Newton's Laws

Procedure

- Add a 200-gram load to the cart and measure the total mass using a <u>triple beam balance</u> at the instructor's desk. Include units and an error estimate.
- Multiply the mass of the loaded cart by g to calculate the force of gravity upon it. (g = 9.80 m/s^2 ± 0.01 m/s^2)
- Set the angle of the incline to 15°. The **bottom** of the indicator should be aligned to the angle mark.
- Tie a cord to the cart, pass the cord over the pulley, and attach a weight hook to the cord.
- The pulley should be extended as far as possible along its rod so that at the largest angles the vertical string is able to clear the lab bench.
- Adjust the pulley to make the cord parallel to the slope.
- Add sufficient slot masses to the hook to achieve a rough equilibrium. It is not necessary to record this rough mass.
- Using slot masses as small as 1 gram, adjust the hanging mass so that the cart will move up the slope at a very slow constant speed (zero acceleration). For the error in the mass on the hanger, estimate how much mass must be added or subtracted to the hanger before you notice a difference in the behavior of the cart.
- Record the slope angle and the amount of hanging mass. Note that the hook itself has a mass of 50 grams.
- Readjust the hanging mass so that the cart will move down the slope at a very slow constant speed (zero acceleration). Record this new hanging mass.
- Calculate the average hanging mass from the up and down trials.
- Find the average tension in the cord at this angle from the average mass (upward and downward motion).
- Repeat for slope angles 20°, 25°, ... , 45° (or as large as feasible).
- It is possible that at the lowest angle 15°, the empty hanger itself may be too heavy to allow the cart to move down the ramp at constant speed. If this is the case, omit the data point at 15°.

Analysis

- Why is it necessary that the cord be parallel to the slope?
- Why is it necessary to roll the cart at **constant** speed?
- Why is it necessary to roll the cart both up **and** down the slope?
- Draw a free-body diagram for the cart. Determine from theory the tension required to achieve equilibrium as a function of angle.
- Plot the measured average string tension T (vertical axis) vs. the angle of inclination θ (horizontal axis). Compare this to the curve predicted from theory. The data should appear as points; the theory should be a solid curve. Do not fit the data points by eye; do

not draw the best straight line though the data (they do not lie on a straight line). Simply plot the data and theory on the same set of axes and observe how closely they match.
- Calculate the propagated error on the tension for one or two angles. Would the error bars on your plotted data points visible on this graph, or are they too small to be seen?
- Identify sources of statistical error and systematic error.