The **Collision Lab** simulation allows students to investigate collisions in 1D and 2D. Experiment with the number of objects and initial conditions. Vary the elasticity to explore inelastic collisions.

Intro Screen

Set up 1D collisions between two bodies and control the initial conditions. Observe the change in momentum and kinetic energy.

DRAG objects to desired position.

DRAG tip of velocity vector to set velocity (when paused)

CHANGE the mass of the balls. Clicking data field will open a keypad.

OBSERVE change in momentum (impulse)

DISPLAY speed and momentum magnitudes

Explore 1D Screen

Experiment with up to four objects in 1D. Enable a Reflecting Border to keep balls contained within the observation window

ENABLE Reflecting Border to constrain balls to observation window

MEASURE the elapsed time

VIEW more data; **CLICK** data field to edit with keypad

VIEW center of mass

COMPARE balls with same diameter

ANALYZE momentum in the system; **ZOOM** to rescale vectors

Explore 2D Screen

Create collisions in 2D with up to four objects.

DISPLAY the total kinetic energy in the system

EXPERIMENT with up to 4 balls

CONTROL elasticity of collisions

REPEAT an experiment

	Mass (kg)	Position (m)		Velocity (m/s)		Momentum (kg m/s)	
		x	y	v_x	v_y	p_x	p_y
1	0.50	-1.74	0.33	1.00	0.30	0.50	0.15
2	1.50	1.30	0.57	-0.50	-0.50	-0.75	-0.75
3	1.00	-0.66	-0.56	-0.57	0.56	-0.57	0.56
4	1.00	0.20	-0.65	1.10	0.20	1.10	0.20

Inelastic Screen

Explore completely inelastic collisions between two objects. The "Slip" mode behaves like inelastic collisions on previous screens and affects the magnitude of the component of the velocity along the "line of action". When in "Stick" mode, the balls will stick together, resulting in rotation.

VIEW ball paths

SET mode of inelastic collision (see Model Simplifications below)

EXPERIMENT with preset configurations or create your own

Insights into Student Use

- Frequent changes to the parameters while the balls are in motion can lead to hard-to-interpret behavior. When setting up an experiment, it may be helpful to first pause the simulation. The step forward and step back buttons can be used to incrementally analyze when paused.

- Turning off Reflecting Borders enables students to focus on ball-ball collisions which conserve Momentum. The ball-wall collisions do not conserve momentum.

Complex Controls

- Mass, position, and velocity can be edited by clicking on the text box and entering a value with the on-screen keypad.

Mass (kg)	Position (m)		Velocity (m/s)	
	x	y	v_x	v_y
0.50	-1.00	0.00	1.00	0.30

- The blue reset button below the observation window can be used to repeat an experiment. It will restore the most recently saved configuration. A new configuration is saved each time there is a change to the number of balls, position, mass, velocity, elasticity, or constant size. However, if any balls have escaped off-screen, no new states will be saved. This allows lost balls to be recovered.

Customization Options

Query parameters allow for customization of the simulation, and can added by appending a '?' to the sim URL, and separating each query parameter with a '&'. The general URL pattern is:

`…html?queryParameter1&queryParameter2&queryParameter3`

In Collision Lab, if you only want to include the 2nd and 3rd screens (`screens=2,3`), with the 2nd screen open by default (`initialScreen=2`) use:

https://phet.colorado.edu/sims/html/collision-lab/latest/collision-lab_all.html?screens=2,3&initialScreen=2

To run this in Spanish (`locale=es`), the URL would become:

https://phet.colorado.edu/sims/html/collision-lab/latest/collision-lab_all.html?locale=es&screens=2,3&initialScreen=2

Query Parameter and Description	Example Links
`screens` - specifies which screens are included in the sim and their order. Each screen should be separated by a comma. For more information, visit the Help Center.	`screens=1` `screens=2,1`
`initialScreen` - opens the sim directly to the specified screen, bypassing the home screen.	`initialScreen=1` `initialScreen=3`
`locale` - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab. Note: this only works if the simulation URL ends in "_all.html".	`locale=es` (Spanish) `locale=fr` (French)
`allowLinks` - when `false`, disables links that take students to an external URL. Default is `true`.	`allowLinks=false`
`supportsPanAndZoom` - when `false`, disables panning and zooming using pinch-to-zoom or browser zoom controls. Default is `true`.	`supportsPanAndZoom=false`

Model Simplifications

- Technical details of the underlying model can be found here.
- The balls are generally non-rotating, with the exception of the "Stick" mode on the Inelastic screen.
- Elasticity affects the ball-wall and ball-ball collisions.
- The stroke weight around the balls represents elasticity. The lower the elasticity, the thicker the stroke. This can be thought of as a rubbery, deformable layer being added to the balls.
- Elasticity, represented as a percentage, indicates the amount of kinetic energy lost during collisions. If the elasticity = 100%, the collision is perfectly elastic and kinetic energy is conserved. Elasticity < 100% affects the magnitude of the component of the velocity along the "line of action" between two colliding balls. The line of action is the line connecting the centers of the balls at the moment of collision. If the elasticity is 30%, then the speed along the line of action after collision is 30% of the value it would have had in an elastic collision. The speed perpendicular to the line of action is not affected. Since these balls are non-rotating, changing the speed perpendicular to the line of action would violate Conservation of Angular Momentum.
- The Inelastic screen supports two types of inelastic collisions, referred to as "Slip" and "Stick". When in "Slip" mode, inelastic collisions behave as described above. When in "Stick" mode, the balls will stick together, resulting in rotation.
- Stepping back only allowed in perfectly elastic collisions, so it is disabled if the elasticity is less than 100%. This is to avoid displaying alternate histories that arise from numerical imprecisions.
- Due to precision limitations, it is possible for values such as velocity, kinetic energy, or momentum to appear to be zero, even when they are not. We have chosen to display these values as "~0.00" to indicate that the values are approximately, but not exactly, zero.
- Balls can be moved by dragging them to the desired position. If the sim is in motion, it will temporarily pause the sim. If a ball is released so that it overlaps a wall or another ball, it will automatically reposition itself to avoid overlap.
- When Constant Size is enabled, all balls will have the same diameter. The color saturation of the ball maps to its density (i.e. larger masses will have a more saturated color).
- If the diameter of the balls change after an inelastic collision in "Stick" mode (either by checking or unchecking Constant Size), the balls will separate.
- If an object is partially out-of-bounds when the Reflecting Border is turned on, it will continue to escape.
- The Momenta Diagram is a graphical display of the momentum vectors arranged tip-to-tail. However, in one dimension, the vectors are vertically offset, so that the students can see the vectors more easily.

Suggestions for Use

Sample Challenge Prompts
- Draw "before-and-after" pictures of collisions.
- Construct momentum vector representations of "before-and-after" collisions.
- Explain why kinetic energy is not conserved and varies in some collisions.
- Determine the change in mechanical energy in collisions of varying elasticity.
- Define elasticity.

See all published activities for Collision Lab here.
For more tips on using PhET sims with your students, see Tips for Using PhET.