In this lab, you will begin to use conservation of energy to determine the motion resulting from interactions that are difficult to analyze using force concepts. You will explore how conservation of energy is applied to real interactions. Although energy is always conserved, it is sometimes difficult to calculate the value of all of the energy terms for an interaction. Not all of the initial energy of a system ends up as visible energy of motion. Some energy is transferred into or out of the system and some becomes internal energy of the system. Since this energy is not observable in the macroscopic motion of objects, we sometimes say that the energy is "dissipated" in the collision.

You will also explore the applicability of conservation of momentum in predicting the motion resulting from collisions. Fortunately, conservation principles can be used to relate the motion of an object before a collision to the motion after a collision, without knowledge of the complicated details of the collision process itself. To fully analyze an interaction, one must often use both conservation of energy and conservation of momentum. To accomplish this lab, you will collide air carts on the frictionless air tracks using the bumpers and calculate the initial and final kinetic energy and momentum.

Pre-Lab

Read Chapter 6, Chapter 7, and Chapter 8 from Young & Freedman's University Physics before you arrive to perform the lab. Study the Work-Energy Theorem, and kinetic and potential energy, as well as Conservation of Momentum. You need to understand how to calculate the kinetic energy of a moving object, the total energy of a system of objects, and the total momentum of a system of objects. You should have completed Lab 0, Lab 1, Lab 2, and Lab 3.

Questions to be answered in your lab journal:

1. Write an expression for the efficiency of the air cart bumper in terms of the initial and final kinetic energy of the cart. What defines a collision as elastic or inelastic?

2. Write an expression for the energy dissipated during the impact with the bumper in terms of the kinetic energy before the impact and the kinetic energy after the impact.

3. Write down the energy conservation equation for the collision between two air carts on the frictionless air track.

4. Solve the equation in 3. for the energy dissipated.

Experiment 1

In this experiment, you will be using only one cart and colliding this cart with the bumper on one end of the air track. You will be capturing the motion of the cart and the collision on video and calculating the efficiency of the bumper, in addition to the kinetic energy and momentum. You will be capturing three videos by using three different total masses on the carts. Don't forget to keep track of the mass on the carts with their respective video.

Procedure:

1. Make sure the bumper on the air cart and the bumper on the air track are functional and not loose or bent. If the bumper(s) need replacing, then advise your TA. Weigh the cart using the mass scales and note the mass in your lab journal.

2. Position the camera overhead near the end of the air track (that is away from the computer) such that the velocity of the cart immediately before and after the collision can be measured. See Figure 1.

3. Select one of the brass masses with a hole in the center and attach on the screws on the side of the cart. Ensure the track is level. Push the cart to collide with the air track bumper and capture the motion to video.

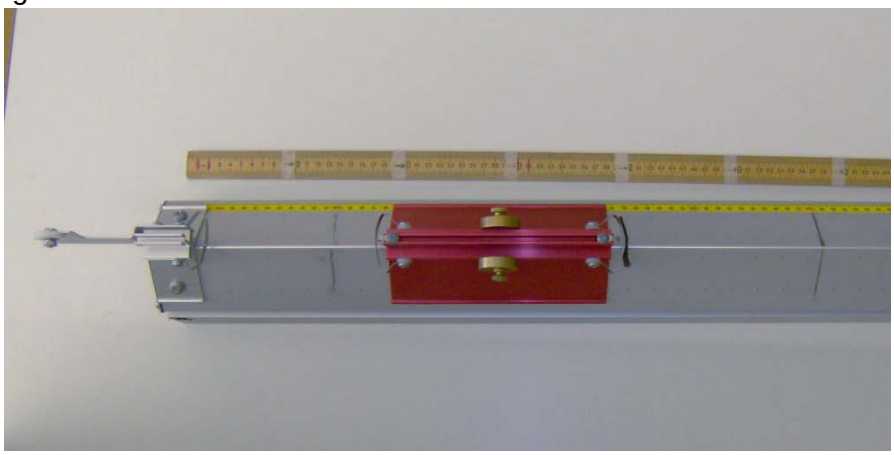

Figure 1

4. Repeat step 3. using two different masses secured to the air cart.

5. After all the movies for Lab 4 have been recorded for all three experiments, remove the memory card from the camera and insert the card into the computer. Copy the movies to your section folder under the C:\218Labs folder.

6. Insert one of the three movies for Experiment 1 into a new LoggerPro sheet. Use the *Set Scale* function and use two tick marks on the air track ruler as your distance. Next, use the *Add Point* function and select the same point on the cart such that you have at least two data points for the cart's motion before the collision and at least two points after the collision. Now *Set Origin* and drag the origin of your coordinate axes to the first point selected. Rotate your axes so that the motion of the cart is aligned with the x-axis. Export your data to a text file and save the text file in your section folder. Remember to also either save this text file to a USB flash drive or email this text file to yourself when you are finished with the lab.

