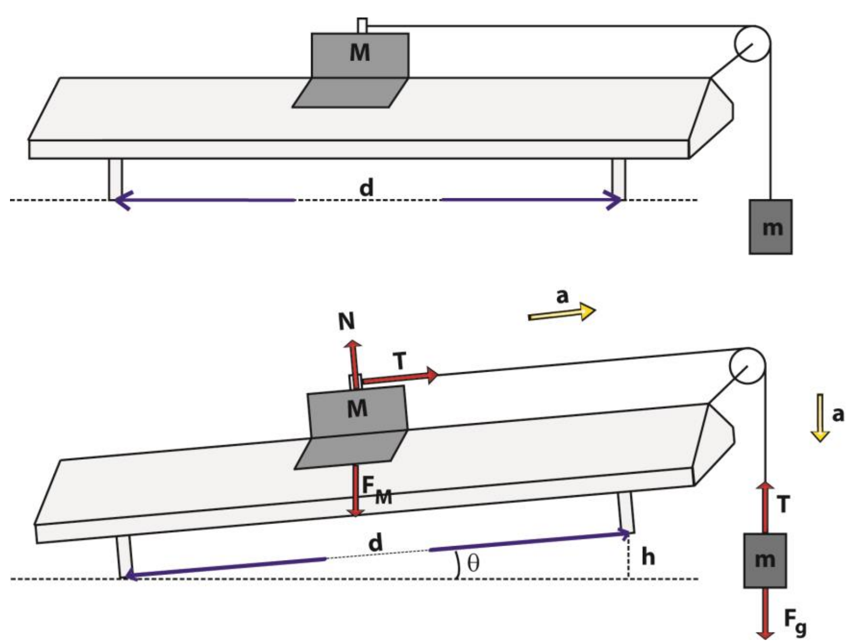
Combine the expressions for Tension and solve for the acceleration.

$$a = \frac{mg - Mg\sin\theta}{M + m}$$

This is the equation used to solve for the dynamical acceleration.

Force Diagram:

- M = mass of cart
- m = descending mass
- T = tension in string
- Fg = force due to gravity on descending mass
- a = acceleration of cart
- g = acceleration due to gravity (9.792 m/s2)
- N = normal force upon cart
- F_M = force due to gravity on cart
- θ = angle of elevation
- d = distance between track supports



Procedures:

1. Measure the mass of the cart and the hanging mass as accurately as possible.
2. Using the caliper measure the heights of each step/stair.
3. Using the meter stick on the air track to measure the distance between track supports.
4. Using trigonometry solve for the angles of incline between the air track and the table. Confirm that the angle measurements are correct by checking with a lab instructor.
5. Start up the appropriate computer interface which is connected to the pulley via a photogate.
6. Make sure that the descending mass is connected with the string to the cart and is going over the pulley.
7. First with the air track level (zero degree angle) pull the cart back until the mass hanger is almost at the pulley, start the data collection, and release.
8. Stop the data collection once the descending mass hits the ground (this doesn't have to be exact).
9. What should be seen on the computer is 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 part of the graph is what should be analyzed. 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 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**.
10. Repeat while increases the height one step at a time (aprox. 5 mm) for 10 trials. Record the slope, standard deviation and height for each trial.
11. Now calculate the dynamical acceleration using the equation provided. The values for the dynamical acceleration (the acceleration calculated using Newton's Second Law) should compare to the values obtained from the computer for the acceleration (the actual physical resultant acceleration).
12. Using your dynamical acceleration calculate the net force on the cart.
13. Graph in excel the kinematic acceleration as function of the net force. This should result in a linear relationship.

Experiment M16b: 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: M16b: Newton's Second Law

NAME: ____________________________   DATE: _________________

Mass of cart (kg): ____________________

Total descending mass (kg): ____________________

Distance between track supports (m): ____________________

Trial #	Height	Angle (θ)	Kinematical Acceleration	Standard deviation	Dynamical Acceleration	Net Force on cart
1	0	0				
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						