

Collision Lab Design

team:

Michael Dubson (lead designer, developer)

Trish Loeblein

Kathy Perkins

Wendy Adams

Noah Podolefsky

Trish Loeblein

Sam Reid

Jon Olson

Table of Contents

1. [Abstract](#)/keywords
2. [Learning Goals](#)
3. [Controls](#)
4. [Mock Up](#)
5. [Mindy's Testing Notes](#)
6. [Notes after Oct 28th](#) meeting especially focusing on features to be added after class use and ideas for new intro tab
7. [Unresolved Issues](#)
8. [Notes starting Oct 7, 2010 about the time of the first deployment](#)
9. [Note from Wendy after use](#)

Abstract:

Investigate collisions on an air hockey table. Set up your own experiments: vary the number of discs, masses and initial conditions. Is momentum conserved? Is kinetic energy conserved? Vary the elasticity and see what happens.

Key Words: 1D, Collision, energy, velocity, elasticity, momentum, conservation, vectors, center of mass, vector addition, conservation of energy, center of mass

Learning Goals

- Draw "before-and-after" pictures of collisions.
- Construct momentum vector representations of "before-and-after" collisions.
- Apply law of conservation of momentum to solve problems of collisions.
- Explain why energy is not conserved and varies in some collisions.
- Determine the change in mechanical energy in collisions of varying "elasticity".
- What does "elasticity" mean?

•

TL: These came as a request from Hisham (let's keep them in mind)

=====

Learning Goals:

To understand that the net force causes changes in momentum

To understand how to find the velocities of particles after a collision.

To understand how momentum depends on mass and velocity

To understand how the momentum of a system evolves during a collision

To understand the difference between elastic and inelastic collisions in terms of momentum and energy

To understand momentum and change in momentum in simple 1-D collisions

To understand impulse

To understand collisions /interactions and conservation of momentum

To understand momentum and change in momentum in 2-D dimensions

-pat loeblein 10/16/09 5:15 AM

Ideas for Teaching tips doc:

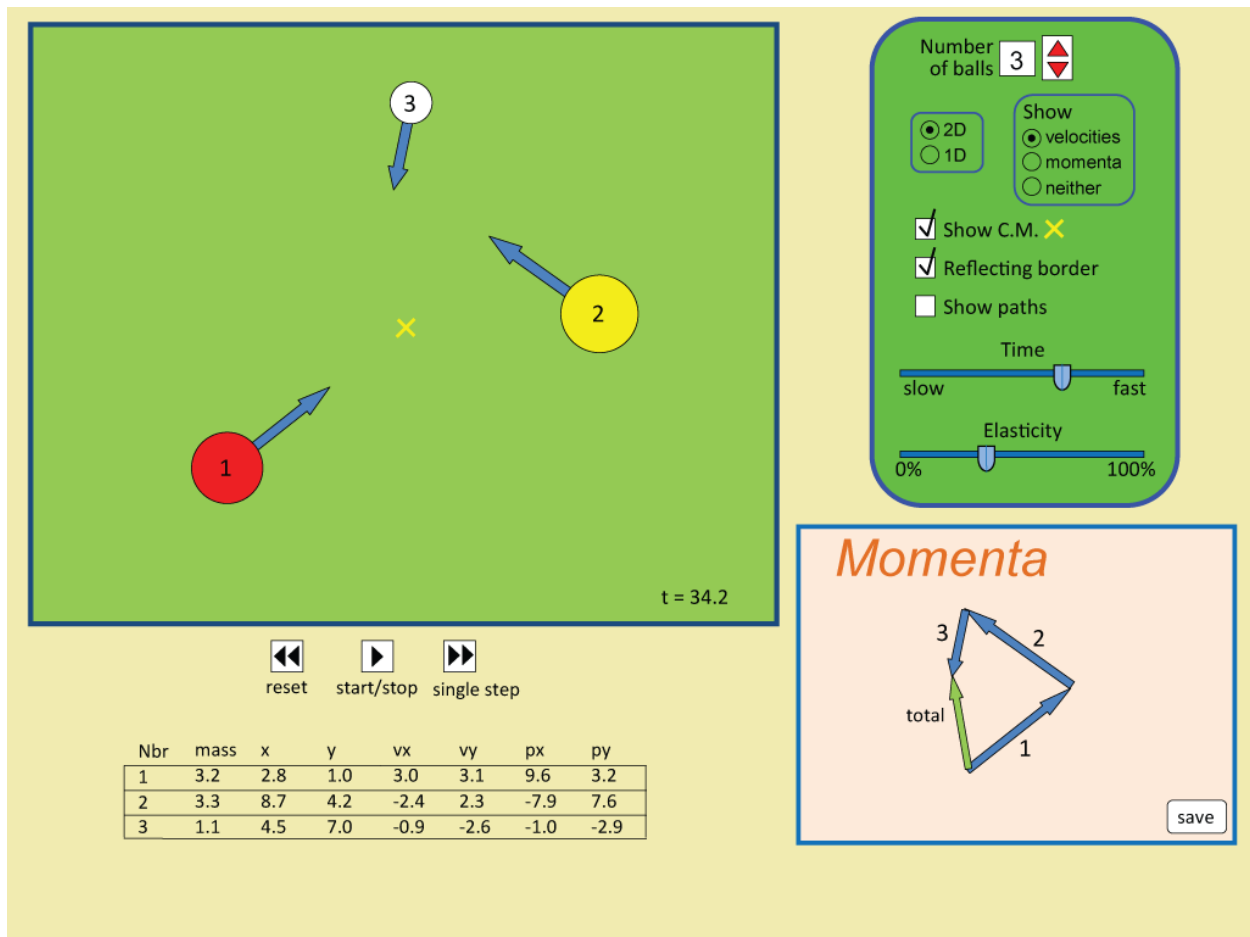
The first version of the teaching tips were published when version 1.00 was deployed on 10/21/10