7. Repeat step 6. for the remaining two movies.

Questions to be answered in your Technical Memo:

1. From your data, determine the velocity of the cart before and after the collision. Use this velocity to find the kinetic energy of the cart before and after the collision, where the kinetic energy is $k = \frac{1}{2}mv^2$. Do this for all three movies.

2. Calculate the energy efficiency *e* for all three collisions using your kinetic energy results. If e < 1, then into what other forms of energy do you think the cart's initial kinetic energy is most likely to transform? Is each collision elastic or inelastic?

3. How much energy is dissipated in the impact? Compute for all three movies.

4. Calculate the difference in momentum of the system before and after the collision for all three collisions, where the momentum is $p = mv$. Is momentum conserved, or in other words, does $p_i = p_f$?

5. Using Excel and the recorded figures in your lab journal for the mass of the cart, graph a plot of energy efficiency e vs. mass m of the cart for all three movies (you will have only three points in your graph). This means energy efficiency e will be on the vertical axis and mass m will be on the horizontal axis.

6. Using Excel and your data for the initial velocity v_i of the cart, make a plot of energy efficiency e vs. initial velocity v_i of the cart for all three movies (you will have only three points in your graph).

Experiment 2

In this experiment, you will be using two carts and colliding these carts with one another so that they stick together. You will be capturing the motion of the carts and the collision on video and calculating the efficiency of the collision, in addition to the kinetic energy and momentum. You will be capturing three videos by using the same total mass on the carts, though shifting the mass from one cart to another for the three movies. Don't forget to keep track of the mass on the carts with their respective video.

Procedure:

1. Make sure the velcro pieces on each cart bumper are functional and easily stick together. If the velcro needs replacing, then advise your TA. Weigh the cart using the mass scales and note the mass in your lab journal.

2. Position the camera overhead the track such that the velocity of the carts immediately before and after the collision can be measured.

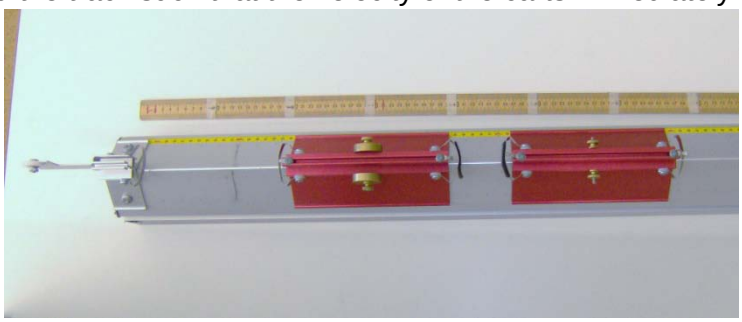

Figure 2

3. For your first movie, place some mass on only one cart. For the other movies, you will be keeping the total mass on the carts constant. Ensure the track is level. Leave one cart stationary. Push the other cart to collide with the stationary cart so that the two carts stick together and both carts are moving in unison after the collision. See Figure 2. Capture all the motion before and after the collision to video.

4. Repeat step 3. by shifting some mass from one cart to the other, but keeping the total mass constant. Capture all the motion to video.

5. Repeat step 3. by shifting all the mass to the other cart, so that all the mass is on the opposite cart as it was on in step 3. Capture all the motion to video.

6. After all the movies for Lab 4 have been recorded for all three experiments, remove the memory card from the camera and insert the card into the computer. Copy the movies to your section folder under the C:\218Labs folder.

7. Insert one of the three movies for Experiment 2 into a new LoggerPro sheet. Use the *Set Scale* function and use two tick marks on the air track ruler as your distance. Next, use the *Add Point* function and select the same point on the cart such that you have at least two data points for the cart's motion before the collision and at least two points for both carts moving together after the collision. Now *Set Origin* and drag the origin of your coordinate axes to the first point selected. Rotate your axes so that the motion of the carts is aligned with the x-axis. Export your data to a text file and save the text file in your section folder. Remember to also either save this text file to a USB flash drive or email this text file to yourself when you are finished with the lab.

8. Repeat step 7. for the remaining two movies.

Questions to be answered in your Technical Memo:

1. From your data, determine the velocity of the carts before and after the collision. Use this velocity to find the kinetic energy of the carts before and after the collision, where the kinetic energy is $k = \frac{1}{2}mv^2$. Do this for all three movies.

2. Calculate the energy efficiency *e* for all three collisions using your kinetic energy results. If e < 1, then into what other forms of energy do you think the cart's initial kinetic energy is most likely to transform? Is each collision elastic or inelastic?

3. How much energy is dissipated in the impact? Compute for all three movies.

4. Calculate the difference in momentum of the system before and after the collision for all three collisions, where the momentum is $p = mv$. Is momentum conserved, or in other words, does $p_i = p_f$?

