Physics 200 (Stapleton) Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Newton Sled Directions

Background:

A *Newton Sled* is powered by the launching of its projectile. Just before the projectile is launched, the sled and the projectile are connected by stretched rubber bands. The rubber bands are held taut by string. When the string is burned, the rubber bands push the projectile in one direction and they push the sled in the opposite direction. According to Newton’s 3rd Law, the rubber band force that pushes the sled equal to (and opposite) the rubber band force that pushes the projectile.

As the rubber bands exert their force, both the sled and the projectile are accelerated in opposite directions. They continue to accelerate until the rubber bands reach their rest position. At this point, the rubber bands stop exerting force. If you add up the acceleration distances of the sled and projectile, the total is equal to the rubber band stretch distance. After the acceleration is over, both the sled and the projectile continue to slide, but now they decelerate until friction brings ultimately brings them to a stop.

Friction is acting during this entire episode, even when the objects are accelerating. The relevant kind of friction here is sliding friction (coefficient µk). Sliding friction opposes the movement of both the sled and the projectile during both the acceleration and deceleration phases. The rubber band force is only acting during the acceleration phases of both objects. Although the rubber band force varies as the rubber bands unstretch (strongest at first; weakening as they return to rest position) we can avoid dealing with this complication by imagining that the force is actually constant. In this case, our calculations will give us the *average* rubber band force, which is good enough.

Sliding Friction Coefficient Calculations:

1. Slide the sled on the surface where you will be conducting this experiment.
   1. Measure sliding distance: Create a starting point by putting a small piece of blue tape on the line at the edge of a floor tile. When you slide the sled, release the sled when the center of mass crosses the floor tile that is even with the blue tape. Measure the distance from the starting point to the new location of the center of mass after the sliding sled has come to a stop.
   2. Measure sliding time: As you slide the sled, start a timer at the moment you release the sled, and stop the timer when the sled comes to rest.
   3. Repeat this process at least three times and record your data.
2. For each trial, calculate the sled’s deceleration.
   1. Average Velocity = distance / time
   2. Initial Velocity = 2\*Average Velocity
   3. Acceleration = ΔV/Δt
3. Average the decelerations to get an average deceleration (acceleration, but it will be negative).
4. Calculate the force of friction. When the sled is sliding, Fnet = FFriction, so Ffriction = ma.
5. Calculate µk.
   1. Find the weight of the sled. w=mg.
   2. Find the normal force acting on the sled. FN = w.
   3. Find µk. Ffriction = µk(FN), so µk = Ffriction / FN
   4. Make µk positive. µk is always positive. Friction can be negative if the sliding object is moving forward. Friction can be positive if the sliding object is moving backward.
6. Assuming that the projectile and the sled are made of the same materials and sliding on the same surface (which they should be), they will have the same µk.

Launch Data Collection:

1. Find a location with plenty of floor space to allow you to launch your sled and projectile without either colliding with an obstacle before coming to rest.
2. Prepare your sled and projectile as shown in the video (either the low mass, high mass, or Earth mass launch).
3. Measure and record the rubber band stretch distance. The rubber bands should be stretched into a V. The rubber band stretch distance is measured from the point of the V to the piece of wood into which the screws insert. Do not measure all of the way to the screws. When the rubber bands spring forward, they stop at the edge of the wood, not at the screws.
4. Place the sled and the projectile on the floor. Mark location of the center of mass of each object with a piece of labeled blue tape. Place the tape so that neither the projectile nor the sled will run over it.
5. Launch the sled/projectile. For each object, measure and record the distance traveled from the blue tape to the new position of the object’s center of mass.
6. Repeat successfully at least two more times, using the same blue starting tapes.

Create a spreadsheet to perform your calculations:

1. Make your own copy of the Newton Sled Calculations Template.
2. Practice data are already entered into the yellow cells of the spreadsheet. Once you get your spreadsheet working properly, you will be replacing the yellow and orange data with your own.
3. Look at the approximate acceleration distances in cells H8 and I8. Enter the Approximate Sled acceleration distance (blue highlighted cell, H8) into the orange cell. When you do this, the projectile acceleration distance will automatically be calculated in cell F11.
4. In cells B11 and C11, enter formulas for deceleration distances for the sled and the projectile. These will be the total distance minus the acceleration distance.
5. Complete Sled Calculations. Enter formulas on row 15, starting from C15 and heading to the right.
   1. Sled weight = sled mass x gravity.
   2. Sled normal force = sled weight.
   3. Sled Sliding friction force = µ x sled normal force.
   4. Sled net force during deceleration = Sled sliding friction force. I made the sign negative, because the sled is decelerating.
   5. Sled Deceleration = Sled net force during deceleration / sled mass
   6. The sled reaches its max velocity just before it begins to decelerate. You can find max velocity using the formula Vx2 = Vox2 + 2aΔx. Apply the formula to the deceleration period, so that the initial velocity is the max velocity and the final velocity is zero. Δx is the “sled deceleration distance.”
   7. The sled accelerates from zero velocity to its max velocity. You can find sled acceleration during its acceleration period by using the same formula as you did in part f, above (Vx2 = Vox2 + 2aΔx). However, for the acceleration event, the max velocity is the final velocity and the initial velocity is zero.
   8. Sled net force during acceleration = Sled acceleration/sled mass.
   9. Sliding friction force is still the same as it was in column E. As long as the object has the same mass and the same coefficient of friction, it will have the same friction force.
   10. Calculate rubber band force in the green cell. Sled net force during acceleration = Rubber band force – Friction force. Therefore, Rubber band force = Sled net force during acceleration + Friction force.
6. Complete Projectile Calculations. Enter formulas on row 19, starting from C19 and heading rightward. The procedure is the same as in step 5, above.
7. Adjust the acceleration distances to find the actual rubber band force.
   1. Why? You should now have two calculations of rubber band force, both in green cells. Unless you are doing this in a frictionless environment, the numbers will be different. According to Newton’s 3rd Law, they should be the same. The reason for their difference is the fact that you started this calculation process by using approximate acceleration distances. You entered an approximate sled acceleration distance into the orange cell.
   2. Using a *guess and check* approach, adjust the sled acceleration distance in the orange cell until the forces in the two green cells are very similar.
   3. Now enter a formula for rubber band average force into the purple cell. For this formula, average the values of the two green cells.

Use the spreadsheet to find rubber band forces and answer the experimental question.

1. Delete the values in your yellow and orange cells.
2. Use cell H8 to get a starting point for the value in the orange cell.
3. Adjust the orange cell value until your two green cells are very close to equal.
4. Your purple cell should display the rubber band force.