A collision between objects creates some interesting questions about which conservation laws apply. In an elastic collision, both kinetic energy and momentum are conserved. In an inelastic collision, only momentum is conserved while some of the kinetic energy of the objects is converted to work and/or heat. In this activity, you will attempt to verify these principles.

**Equipment:**
- Dynamics track
- Vernier interface
- Motion Detector
- iBook computer
- Cart Launcher
- Dynamics Cart
- Sound reflector
- Collision Cart
- (2) 500g masses

**Cautions:**
Never leave a cart on its wheels unless it is sitting on the track, as it will roll quietly off of the table when you least expect it! The position sensor is fragile and must be handled gently.

**Procedure to set up the Momentum, Collisions, and Energy experiment:**
1. Set the dynamics track on the lab table with the measurement scale toward you. Make sure that the track is secure and not going to be bumped by passersby.
2. Level the track by placing a cart on it and adjusting the legs until the cart will remain stationary in the middle of the track. *Leveling is easier if you leave the two center feet retracted until the leveling is complete. Then extend the center legs until they just touch the tabletop. Sight down the edge of the track and adjust the center support to take any “bow” out of the track.*
3. Adjust the cart launcher so that the spring is compressed 1.5cm in the cocked position. Do this by:
   - a. Place the launcher in the cocked position (the round latching clamp held by the hook)
   - b. Loosen the wing nut on the latching clamp
   - c. Slide the shaft until its index line is at the 1.5cm mark
   - d. Tighten the latching clamp.
   - e. Release the launcher so it won’t go off at the wrong time!
4. Mount the cart launcher on the left end of the track. Slide its nut into the groove in the track and secure it to the track by firmly tightening the mounting screw.
5. Place the collision cart in the middle of the track.
6. Open the motion detector 90° and place it on the right end of the dynamics track, with its sensor even with the 200cm mark. Aim the gold sensor disc at the cart placed in the middle of the track. The easy way to check this is to put your head in front of the cart and look toward the motion detector. If you see your face reflected in the gold sensor disc the aim is right!
7. If it hasn’t been done already, set up the Vernier LabPro interface as follows:
   - a. Plug the cable from the motion detector into the “DIG/SONIC 1” socket on the interface.
   - b. Plug the wire from the power supply cube into the interface.
   - c. Plug the USB cable into the interface.
   - d. Place the iBook computer to the right of the dynamics track.
   - e. Open the iBook computer. *If desired, you can hook the iBook to its power supply and line power.*
f. Plug the USB cable into socket 1 on the left side of the iBook.
g. Push the power button near the screen on the iBook. *Wait for the computer to come up and for the login to appear*. Login as Student. The password is “student”.
h. A student folder should appear with icons. *If not, click on the “tab” labeled student.*
i. Click once on the icon labeled “Lyle’s Collisions”.
j. Check to see if there is a button near the top of the screen labeled “Collect”. The presence of this button indicates that the computer is ready to collect data.

The dynamics cart (the one with the plunger) has two ends. One end has two Velcro tabs on its face, which mate with similar Velcro tabs on the other cart to provide a totally inelastic collision. The other end has no Velcro, and contains two small magnets behind the plastic end cap. The magnets serve as an excellent frictionless spring to allow perfectly elastic collisions. The dynamics cart will be given a repeatable push by the cart launcher. Since the push and the mass of the dynamics cart remain the same, the cart will have exactly the same amount of momentum and kinetic energy for every trial.

Since both carts have the same mass, we’ll use the collision cart to find the momentum and kinetic energy imparted by the cart launcher.

**Finding the momentum and kinetic energy of an empty cart:**
1. Cock the cart launcher.
2. Place the collision cart against the cart launcher. Make sure that there is no gap between the cart and the plunger on the launcher.
3. Click the “Zero” button near the top of the screen on the iBook. The motion detector will buzz momentarily.
4. One group member will click on the “Collect” button on the iBook. Another will stand on the opposite end of the track, wait for the motion detector to start buzzing, and pull the launch string to trigger the launcher.
5. A group member will stop the cart before it strikes the motion detector.
6. Examine your data. The distance graph should show a diagonal line passing out the top of the graph. The velocity graph should show an abrupt rise in velocity, followed by a near-horizontal line. The acceleration graph should show an abrupt spike that immediately drops back to zero. You may see some effects of friction; such as a slight deceleration while the cart is in motion. This is normal. Also, don’t worry about any wild data after the third second. The motion detector doesn’t work if the cart gets closer than 40cm.

**Saving Data & Preparing for next Run**
1. On the iBook, Click on “File”
2. Click on “Save As…”
3. Save this data in the following format: P1G2R1. Whereas, P is period and corresponding number; G is group; and R is run.
4. After each of the remaining runs save that data in the same format as above, incrementing the run number.

