PHYSICS 332

MECHANICS LABORATORY

COLLISIONS

***Purpose**:* In this lab you will analyze elastic and inelastic collisions, confirm the conservation of linear momentum, and study kinetic energy loss.

***Apparatus**:* The chief components of the experiment are various pucks, an air compressor, a spark timer, a collision table, a large sheet of carbon paper, and several large sheets of plain paper.

***Theory**:* See any introductory mechanics text under the heading of collisions (in one and two dimensions, elastic and inelastic). In particular, momentum is conserved in all collisions. Kinetic energy is conserved in elastic collisions only.

Procedure:

1. Make sure that there is a sheet of carbon paper lying on the collision table, black side up. Be careful not to rip this since it is hard to replace. Place an unused plain large sheet on top of the carbon paper.

2. The pucks will glide on the collision table atop a cushion of air. The air is supplied from the compressor and delivered through latex surgical tubing. This tubing is somewhat delicate, so avoid handling it directly to the extent possible. Your first collisions will be performed using the *non*-magnetic pucks. If the magnetic pucks are attached to the tubing, they can be removed by pulling the clear plastic plug out of the larger tube attached to the puck. Pull only on the clear plastic plug, not on the latex tubing.

3. Plug in the air compressor and place both non-magnetic pucks on the collision table. Get a feel for how to push them so that they glide freely. If the pucks do not glide freely, make sure that all of

the air hoses are attached properly. Practice collisions using one as a stationary target. This collision should be glancing so that both pucks move off in different directions after the collision.

4. When you are confident that you can produce a glancing collision on a stationary target, plug the spark timer in and turn it on. The spark timer will become activated when the foot pedal is depressed, but do NOT do so yet until you understand how it works. The spark timer sends out a series of high voltage pulses at a rate determined by the dial setting (I have found 20 Hz works well, but you can experiment with other settings if you wish). The pulse travels down a copper chain inside one of the latex surgical tubes and into the metal puck. It jumps ("sparks") across the air and paper gap between the puck and the carbon paper. In the sparking process, some of the carbon is transferred to the back side of the paper, marking where the puck is at that instant. The pulse travels through the carbon paper (carbon is an electrical conductor) to the other puck, which it reaches by sparking again, producing a second dot. The pulse then continues through the copper chain in the second latex tube, returning to the timer and thus completing the circuit. *Since this is a high voltage pulse, it is important that the circuit be completed as described and not completed through you!!!* Take the following safety precautions:

a) **The spark timer should be plugged in only when both pucks are on the table and only when you are about to record a collision. Unplug the timer immediately after each use.**

b) **When the timer is plugged in, do not touch the disks by their metal edges. Handle them only by the large plastic tube at the top of each disk.**

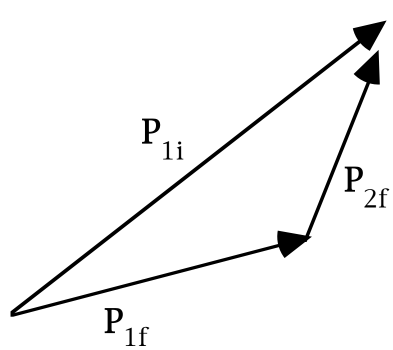
c) **Do not depress the foot pedal to activate the spark timer until after you have released the pucks.**

5. When you are confident that you can safely use the spark timer, perform the glancing collision described above. Immediately

after performing the collision, turn the paper over and label the page, showing incoming and out going pucks and describing the collision (e.g., elastic collision #1 using non-magnetic pucks with stationary target).

