NORTHERN ILLINOIS UNIVERSITY

PHYSICS DEPARTMENT

Physics 210 – Mechanics & Heat   Spring 2022

Lab #9

Lab Writeup Due: Tue/Wed/Fri, April 5/6/8, 2022
Read OpenStax: Chapter 7.1-7.6, 8.1-8.5, Lecture Notes #7,#8

Collisions

Apparatus

An ideal track would be without friction, but friction can be minimized with well lubricated and aligned wheels on a cart. The track must also be level to negate any effects of gravity. There are two carts: a heavy cart of mass m_1 and length ℓ_1 and a light cart of mass m_2 and length ℓ_2. The carts use repulsive magnets to cause elastic collisions, and the carts use velcro to cause inelastic collisions.

A t-shaped metal bracket, or fin, is attached to each cart which will block a photogate beam. Two photogates are positioned over the track and can measure the time Δt that a cart passes through the beam. The times can be read from the Logger Pro software when the photogates are attached to the computer. The photogates record the elapsed time between the time the rectangular fin blocks the beam until it is no longer blocked, but not the direction of motion. The experimenter must determine the direction of motion.

Theory

Velocity is the time rate of change of position of an object. If the time it takes to travel a known distance is measured, then the velocity is

$$v = \frac{distance}{elapsed\ time} \tag{1}$$

The sign of the velocity depends on the direction of the object. If it is moving in the positive direction, the velocity is positive, and if it is moving in the negative direction, the velocity is negative. An object at rest has a velocity of 0.

Momentum, p, is the product of mass, m, and velocity, v. Since velocity is a vector and has direction, so does momentum. For two or more interacting objects, the total momentum is just the sum of the individual momenta. For two masses (m_1, m_2) and velocities (v_1, v_2) moving only in one dimension, the total momentum, P, is

$$P = p_1 + p_2 = m_1 v_1 + m_2 v_2 \tag{2}$$

If there are no forces acting on a set of objects other than internal interactions between them, the system is called an *isolated syste*m. In any isolated system the total momentum of a set of objects is constant. We say that the total momentum in an isolated system is *conserve*d. During a collision the time is so short that any external forces present do not have much effect on the momentum of the system. This allows us to describe all collisions in this lab as occurring in an isolated system and allows us to use conservation of momentum. If the initial total momentum is P_i and the final total momentum is P_f, conservation of momentum is $P_i = P_f$.

Objects in motion also possess kinetic energy. Kinetic energy, K, is a scalar quantity that is never negative. It also depends on the mass and velocity according to

$$K = \frac{1}{2} m v^2 \tag{3}$$

Like the total momentum, the total kinetic energy of a system is just the sum of the individual kinetic energies. For a system of two objects the total kinetic energy is

$$K = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 \tag{4}$$

In certain collisions between objects that only involve a conservative force, such as an ideal spring (magnetic spring), the initial total kinetic energy, K_i, equals the final total kinetic energy, K_f. This type of collision is called an *elastic* collision.

Other collisions are called *inelastic* and involve some loss of energy during the collision. The final total kinetic energy is always less than the initial total kinetic energy of the system. A completely inelastic collision occurs when the two objects collide and stick together. This means that the two objects leave the collision with identical velocities: $v_{1f} = v_{2f} = v_f$. We can write Eq. (2) for a completely inelastic collision as

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f} = \left(m_1 + m_2\right) v_f \tag{5}$$

Data Collection

You must show all your calculations in the Analysis section below to your TA ***<u>before you leave the lab</u>***.

(1) Each cart should have a metal L-shaped fin mounted on them. The *heavy cart* is the one with a silver plunger on one side and velcro on another, and it should have an additional magnetically attached mass on top of it. The *light cart* has no plunger—it only has velcro on one side. Measure and record the total mass (m_L (*light cart*) and m_H (*heavy cart*)) of the two carts (you will need to measure the mass of the cart, fin, and attached mass separately—to measure the mass of the magnetically attached mass, use the Newton spring scale since it is too heavy for the balance scale). Also measure the length of the L-shaped fin of each cart (d_L and d_H).