- The display for the values in the data table are rounding to 3 decimal places, so students calculated values may not exactly match the momentum display values. If the values are typed into the value box, the numbers will be exact -pat loeblein 11/4/10 7:20 AM
- "Rewind" takes the sim back to the positions and velocities that were last set, some students thought it would work like "Reset"-pat loeblein 11/4/10 7:21 AM
- When elasticity = 0, momentum is conserved, but the velocities of the balls are different after a collision. In 2D, the v are not the same just in 1D. The rule for inelastic in 2D, the component along the line of the centers is changed.-pat loeblein 11/4/10 8:45 AM

Controls (similar to controls in My Solar System)

- Set number of balls: 1 to unlimited (default is 2)
- Set initial positions and velocities, either by dragging in play area or entering numbers in table
- Set initial masses by entering numbers in table
- Option to show center-of-mass (c.m.) of system
- Option to show 2D or 1D motion. (Setting 1D collapses balls onto x-axis)
- Option to show velocity or momentum arrows or neither while balls are in motion. (Tried this in My Solar System, but play area was too cluttered.)
- Option to have reflecting border around play area: collisions with border are perfectly elastic
- Option to show ball trajectories during motion
- Slider to set elasticity of collisions: perfectly elastic to perfectly inelastic (objects stick when collide)
- Slider to set rate that time passes. Users will want to slow down time to view details of collisions.
- Option to save Momenta diagram to compare before and after collision
- Detailed readout for a ball when mouse held over ball
- Momentum arrows in Momenta Panel are draggable with mouse. User can translate arrows but not change magnitude or direction.

Mock Up



Mindy's testing results 11/2/2010

1. When one component of velocity is set to "0" in 2-D, it doesn't always stay 0. I set it up so that I was in 2-D, but set all the V_y 's to 0.000, and had the 2 balls collide. After the collision, the y-component of momentum and velocity were non-zero. See pictures below. Kathy told Mindy this is the correct behavior. I'll ask Mike about if he thinks we should explain this behavior in the Tips or the Advancd part maybe? -pat loeblein 11/4/10 7:26 AM

Before

collision:

After collision:

2. Some error in momentum calculations – looks like an inconsistency in the significant digits used for the calculations versus the sig figs shown in the sim. See figure for an example. If you look at ball 4, and calculate p_x , you get 0.71, but 0.709 is shown. If you calculate p_y for ball 4, you get -1.994, but -1.993 is shown. I made a note to add to the Tips remarks about rounding. -pat loeblein 11/4/10 7:23 AM

