Project #1: Investigate momentum conservation for an “explosive” separation.

Project #2: Is momentum conserved for an inelastic collision?

Make sure the motion detector is plugged into PORT 2. Turn on the computer and the ULI box.

Start Logger Pro. Click on File, Open, select Probes & Sensors, then Motion Detector, and then Motion Detector again. (Click OK if you get an error message.)

You should now have 3 graphs; distance, velocity, and acceleration. Click on Setup, Data Collection, Sampling, and type 50 into the “samples/sec” box. Click OK.

Make a trial run to be sure the motion detector can “see” the cart clearly for the full length of the track.

Change the scales on the vertical axes to reasonable values, e.g., 0 to 2 …

Project #1: Momentum (and energy) conservation for an “explosive” separation?

One of the carts has a spring loaded plunger on one end. You can lock the plunger in the compressed position by pushing upward slightly (after pushing it in). To release the plunger, tap the release button on the top of the cart.

In this project, you will investigate how the velocity of this cart depends on its mass and the mass of the object from which the cart pushes off. This scenario is analogous to a radioactive decay event, where one nucleus, initially at rest, splits into two pieces, which fly off in opposite directions. If the cart pushes off of another cart, the picture is:

initial state:

final state:
1. First estimate the strength of the spring. Stand the cart on its end (so the spring plunger points straight up) and balance the two 500g bars on the plunger. Use a ruler behind the cart to estimate the amount of compression of the spring. Use Newton’s 2nd Law for this situation ($kx - mg = 0$) to calculate the spring constant (Remember $x$ = change in length of the spring!):

$$x =$$

$$k =$$

2. Predict (qualitatively) how the velocity of cart 1 will be different for the separation events shown below. Give a qualitative explanation of your predictions!

A. $m_1 = \text{mass of cart } 1 + 1000g$ $m_2 = \text{mass of cart } 2$ $m_1 > m_2$

B. $m_1 = \text{mass of cart } 1$ $m_2 = \text{mass of cart } 2$ $m_1 \approx m_2$

C. $m_1 = \text{mass of cart } 1$ $m_2 = \text{mass of cart } 2 + 1000g$ $m_1 < m_2$

D. $m_1 = \text{mass of cart } 1$ Wall attached to earth so $m_2 \to \infty$ $m_1 << m_2$
3. Test your predictions by doing the above experiments and recording the velocity of cart 1 (using Logger Pro) each time. Use the greatest spring compression on each experiment.

mass of empty cart 1: _________ kg \((\neq m_1)\), mass of empty cart 2: _________ kg \((\neq m_2)\)

<table>
<thead>
<tr>
<th>experiment</th>
<th>(m_1 / m_2)</th>
<th>(v_{1f} \text{ (m/s)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
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<td>B</td>
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<td>C</td>
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<td>D</td>
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Q. Are your results consistent with your predictions? Explain giving evidence to support your opinion.

4. The principle of conservation of energy says that the initial energy of the compressed spring \((\frac{1}{2} kx^2)\) is transformed into the kinetic energies \((\frac{1}{2} mv^2)\) of the carts. In the HW you will use conservation of energy and momentum \((p_{initial} = 0 = p_{final})\) to derive the following equation for the final velocity of cart 1.

\[
v_{1,\text{final}} = \sqrt{\frac{m_2}{m_1} \frac{kx^2}{m_1 + m_2}}
\]

Q: Does this equation make sense (mathematically and physically) in the following limits? Show the result mathematically. Do not plug in numbers. Do it algebraically.

\(m_1 \gg m_2\)

\(m_1 \ll m_2\) \hspace{1cm} \text{(hint: if } m_1 \ll m_2 \text{ then } m_1 + m_2 \cong m_2)\)
**Project #2**: Is momentum conserved for an inelastic collision?

In a completely inelastic collision the carts stick together after the collision (and kinetic energy is *not* conserved). Perform the following experiment. Keep trying until you get a final velocity (for the carts stuck together) close to 0.2 m/s. Make sure the detector has enough time to record both the initial velocity of cart 1, as well as the final velocity of both carts stuck together. Note that the velcro will stick the carts together.

**initial state:**

<table>
<thead>
<tr>
<th>1</th>
<th>v₁ᵢ</th>
</tr>
</thead>
</table>

| 2   | v₂ᵢ = 0 |

**final state:**

<table>
<thead>
<tr>
<th>1</th>
<th>vᵢ</th>
</tr>
</thead>
</table>

| 2   | vᵢ = 0 |

What initial velocity of cart 1 resulted in a final velocity of about 0.2 m/sec for the carts stuck together?

1. Predict (qualitatively) how the **initial velocity of cart 1** will have to be changed for the following experiments, if the **final** velocity (of the carts stuck together) is to remain 0.2 m/s:

   **A**.

   | v | 1 | 2 |

   **B**.

   | v | 1 | 2 |

2. Perform the experiments and record the initial velocities of cart 1 in each of the two cases. Do they agree with your predictions?

   A: initial velocity =

   B: initial velocity =
Homework:

**H1.** Using conservation of energy and momentum derive the equation for the final velocity of cart 1 from project #1 (see step 4 above).

hint #1: Write down the equation for conservation of mechanical energy. The initial spring potential energy is transformed into the kinetic energies of the carts.

hint #2: Write out both sides of the conservation of momentum equation. Solve for $v_{2\text{final}}$, then substitute into the energy equation. $p_{\text{initial}} = p_{\text{final}}$

**H2.** Derive an equation for the final velocity for the completely *inelastic* collision of project #2. Remember that cart #2’s initial velocity is zero, and the carts stick together.
H3. What does the above equation (from H2) say the velocity will be for the following limits? Show the math.

\[ m_2 = 0 \]

\[ m_2 = m_1 \]

\[ m_2 = \infty \text{ (infinity)} \]

H4. Sketch a graph of momentum vs. time for a ball being thrown up in the air, and explain your graph.

H5. What are the units of momentum?

H6. In project #1, when cart 1 pushed away from the other cart loaded with the two 500g bars (experiment C), which cart had more momentum? Please explain your answer.