The mass of the cart is 0.5kg. Read the maximum velocity from the graph and calculate the momentum and kinetic energy of the cart below.

**Hint:** \[ KE = \frac{1}{2}mv^2 \] \[ P = mv \]
Elastic Data:

<table>
<thead>
<tr>
<th></th>
<th>Total Mass</th>
<th>Max Velocity</th>
<th>Momentum</th>
<th>Kinetic Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Cart</td>
<td>0.5kg</td>
<td>m/s</td>
<td>kg-m/s</td>
<td>J</td>
</tr>
<tr>
<td>Elastic collision with 0.5kg cart</td>
<td>0.5kg</td>
<td>m/s</td>
<td>kg-m/s</td>
<td>J</td>
</tr>
<tr>
<td>Elastic collision with 1.0kg cart</td>
<td>1.0kg</td>
<td>m/s</td>
<td>kg-m/s</td>
<td>J</td>
</tr>
<tr>
<td>Elastic collision with 1.5kg cart</td>
<td>1.5kg</td>
<td>m/s</td>
<td>kg-m/s</td>
<td>J</td>
</tr>
</tbody>
</table>

Creating an elastic collision:
1. Move the collision cart until it is lined up with the 100cm mark on the track’s scale.
2. Click the “Zero” button near the top of the screen on the iBook. The motion detector will buzz momentarily.
3. If the plunger of the dynamics cart is extended, push it in and upward to lock it in place.
4. Cock the cart launcher
5. Place the dynamics cart on the track, with its plunger end resting against the cart launcher. *This puts the magnetic end toward the other cart for an elastic collision.*
6. One group member will click on the “Collect” button on the iBook. The other will stand on the opposite end of the track, wait for the motion detector to start buzzing, and pull the launch string to trigger the launcher.
7. A group member will stop the cart **before** it strikes the motion detector.
8. If the data looks good (smooth curves that describe what the cart really did!), save it. Then record the maximum velocity from the graph in the appropriate blank in the data table above.
9. Place a 0.5kg mass on the collision cart.
10. Repeat the steps above to collect kinetic energy and momentum data for this configuration. Remembering that the mass used in calculations is now 1.0kg, save your data. If time permits, fill in the appropriate areas of the data table.
11. Add another 0.5kg mass to the cart, sliding it back against the first mass.
12. Again, repeat the steps above, save your data, and fill in the remaining areas of the data table time permitting. In your calculations, don’t forget that the mass is now 1.5kg.

Analyze your data and answer these questions:

How did the kinetic energy change as the mass of the struck cart was increased?

How did the momentum change as the mass of the struck cart was increased?
Many students find these results, particularly the result for momentum, unexpected. Explain why the momentum does what it does (Hint: Watch the action of the striking cart after the collision. Is momentum a scalar or a vector?)

Creating an inelastic collision:
1. Turn the dynamics cart around, so that its plunger is pointing toward the other cart. This puts the Velcro dots forward to engage the other cart.
2. In exactly the same way as you did previously, collect maximum velocity data for the collision cart unloaded, with 0.5kg, and with 1.0kg on board. Fill in the following table. You may simply copy the single cart data from the Elastic Data. Remember that the post collision momentums and energies for the inelastic collisions must include the mass of both carts, since they stick together.

<table>
<thead>
<tr>
<th>Inelastic Data:</th>
<th>Total Mass</th>
<th>Max Velocity</th>
<th>Momentum</th>
<th>Kinetic Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Cart</td>
<td>0.5kg</td>
<td>m/s</td>
<td>kg-m/s</td>
<td>J</td>
</tr>
<tr>
<td>Inelastic collision with two 0.5kg carts</td>
<td>1.0kg</td>
<td>m/s</td>
<td>kg-m/s</td>
<td>J</td>
</tr>
<tr>
<td>Inelastic collision with two 0.5kg carts and one 0.5kg mass</td>
<td>1.5kg</td>
<td>m/s</td>
<td>kg-m/s</td>
<td>J</td>
</tr>
<tr>
<td>Inelastic collision with two 0.5kg carts and two 0.5kg masses</td>
<td>2.0kg</td>
<td>m/s</td>
<td>kg-m/s</td>
<td>J</td>
</tr>
</tbody>
</table>

Analyze your data and answer these questions:

How did the kinetic energy change as the mass of the struck cart was increased?
Where did the unaccounted energy go?

How did the momentum change as the mass of the struck cart was increased?

Did the momentum change you observed comply with the law of conservation of momentum?

Finally
5. Click on “Data”
6. Click on “Clear All Data”
7. Click on the “Yes” button. *Now the computer is ready for the next lab group.*
8. Remove the masses and leave the area ready for the next group.