3. Inconsistency in how velocity vectors work – while the sim is running, and balls are moving, sometimes the velocity vector goes in front of the other balls, and sometimes it goes behind the other balls. Mike said that the vector and the ball act like one object and that the object that was last clicked is always on top. -pat loeblein 11/4/10 7:23 AM If we want to change the sim so that the vectors are always on top, then the programming will need to be changed.
4. Inconsistency in how the COM works – similarly to #3 above, sometimes the COM “x” goes in front of the balls, and sometimes behind. It seems to always go behind balls 1 and 2, and in front of balls 3, 4, and 5. Mike and I discovered that if you click on the velocity vector, it can cover up the CM marker. This is a bug that needs to be solved. -pat loeblein 11/4/10 7:25 AM
5. Rewind inconsistency – Pushing the rewind button does not always put the balls back to their original velocities. From what I can see, they always go back to their start positions, but the velocities of one or all of the balls goes to 0 when you push rewind. See pictures below for an example. I am added a note to explain why this happens to the Tips. But Mindy thinks there may be a bug too - pat loeblein 11/4/10 7:26 AM

Initial Start:
pushing Play>Pause>Rewind

After

6. Inconsistency in tip-to-tail from 1-D to 2-D – When in 1-D, the vectors in tip-to-tail are offset, but then when you click on 2-D, even though the balls are still in a 1-dimensional configuration, then vectors are overlapping. Mike and I could not reproduce this. The vectors were always offset. I wonder if Mindy might have had "Tip to Tail" unchecked? -pat loeblein 11/4/10 7:29 AM

7. Elasticity – It seems like you should be able to type in a value for the elasticity, since it looks like a text box, but you can't. Seems like a feature we should implement: either change the box so it doesn't look like you can type in it or make it look like a display. In the data table, the momenta have no box. -pat loeblein 11/4/10 7:30 AM

8. Conservation of Momentum – I tested out several different situations in 2-D, and found that momentum seems to be conserved correctly. The only thing I found that could be fixed is probably

related to the inconsistency mentioned in #1 and #2 above with the sig figs. Sometimes the calculation using the displayed masses and velocities was a little off of the displayed momentum, but only by a little (usually about ± 0.001). This is about rounding -pat loeblein 11/4/10 7:32 AM

9. When elasticity = 0, momentum is conserved, but the velocities of the balls are different after a collision. Shouldn't the velocities of two balls that collide be equal after the collision? Is this supposed to be a completely inelastic collision? See pictures below for an example of a collision with elasticity=0, but the balls velocities are not equal after the collision. Does the COM have a momentum vector that is equivalent to the momentum vectors of the balls added together? Regardless, we need to put something in teaching tips about this. In 2D the v are not the same just in 1D. The rule for inelastic in 2D, the component along the line of the centers is changed. Added to Tips list -pat loeblein 11/4/10 8:23 AM

Before Collision:
collision:

After

10. Ball can move through Reflecting Border wall. Once again, I set up a situation with elasticity=0, and the balls collided and then moved towards the wall. When they hit the wall, they were still slowly moving down the wall, and the bigger ball pushed the smaller ball outside of the wall (ball 1 was in the corner when it got pushed out). known bug for corner and inelasticity -pat loeblein 11/4/10 8:25 AM

**Before collision:
collision (where ball is outside of wall):**

After

Ideas from Oct 28th meeting with Sam, Jon, Trish, Noah, Mindy, Kathy and Mike

Questions not resolved highlighted in yellow

A. Things that need to be addressed for the present version:

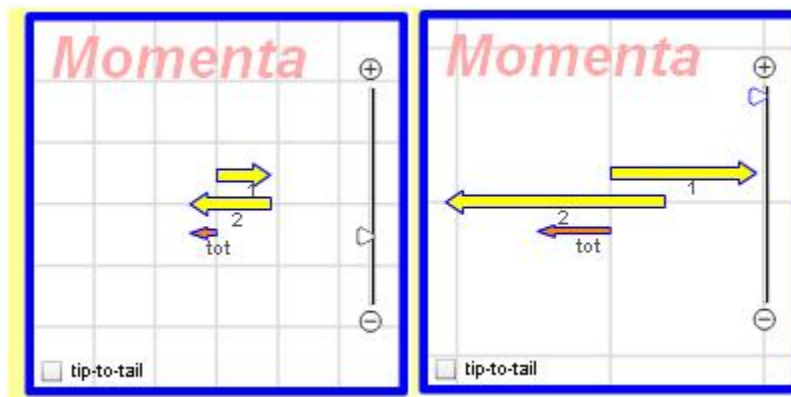
- 1. Feature: Identify data to more clearly associate to balls: add a circle around the number with the appropriate color as**

ball	mass	x	y	Vx	Vy	Px	Py
1	0.5	1.000	0.000	1.000	0.300	0.500	0.150
2	1.5	2.000	0.500	-0.500	-0.500	-0.750	-0.750