(2) Check that the computer is on and running the Logger Pro program. Confirm that the red light on each photogate flashes as the cart passes through the photogate. Find the magnetic end of each cart by seeing how they repel each other.

(3) Place the *heavy cart* at one end of the track with the magnetic end pointing toward the center of the track. Make certain that the tracks are very close to level (otherwise you will not get good results). As a trial run, push the cart, but not too hard, so that it passes through both photogates, making sure to **<u>catch it before it hits the end of the track</u>**. Do a run and record the data. Make certain to record in your lab notebook the (a) distance between photogates, (b) the times for going through the 1st photogate, and (c) the times for going through the 2nd photogate. Do the problem in **Analysis** (1) before continuing. Confirm with your TA to make certain your analysis is correct.

(4) Place the *light cart* in the middle of the track (with it magnetic end pointing towards the magnetic end of the *heavy cart*). Make sure the *heavy cart* is positioned so the *light cart* will bounce off of it due to the <u>opposing magnetic fields</u>—test it out first. *Make certain that the collision does not activate a spring loaded rod*—if this happens, the orientation of the carts is incorrect.

(5) Place the *heavy cart* at one end of the track and hit the green "Start Collection" button on Logger Pro and push the *heavy cart* through the first photogate toward the *light cart*. After the *light cart* passes through the second gate **lift it off the track <u>before</u> the large cart passes through the second photogate.**

(6) After the *heavy cart* passes through the second photogate, **lift it off the track**. Record the elapsed time for the *heavy cart* going through photogate 1 and 2 and the *light cart* going through photogate 1.

(7) Repeat Steps (5) and (6) with the *heavy cart* in the middle and pushing the *light cart* towards it making sure that the *light cart* bounces back through the first photogate (you may need to position the heavy cart closer to the first photogate, rather than in the middle of the track.

(8) Reverse the direction of the *light cart* so that its velcro end points toward the velcro end of the *heavy cart*.

(9) Place the *heavy cart* at one end of the track and hit the green "Start Collection" button on Logger Pro, then push the *heavy cart* through the first photogate toward the *light cart*. The carts will stick together and continue through the second photogate. Record the elapsed time (Δt) for the *heavy cart* through the first photogate and the elapsed time for the "stuck together" carts through the 2^{nd} photogate (Note: there will be four times recorded in Logger Pro for the "stuck together" carts because each carts flag will record a start & stop time. The elapsed times (Δt) for each of the "stuck together" cart's fins will be the same, so record one of them.

(10) Swap the locations of the *heavy* and *light carts* and Repeat step (9)

Data Analysis

(1) Using Eq. (1), find the velocity of the *heavy cart* through ***<u>each</u>*** photogate taken in Step (3). Determine the kinetic frictional force for the cart. *What is the coefficient of kinetic friction for the cart?* (remember to 1^{st} draw your free body diagram and then write Newton's 2^{nd} law along the x and y -directions and use the kinematical equations of motion)

(2) For each of the elastic collisions, Steps (5), (6) & (7) and the collisions in Step (9) & (10), use the length and time information to find the velocity (using Eq. (1)) and kinetic energy, of each cart before the collision and after the collision. *Is the total kinetic energy of the carts before the collision equal to the total kinetic energy of the carts after the collision? Is conservation of energy being violated? Where is the missing energy going? What type of energy is this missing energy? Can you account for the discrepancy using the results in Data Analysis (1)? (assume the coefficient of kinetic friction is the same for both carts)*

(3) From Steps (5), (6) & (7) find the total momentum for the carts before and after each collision using Eq. (2). Do the same for Steps (9) & (10), for the final momentum from the collisions using Eq. (5). *Is the total momentum of the carts before the collision equal to the total momentum of the carts after the collision? Is conservation of momentum being violated? How does friction influence the results? What approximation do you have to make to ignore friction? Is this approximation reasonable for your experiment?*

(4) Which collisions in your lab were *elastic* or *inelastic*? Explain why.