Determining the Coefficient of Kinetic Friction

In the setup we used to verify Newton's second law, suppose that we take into account the effect of kinetic friction. **Without** kinetic friction the acceleration of the cart sliding on the horizontal track and pulled by the hanging mass is given by Newton's second law:

$$(m + m')a = mg$$

where m' is the mass of the cart and m is the hanging mass. To take friction into account, we add to the right hand side the force of friction, $f_k = -\mu_k N = -\mu_k m'g$. Then we get the modified equation of motion:

$$(m + m')a = (m - \mu_k m')g$$

Solving for the coefficient of friction, we find

$$\mu_k = \frac{mg - (m + m')a}{m'g}$$

This provides us with a method for calculating μ_k, the coefficient of kinetic friction between the sliding surfaces.

We will use an inclined air track, two photogates, a counter/timer, a meter stick, a micrometer and a balance and a collection of masses. The results you obtain from this experiment are highly dependent on the accuracy of your measurements, so be careful!

Name:

Lab Partners:

Procedure

1. Level the air track. Do this by placing a cart on the track in the middle, turning the air supply **on**, and adjusting the feet (evenly on each side of the track) so that the cart does not move toward either end.

2. Turn the air supply **off**.
3. Measure the effective length of the cart with a ruler.

l_{eff} = ______ cm

4. Measure the mass of the cart.

$m' = m_{\text{cart}} =$ ______ g

5. Place the photogates **D** = **40 cm** apart and at the appropriate heights to be triggered by the cart as it rides along the track. Plug each **photogate** into input channel 1 on each **smart timer**, and set the timers for "Time/Stopwatch" mode. Press **Start** before each trial.
6. Measure the mass of the hanger.

$m_{\text{hanger}} =$ ______ g

Then place a 100 g mass on the hanger, so that the total hanging mass is

$m = m_{\text{hanger}} + 100 =$ ______ g

7. Record the times measured for gates A and B for each of ten trials. Be sure to reset the timer before each trial, and be sure to release the cart from the **same point** on the track on each trial. Practice for a few trials before recording data. This will improve your consistency. Record all digits in the timer display.

$t_{A,1}$ = ______ s $t_{B,1}$ = ______ s

$t_{A,2}$ = ______ s $t_{B,2}$ = ______ s

$t_{A,3}$ = ______ s $t_{B,3}$ = ______ s

$t_{A,4}$ = ______ s $t_{B,4}$ = ______ s

$t_{A,5}$ = ______ s $t_{B,5}$ = ______ s

$t_{A,6}$ = ______ s $t_{B,6}$ = ______ s

$t_{A,7}$ = ______ s $t_{B,7}$ = ______ s

$t_{A,8}$ = ______ s $t_{B,8}$ = ______ s

$t_{A,9}$ = ______ s $t_{B,9}$ = ______ s

$t_{A,10}$ = ______ s $t_{B,10}$ = ______ s

8. Repeat **steps 6 and 7** , adding masses of 20 g, 40 g, 60 g, and 80 g on the **cart**. Remember that, in each case, the new mass of the cart will be

   $m' = m_{\text{cart}} + m_{\text{added}} =$ ______ g

Analysis

1. Make the Excel table below for each set of trials, *i.e.,* for each of the masses (0 g, 20 g, 40 g, 60 g and 80 g) that you placed on the cart:

n	**t1**	**t2**	**v1**	**v2**	**a**	μ_k
1						
2						
…						

2. Compute the velocities using $v_i = l_{eff}/t_i$
3. Compute the acceleration using

$$a = \frac{{v_2}^2 - {v_1}^2}{2\,D}$$

4. Compute the value of the coefficient of friction, μ_k, using the formula

$$\mu_k = \frac{mg - (m + m')a}{m'g},$$

   where $g = 981$ cm/s^2. Do this for each trial.

5. Find the average value of the coefficient of kinetic friction, μ_k in each set of trials, to get five average values: μ_{k1}, μ_{k2}, μ_{k3}, μ_{k4} and μ_{k5}
6. For each set of trials, determine the standard deviation in μ_k, *i.e.,* determine σ_{μ_k}.
7. Why is μ_k expected to be the same in all three sets of trials?

8. Determine the average value of μ_{ki}, *i.e.,*

$\mu_{k\text{ avg}} =$ ______

9. Estimate your percentage error in each set of trials:

$$\Delta_i\% = \frac{|\mu_{ki} - \mu_{k\text{ avg}}|}{\mu_{k\text{ avg}}} \times 100\%$$

$\Delta_1\% =$ ______

$\Delta_2\% =$ ______

$\Delta_3\% =$ ______

$\Delta_4\% =$ ______

$\Delta_5\% =$ ______