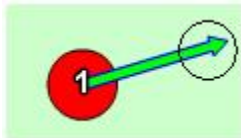
- 2. Feature: More text on data table: Decision was to add units, but see if the intro tab solves the issue of variable names for the by giving more clues on the first tab. (image just an approximation)**

ball	mass	x	y	Vx	Vy	Px	Py
	(Kg)	(m)	(m)	(m/s)	(m/s)	(kgm/s)	(kgm/s)
1	0.5	1.000	0.000	1.000	0.300	0.500	0.150
2	1.5	2.000	0.500	-0.500	-0.500	-0.750	-0.750

3. Feature: add "Return Ball" when one ball leaves play area
4. Feature (or bug): the tail of the momenta vectors in the momenta diagram do not stick to the grid lines when the zoom is used and "tip-to-tail" is unchecked . It was agreed that they should. This is what it looks like now, but in "Tip to tail" the tails do stick.



5. Problem: Students did not figure out to change the velocity by grabbing the head of the vector. The decision was to include the black circle that presently appears only when the vector is too small on the head of the velocity vector anytime the user mouses over the vector. (Question do we want the circle to appear when the user mouses over the ball or the vector or just the vector?) np says yes to both

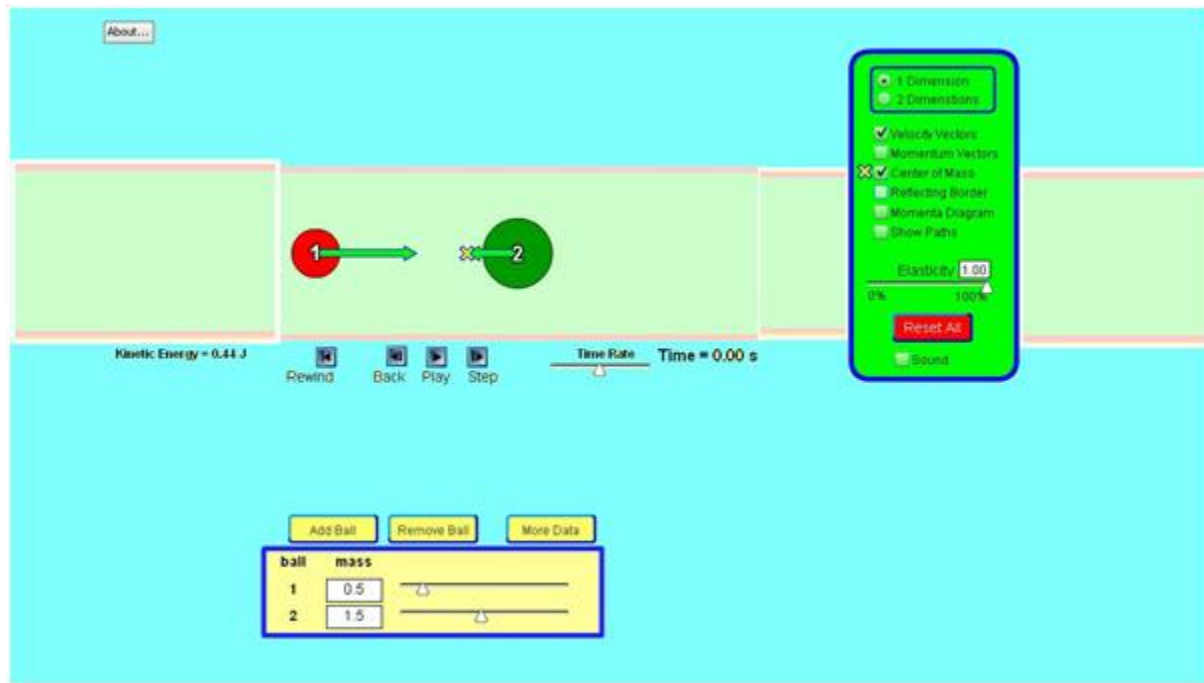


6. There was a discussion about number of digits to display and it seems like for now, no change has been recommended

B. Intro tab: These decisions were made:

1. Only 2 balls possible , mass slider still present at beginning NP says left ball has non-zero velocity, right ball has zero velocity only 2 balls (no add / remove ball option)

