Walk-in Lab 10
Rolling
Physics 121

CID(s): ____________________

Description
In class we had a race between a disk and a ring rolling down a wooden ramp. The disk won the race because with its lower moment of inertia, more of the initial potential energy went into translation and less into rotation. As every runner knows, you win by translating, not by spinning.

Today you get to recreate this race with the added bonus of measuring the speed of the rolling object and comparing this measured speed to what conservation of energy predicts. Have fun, work in groups of up to three people, and email me your ideas for making the lab better. See you in class, and have a great day.

Objective: To understand how conservation of energy applies to rolling objects.

Equipment: ramp, carpet-lined catcher, some rolling things, photogate, tape measure, air track, glider.

Part A
Let’s do a little sanity check and apply the conservation of energy to something that does not roll. The glider on the air track has almost no friction. If you measure the gravitational potential energy difference between the glider at the top of the track and the glider at the photogate this potential energy difference ought to equal the glider kinetic energy at the photogate.

Put the glider on the track and hold it there. Measure how high it is above the table. With the glider on the track, hold it in the middle of the photogate and measure how high the glider is above the table. The difference between these two numbers is the height $h$. Write your answer here:

$h =$ (m)

Now put the glider back at the top of the track, make sure the air is on, and let the glider slide through the photogate. The speed of the glider at the photogate is the length of the glider divided by the elapsed time on the readout. Write your answers here:

$L_{\text{glider}} =$ (m), $\Delta t =$ (s), $v_{\text{glider}} = L_{\text{glider}}/\Delta t$ (m/s)

Let’s see if this number makes sense. Use conservation of energy ($mgh = \frac{1}{2}mv^2$) to calculate the speed of the glider at the bottom of the ramp. Write your formula here:

$v_{\text{calc}} =$ (The formula goes here.)

Now plug in your number for the height and calculate the speed. Write your answer here:

$v_{\text{calc}} =$ (m/s), and % error =

Does it agree with what you measure? If you are careful and if the glider slides freely, your measured and calculated values should agree to better than 5%.

Part B
Now we are ready to roll, so to speak. You should find a ball, a disk, and a ring to roll down the ramp. (The “ring” has a lightweight disk inside of it. This is required so that it can block the photogate, but the disk
is so light that the object still has almost the same moment of inertia as a ring.) We want to do the same thing here that we did with the glider. First, measure the height difference \( h \) between the starting point of the rolling object and its position at the center of the photogate. Write your answer here:

\[ h = \text{__________ (m)} \]

Measure the diameter \( D \) of the three rolling objects. This will be the length of the object that passes through the photogate. If the photogate is aligned properly, the diameter of the object will pass through the laser beam of the photogate. The three objects do not quite have the same diameter, but as long as the laser beam is close to the center of the ball it will be close enough to the centers of the other two objects to get good results. You may need to adjust the height of the photogate so that the laser beam tracks along the diameter of the ball as it rolls through. Write your answers here:

\[ D_{\text{ball}} = \text{__________ (m)}, \quad D_{\text{disk}} = \text{__________ (m)}, \quad D_{\text{ring}} = \text{__________ (m)} \]

Put these objects (one at a time) at the top of the ramp, reset the timer, and let the objects roll down through the photogate. Write your measured times for each of the objects here:

\[ \Delta t_{\text{ball}} = \text{__________ (s)}, \quad \Delta t_{\text{disk}} = \text{__________ (s)}, \quad \Delta t_{\text{ring}} = \text{__________ (s)} \]

Now use \( D/\Delta t \) to calculate the speeds. Write your answers here:

\[ v_{\text{ball}} = \text{__________ (m/s)}, \quad v_{\text{disk}} = \text{__________ (m/s)}, \quad v_{\text{ring}} = \text{__________ (m/s)} \]

The last thing you need to do is to use conservation of energy to find out what the speed should be. Because of rotational kinetic energy, the equation you used in Part A picks up an extra term. Now conservation of energy is \( mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 \). Look up the values of \( I \) for your three objects (ignore the lightweight disk in the center of the ring) in your book (hopefully someone brought their book, or maybe someone wrote it down for you in the lab somewhere). Recall that \( \omega = v/R \) and rewrite the conservation of energy equation, substituting in your expressions for \( I \) and \( \omega \). Do some algebra magic and find a new expression for \( v \). Write your formulas, your calculated values, and the percent error between your calculated and measured values here:

\[ v_{\text{ball}} = \text{__________ (formula) and } v_{\text{ball}} = \text{__________ (m/s, the number)} \quad \% \text{ error} = \text{_______} \]

\[ v_{\text{disk}} = \text{__________ (formula) and } v_{\text{disk}} = \text{__________ (m/s, the number)} \quad \% \text{ error} = \text{_______} \]

\[ v_{\text{ring}} = \text{__________ (formula) and } v_{\text{ring}} = \text{__________ (m/s, the number)} \quad \% \text{ error} = \text{_______} \]

Your values should agree to better than 5% accuracy if you are careful.