5. Using Excel and the recorded figures in your lab journal for the mass of the cart initially in motion, graph a plot of energy efficiency *e* vs. mass *m* of the cart for all three movies (you will have only three points in your graph). This means energy efficiency *e* will be on the vertical axis and mass *m* will be on the horizontal axis.

6. Using Excel and your data for the initial velocity v_i of the cart initially in motion, make a plot of energy efficiency *e* vs. initial velocity v_i of the cart for all three movies (you will have only three points in your graph).

Experiment 3

In this experiment you will be using two carts and colliding these carts with one another so that they bounce off one another and do not stick together. You will be capturing the motion of the

carts and the collision on video and calculating the efficiency of the collision, in addition to the kinetic energy and momentum. You will be capturing three videos by using the same total mass on the carts, though shifting the mass from one cart to another for the three movies. Don't forget to keep track of the mass on the carts with their respective video.

Procedure:

1. Make sure the bumpers on the air carts are functional and not loose or bent. If the bumper(s) need replacing, then advise your TA. Weigh the cart using the mass scales and note the mass in your lab journal.

2. Position the camera overhead the track such that the velocity of the carts immediately before and after the collision can be measured.

3. For your first movie, place all the mass on one cart (no more than a total of 100 grams). For the other movies, you will be keeping the total mass on the carts constant. Ensure the track is level. Leave one cart stationary. Push the other cart to collide with the stationary cart so that the two carts bounce off one another and do not stick together. The cart that was stationary before the collision will now be moving, while the cart that was in motion before the collision may be stationary or just slightly moving. Capture all the motion before and after the collision to video.

4. Repeat step 3. by shifting some mass from one cart to the other, but keeping the total mass constant. Capture all the motion to video.

5. Repeat step 3. by shifting all the mass to the other cart, so that all the mass is on the opposite cart as it was on in step 3. Capture all the motion to video.

6. After all the movies for Lab 4 have been recorded for all three experiments, remove the memory card from the camera and insert the card into the computer. Copy the movies to your section folder under the C:\218Labs folder.

7. Insert one of the three movies for Experiment 3 into a new LoggerPro sheet. Use the *Set Scale* function and use two tick marks on the air track ruler as your distance. Next, use the *Add Point* function and select the same point on the cart such that you have at least two data points for the cart's motion before the collision and at least two points for both carts after the collision. If only one cart is in motion after the collision, then you only need to select data points for that cart in motion. If both carts are in motion after the collision, then you must select points off both carts. You can do this by adding a second data series in your current LoggerPro sheet, or by exporting your current data to a text file, then opening a new LoggerPro sheet and inserting the movie, then selecting only those data points for the other cart in motion after the collision. Now *Set Origin* and drag the origin of your coordinate axes to the first point selected. Rotate your axes so that the motion of the carts is aligned with the x-axis. Export your data to a text file and save the text file in your section folder. Remember to also either save this text file to a USB flash drive or email this text file to yourself when you are finished with the lab.

8. Repeat step 7. for the remaining two movies.

Questions to be answered in your Technical Memo:

1. From your data, determine the velocity of the carts before and after the collision. Use this velocity to find the kinetic energy of the carts before and after the collision, where the kinetic energy is $k = \frac{1}{2}mv^2$. Do this for all three movies.

2. Calculate the energy efficiency *e* for all three collisions using your kinetic energy results. If e < 1, then into what other forms of energy do you think the cart's initial kinetic energy is most likely to transform? Is each collision elastic or inelastic?

3. How much energy is dissipated in the impact? Compute for all three movies.

4. Calculate the difference in momentum of the system before and after the collision for all three collisions, where the momentum is $p = mv$. Is momentum conserved, or in other words, does $p_i = p_f$?

5. Using Excel and your recorded figures in your lab journal for the mass of the cart initially in motion, graph a plot of energy efficiency *e* vs. mass *m* of the cart for all three movies (you will have only three points in your graph). This means energy efficiency *e* will be on the vertical axis and mass *m* will be on the horizontal axis.

6. Using Excel and your data for the initial velocity v_i of the cart initially in motion, make a plot of energy efficiency *e* vs. initial velocity v_i of the cart for all three movies (you will have only three points in your graph).

EQUIPMENT LIST FOR LAB 4:

Camera (memory card and AC charger)
Heavy duty stand with finger clamp
Air track and carts (2)
Meter stick
Masses with hole in center (50g – 2 ea, 20g – 2 ea, 10g – 2 ea)
Mass scales (on sink table)

THINGS TO DO AT THE END OF THE LAB SESSION:

1. Replace the heavy stand, rod, clamp on the shelf of the lab table.
2. Replace the camera (with the LCD view finder window closed) on the shelf of the lab table.
3. The meter stick should be put on the shelf of the lab table.
4. The memory card should be left in the slot in the computer monitor.
5. Put the masses back on the outline sheet on the lab table shelf.
6. Leave the other items in neat order on the lab table.