2. **No walls** : also play area extends the length of the window. (It was decided that it is not a problem for the balls to go behind the control panel. This is just a mock-up of the play area.) NP says no walls ever (remove "Reflecting border" option)



3. **Add "Return ball" button when one ball leaves screen.** np

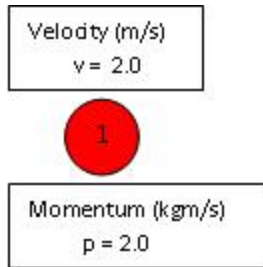
np: add "Return Balls" when both balls are off screen; will have same effect as "Rewind" button (I thought about doing this with just one ball off screen, but might be distracting, and you can always hit rewind).

4. **Default velocity beginning:** One ball with no velocity, one with zero velocity,

5. **Default mass** was not discussed (it has already been decided that mass should not = 1, because then the velocity vector = momentum vector) **Question: do we want the masses to be equal or unequal?**

6. There was a decision to leave the "tip to tail" check box as is (Sam recommended that we get rid of horizontal grid lines, but that was tabled)

7. **New feature:** When the user mouses over a ball, a readout box appears over the ball with the velocity and below a readout box for momentum.



8. Fewer controls (and one extra):

- No reflect border, 1D or 2D, show paths, add ball, remove ball
- Keep these check boxes: Velocity vector (checked by default), Momentum Vectors (unchecked by default), Center of mass (unchecked by default), Elasticity (slider set at 100% by default), Reset all, Sound (unchecked by default)
- Keep all things just under the play are: Kinetic energy total, Rewind, back, play, step, Time rate slider and time = 0.00 s
- Keep "More data" above Mass slider (with units added as mentioned above) NP-says remove this, but then what would happen to mass slider?
- Add a check box for "Show values" This will enable leaving the readout for velocity and momentum on instead of just appearing when the user mouses on ball.



9. NP says center or mass off by default

NP- here is what I recommend: I have moved all these to the oct 28th notes -pat loeblein 11/5/10 9:33 AM

- default is: left ball has non-zero velocity, right ball has zero velocity moved to notes from oct 28 -pat loeblein 11/5/10 9:29 AM

- only 1 dimension (remove 1d/2d radio buttons) already in spec -pat loeblein 11/5/10 9:28 AM

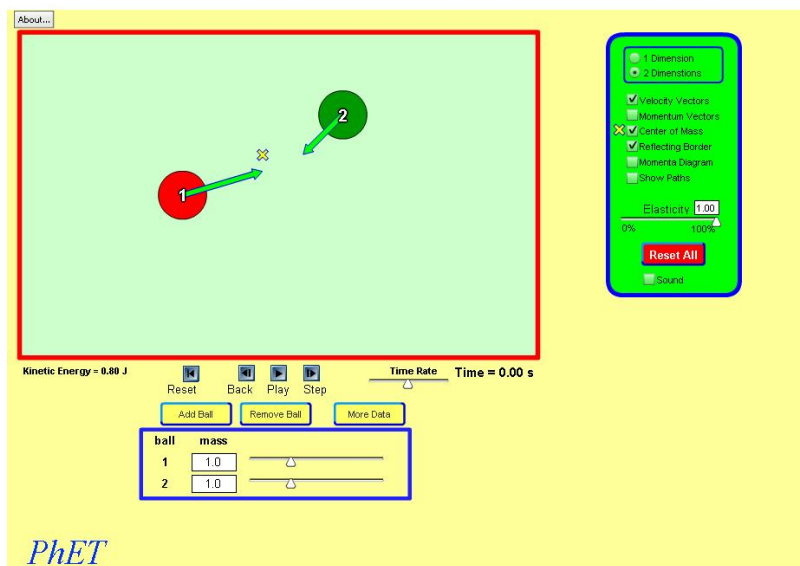
- only 2 balls (no add / remove ball option) moved to notes from oct 28 -pat loeblein 11/5/10 9:29 AM
- no walls ever (remove "Reflecting border" option)moved to notes from oct 28 -pat loeblein 11/5/10 9:29 AM
- center of mass *off* by default moved to notes from oct 28 -pat loeblein 11/5/10 9:29 AM
- remove "Show Paths" option already in spec -pat loeblein 11/5/10 9:28 AM
- remove "More Data" button removed to notes from oct 28, but then what happens to mass slider -pat loeblein 11/5/10 9:29 AM
- add "Return Balls" when both balls are off screen; will have same effect as "Rewind" button (I thought about doing this with just one ball off screen, but might be distracting, and you can always hit rewind)moved to notes from oct 28 -pat loeblein 11/5/10 9:29 AM
- circle appears around velocity vector arrow when user hovers over ball or arrow. This is to cue user that velocity vector is grabbable. This will look like the circle that appears when the vector tip is inside the ball. This "inside ball" circle will still appear same as before. Only difference is that it will also appear when user hovers over ball or vector.moved to notes from oct 28 -pat loeblein 11/5/10 9:29 AM
- add "Velocity; $V = ??? \text{ m/s}$ " above ball and "Momentum; $P = ??? \text{ kg m/s}$ " below ball. already in spec -pat loeblein 11/5/10 9:28 AM

