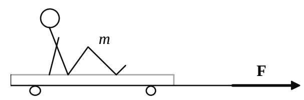
Newton's Second Law

Theory

Newton's second law states that *the net force on a body equals the product of the body's mass and acceleration:* $\Sigma \mathbf{F} = m\mathbf{a}$. The purpose of this experiment is to give you a "feel" for Newton's second law by experiencing the effect of a resultant force on your body.



Equipment

Rollerblade platform and tow rope, 50 N spring scale, weights for calibrating the scale, timer, chalk in assorted colors, post-it strips in assorted colors, and a 30 m tape measure. (Check the accuracy of your scale by hanging weights from it)

Procedure

I. Qualitative Run   Work in groups of three. Find a hallway or sidewalk that is flat, level, and clear of traffic over a distance of 15 to 20 m. One student sits on the platform and the other pulls the platform through the hall in a straight line with a constant force. The tow rope should be long enough that it is nearly horizontal when held at a convenient height. A spring scale attached to the end of the rope reads the force applied to the rope. The platform must be pulled in such a way that the reading of the spring scale is as constant as possible. It will probably take a few trials before you are able to do this. Then switch roles, so that each of you pulls the cart. Think about how you have to move in order to keep the force constant.

II Quantitative Run   Choose one person to pull, another to ride, mark positions, and a third to time the motion. Choose a value for the force that facilitates measurement (motion neither too fast nor too slow). Values in the range of 20 N to 40 N (depending on the mass of the rider) work well. The rider should be positioned with heels extended over the front edge of the cart, to serve as brakes. The rider should hold the timer in one hand and the marker in the other hand, which should be held beside a fixed point on the cart, just above the level of the floor, so that marks can be made easily and quickly.

With "brakes" engaged, and the one who pulls applying a constant force (but not yet moving the cart), the rider should make the first mark on the floor. This mark will serve as the origin of the x axis. When ready, the rider should simultaneously lift her heels and start the timer, so that the cart begins to move at $t = 0$. The rider then marks the floor at two second intervals, up to about 8 to 12 seconds. The only responsibility of the one who pulls the cart is to move in a straight line with as constant a force as possible, and to stop before the speed becomes dangerous.

Repeat, using different colored chalk to distinguish runs. Use post-it strips to help locate marks. Do two accurate runs, with position marks that are consistent. Use the tape measure to measure the positions, and record positions and times in the table provided. Measure to the midpoints between the marks from the two runs, so that you effectively average the results of two measurements. Also record the mass of the rider, and your estimates of the average force applied to the cart, and the uncertainty in this average force.

III. Measuring Friction   Find a simple way to measure the friction between the wheels and the ground, and make a measurement of this force. This rolling friction force turns out to be constant, independent of the speed of the cart.

Data, Analysis – Newton's second law **Name _______________** **Sect (day, time) _____**

Partner _______________ TA_____________

Time and Position of Cart

t(s)	t^2 (s^2)	x (m)	$\pm \Delta x$ (m)
0	0	0	0

Applied Force ___________ Mass of Rider _________

Total Mass _____________

Estimated Average Applied Force __________________

Estimated Uncertainty in Average Force _____________

Describe how you measured friction.

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Measurement(s) of friction ____

Average friction ____________________ Uncertainty in friction____________________

Calculate the net force on the cart:

Calculate the uncertainty in the net force. (You must use the minimum and maximum possible values of both the applied force and friction to compute the minimum and maximum values of the net force.) Show your work.

Net force:_____________ Uncertainty in the net force _______________

Fractional uncertainty in net force _______________

Use Newton's second law to predict the acceleration of the cart. Draw a FBD and show your calculations clearly.

Acceleration predicted by Newton's second law _______________

Fractional uncertainty in predicted acceleration _______________

Uncertainty in predicted acceleration____________________

Determine the observed acceleration of the cart, as found from the graph of x vs t^2.

Slope of graph __________   Observed acceleration ___________

Percent difference between predicted and observed acceleration ___________

Questions

What kind of motion is required to keep the force constant as the cart is pulled? Describe the motion in simple, qualitative terms.

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Can you keep the force perfectly constant? If not, is the average force reasonably constant?

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What is the shape of your graph of x vs t^2?

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What does this tell you about the velocity and acceleration of the cart?

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How would your results have changed if you had pulled the platform with the same force, but with the rope at an angle of 45°? ____

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Estimate the actual angle that your rope made with the horizontal, and show that this caused negligible error. Don't rely on a simple visual estimate, as this is very unreliable. Use trigonometry.

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