6. Repeat this collision once more, using a fresh sheet of paper.

7. To evaluate the data, note that the displacement between subsequent points can be used to represent either the velocity vector or the momentum vector (why?). Use the pair of pre-collision points closest to the collision (but nevertheless still clearly pre-collision) to represent the initial momentum vector. Similarly obtain the final momentum vectors from pairs of points immediately after the collision. Being careful not to rotate the vectors with respect to each other (only translations are allowed), trace the vectors onto a new sheet of paper so that the final momentum vectors can be added up using the head to tail rule and compared to the initial momentum vector. If the resulting vectors are too small to evaluate with precision, use lines drawn through three consecutive points instead of two. Your incoming momentum vector should be at least an inch long for proper analysis. Tip: Draw a long straight line on your collision sheet and use it as a reference line when tracing your collision vectors. If you trace your vectors onto grid paper, just make sure your reference line is always parallel to a grid line. This keeps you from inadvertently rotating a vector when you trace it.



8. Draw the momentum addition diagram for each of the first two collisions. Using the protractor in the lab, measure the angle between the two final momentum vectors. In an ideal elastic collision, this angle should be 90°. *In your lab report Introduction, you should indicate why this result is expected.*

9. Now replace the non-magnetic pucks with magnetic pucks and repeat the above glancing collisions (i.e., two collisions). Note that the magnetic pucks will experience a collision (a sudden momentum change) even though they do not come into direct contact. The magnetic pucks interact somewhat at a distance, causing them to move along curved trajectories when they are near each other. For simplicity, choose data points along the straight portion of the paths.

10. By comparing the results for magnetic and non-magnetic pucks, decide which produce more nearly ideal elastic collisions. Use those pucks for the next step.

11. Perform one glancing elastic collision with *both* pucks initially in motion.

12. The last collision will be inelastic. Place the velcro bands around the *nonmagnetic* pucks and attach them to the latex surgical tubing if you have not already done so. Practice head on collisions with one of the pucks initially at rest. Your goal is to have as little twisting motion as possible after the collision since that makes it harder to decipher the data. When you are ready, set up an inelastic collision on the left side of the sheet of paper, and then set up a second on the right side.

13. When you analyze your data for all of the collisions, you should show the momentum addition diagrams. You should also calculate numerically the ratio of the final kinetic energy to the initial kinetic energy. For the elastic collision, this ratio should be 1, for the completely inelastic collision, it should be 1/2. *Your Introduction should explain why you expect these results.* Finally, for the elastic collisions with stationary targets, your diagrams should all indicate the angle between the two outgoing momenta.

14. Some students wonder about the influence of friction between the pucks and the paper. Remember that the collision itself is so quick that friction does not have a chance to change the momentum much during the collision. However, when we measure the puck's velocity, we cannot do so instantaneously before or after the collision. Hence friction affects our ability to measure the puck's velocity. To get a feel for its influence, place both pucks on a fresh sheet of paper (both must be there to ensure a complete circuit), but put one off in a corner. Push the other across the paper at a typical speed you used during the collision experiments and use the spark timer to record its progress. In the absence of any net force on the puck, you should see a straight line of uniformly spaced dots. Any deviation from this ideal is an indication of the presence of forces (such as friction) whose influence you can now estimate from this data. You should discuss this in your Results section.

15. You or your partner should submit your original collision sheets with your report.

REMEMBER TO UNPLUG BOTH THE SPARK TIMER AND THE AIR COMPRESSOR BEFORE YOU LEAVE.

What is due: You need to submit a complete report, including (for the first time) the Procedures section. This section should describe the apparatus and methods in a manner complete enough so that a reader who has never seen the apparatus can understand what you did and why you did it. In each action described it should be clear how that action helped you measure a quantity necessary to achieve your objectives or minimize and/or assess error in measurements. In most reports, a diagram of the set-up will be required. Under no circumstances should you copy word for word major sections of the lab hand out. In this section, you should describe what you actually did, not what the lab manual said you should do. Thus sentences will typically begin with "We measured the..." rather than "You measure...." If you repeated a measurement several times, which is usually a good thing to do, indicate that. Furthermore, try to supply good detail but only relevant detail. A sentence like "We then depressed the foot pedal." Is not particularly relevant. What is relevant is that you activated the spark timer. Finally, **explain *why* you did what you did.** Put another way, the purpose of this section is to tell the reader how you accumulated your data (it is *not* the purpose to teach the reader how to perform the experiment).