Unresolved issues: from 2009 -pat loeblein 10/22/10 4:10 PM

- What about radius of each ball:? Not an issue in 1D, but affects dynamics in 2D. Should radii be constant, scale with mass, or be user-settable?
- No option to turn on gravity in this sim. In 2D turning on gravity would be like playing pool on a tilted table. Might be fun and instructive, but controls are already numerous, danger of cognitive overload. Perhaps in Advanced Tab?
- Might include pull-down menu of presets: collection of interesting initial conditions. This was very useful in My Solar System.
- Might include option for xy grid, or tape measure.
- Option to have exploding ball?
- Option to have a game, with scoring? Pool table with corner and side pockets?

Below are ideas from Oct 7, 2010 and later -pat loeblein 10/22/10 3:59 PM

These ideas were developed on Oct 7 as a result of 4 interviews done by Mindy, and ideas from the major contributors listed above by Trish meeting with individuals, Phet group meeting ideas, and a meeting with Kathy and Noah which occurred. On Oct 21, all identified bugs have been fixed and some feature requests implemented. This document is to help discuss possible features, the major problem with the present sim identified in interviews, and suggestions for an intro tab. It has been agreed that we will deploy version 1.00 and add an intro tab and redeploy soon (like 2 months). Jon may be working on the new tab. Below is a screen capture of version 1.00.



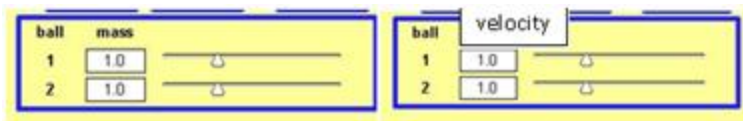
1. 10/21 new bug: "Reset all" doesn't move the momentum vectors back to the box and "tip to tail".
2. Feature: add a "return ball" Will be done before deployment? **Done in version.15 10/21**
3. Feature: change initial mass so momentum and velocity vectors are not the same size by default. Will be done before deployment **done in version .1510/21**
4. Feature: add color coding to data table like in My Solar system (color of rows match bodies in paly area). Something to consider is what to do about knowing what is changing when you drag the velocity vector because right now the boxes get highlighted; Mike suggested bolding perhaps. Will be done before deployment? **Decided not yet at Phet status meeting 10/21**
5. Feature: More text on tools for example, titles to the columns would have the words position, velocity momentum like in the image above from My Solar System. Will be done before deployment? **Decided not at Phet status meeting 10/21** Wendy used version 1.00 in class and also commented that this would be helpful -pat loeblein 10/22/10 4:02 PM

gs.		Position		
	mass	x	y	x
body 1	200	0	0	
body 2	10	142	0	

6. Problem: Students struggled with "how to get started" which requires selecting Play and they don't easily find that the velocity is changed by grabbing the green velocity vector on a ball. Will be done before deployment? **Decided not at Phet status meeting 10/21** I grouped these problems because they are critical to start investigating collisions. Most quickly found the play button, but didn't know how to change velocity. They did play with the mass slider.

Solution thoughts: Mindy and I looked at several sims to see what types of solutions for students not knowing how to start, ie: PhET has to clue students about what to do first. Here are a list: (I could include more screen captures if it would be helpful)

- a. Wiggle me like in Moving Man
- b. Big note at beginning like Robot game , Masses and Springs, and Lunar Lander
- c. Keep help up like in Robot game the directions to use the arrow keys stays in the upper corner
- d. Help buttons with arrows like Curve Fit, Masses and Springs (Mindy really liked this idea even if it is not used just to get students started)
- e. Help as needed like "Return Balls" as in Skatepark use Return Skater (this feature will definitely be added as per Mike and Trish conversation 10/21/10)
- f. Use sliders for interface to encourage engagement. for example, we might add a velocity slider.



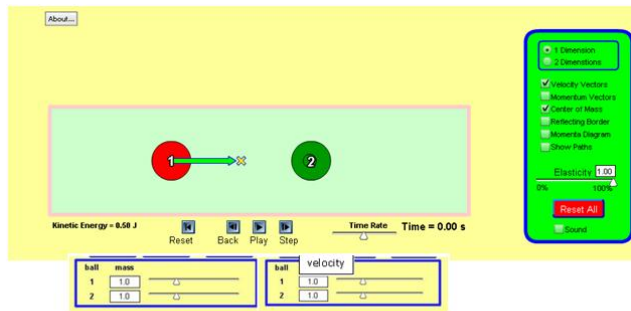
- g. Add an Intro tab to provide more scaffolding
7. Intro tab: It was agreed that there needs to be an intro tab because Mindy saw that students struggled with the complexity of the present sim and Kathy, Noah and Trish agree that the sim needs scaffolding for beginners whether they be MS, HS or non-science majors. Some ideas are:

- a. Only 2 balls possible or maybe not?
- b. No walls by default
- c. Add "Return ball"?
- d. Fewer controls but not decided which. Strongly recommended sliders for mass and velocity (question: will students figure out on second tab that the velocity is changed by green vector which is really nice for 2D? Back to the problem identified in #5 and a solution should be identified.) Take out "tip-to-tail" option, but allow dragging vectors into play area (perhaps?)
- e. One ball with no velocity and one with zero velocity
- f. No Add or remove more data

NP says - here is what I recommend:

- default is: left ball has non-zero velocity, right ball has zero velocity
- only 1 dimension (remove 1d/2d radio buttons)
- only 2 balls (no add / remove ball option)
- no walls ever (remove "Reflecting border" option)
- center of mass *off* by default
- remove "Show Paths" option
- remove "More Data" button
- add "Return Balls" when both balls are off screen; will have same effect as "Rewind" button (I thought about doing this with just one ball off screen, but might be distracting, and you can always hit rewind).
- circle appears around velocity vector arrow when user hovers over ball or arrow. This is to cue user that velocity vector is grabbable. This will look like the circle that appears when the vector tip is inside the ball. This "inside ball" circle will still appear same as before. Only difference is that it will also appear when user hovers over ball or vector.

- add "Velocity; $V = ??? \text{ m/s}$ " above ball and "Momentum; $P = ??? \text{ kg m/s}$ " below ball.



- Some things before deployment: Trish will finish Tips, goals and abstract before deployment and test. Mike will tell Sam when ready to deploy. Wendy said when they used version 1.00, they were able to break the sim, but gave no specifics. -pat loeblein 10/22/10 4:06 PM

Wendy used the sim the day after of deployment to a class of pre-service grade school teachers and wrote this note -pat loeblein 11/10/10 6:53 AM Collision lab was a hit today. These were calc based physics students. 70 of them in a lecture room with tiny desks and I had them work in groups of 2-4 with their own laptops. They don't usually do this sort of thing but they settled in right away.

- Most did not know that p is momentum and I had to tell them (they couldn't figure it out from the sim)
- One group asked what V_x and V_y were. When I told them they were velocity they were confused since the balls were stationary (they hadn't hit play yet). Not sure what you can do about that.
- A couple of boys found multiple ways to make the balls bounce around erratically. They were pleased with themselves for making the 1-d version exhibit 2-d behavior by making a very massive ball that would start jiggling between the sides. In 2D they did some other extreme similar thing and had

the balls translating from spot to spot and just let it run that way for at least 15 minutes. Not very productive but they were the only group doing this.

Pretty much everyone thought it was really useful and were looking forward to it when they started doing momentum in 2 dimensions. One gal wanted to know if PhEt was available for her because she's going to be a high school teacher and was thrilled when she heard it was online and free. (never mind the fact they were using it online for free.....)

Oh and they were very pleased to know they were the first class to use the sim after it went live on the site.

Wendy