COLLISIONS

Mechanics

Unit 5

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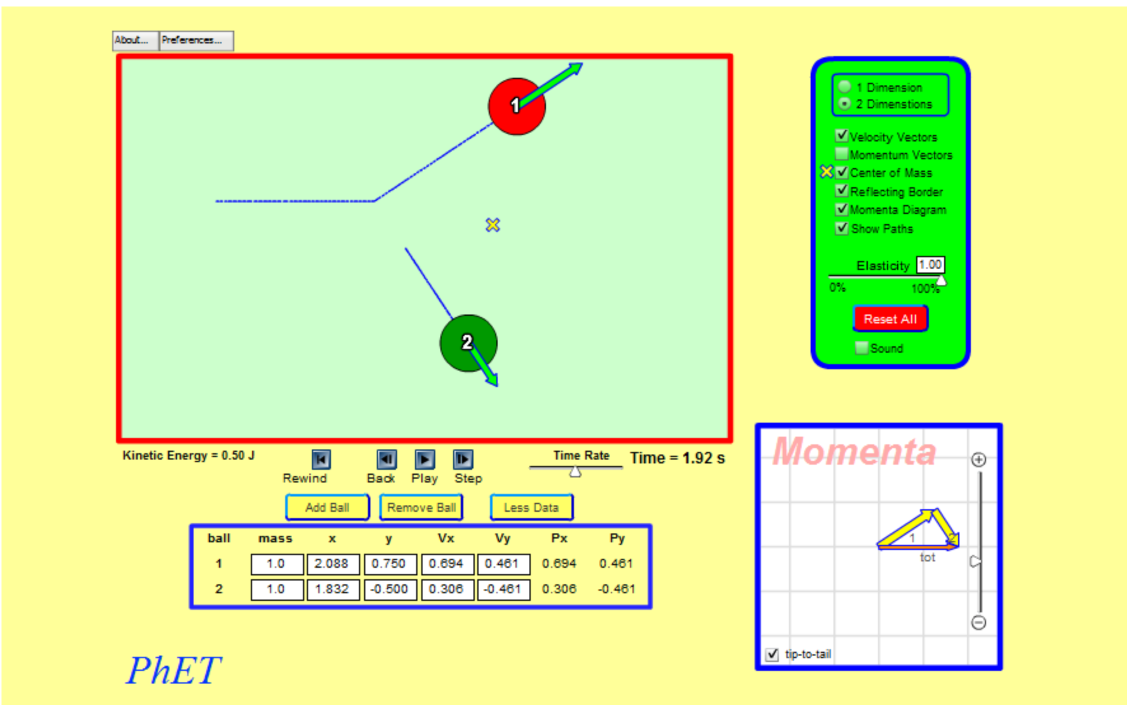
Simulation Activity #5: Collision Lab *Simulation created by the Physics Education Technology Project (PhET) c/o The University of Colorado at Boulder http://phet.colorado.edu/*



Investigating Momentum: one dimensional and two dimensional momentums

Objective:

This activity is intended to enhance your physics education. We offer it as a virtual lab online. We think it will help you make connections between predictions and conclusions, concepts and actions, equations and practical activities. We also think that if you give this activity a chance, it will be fun! This is an opportunity to learn a great deal. Answer all questions as you follow the procedure in running the simulation.

Familiarize yourself with The Collision Lab: There are controls that will help you setting up a scenario to carry out the simulation and extract the outcome. These features are found to the right and underneath of the simulation display. Controls in the green box to the side of the simulation screen are the following.
Dimension: selecting “1 dimension” makes the balls inline and minimizes the screen. Selecting “2 dimensions” will basically maximize the display box.
Vectors: If you want to see velocity and/or momentum vectors on the balls you added on the screen, you can select the “Velocity vectors” and/or “Momentum vectors”. It is also possible to see vectors in a separate display by selecting “Momenta diagram”. Actually, you can see the total momentum of the system in real time by checking “tip-to-tail” box at the bottom left corner of the momenta diagram. It is also possible to maximize or minimize the vectors using the slide on the momenta diagram.
Elasticity: Changing the percentage of elasticity on the slide controls the loss in kinetic energy of the system after collision. The two ends of the slide bar differentiate *elastic* from perfectly *inelastic* collisions. If you set the elasticity to 100%, the collision is *elastic*, but it is *perfectly Inelastic collision* if you set it on 0%. All other collisions that are not completely elastic can be represented between 0% and 100%.
Additional controls: If you want to display the center of mas, check the “Center of Mass” box. You can also check the “Show Paths” to display footpath of the collision. You can check the “Reflecting Boarder” if you want to bound the collisions inside the box. Whenever you click on the “Reset” button, you will find two balls on the screen located diagonally and “2Dimensions”, “Velocity Vector”, “Center of Mass”, “Reflecting Border” checked with 100% elasticity. If you make it more fun you can add sound.

Underneath the simulation display, there are three buttons of which the two are used to add or remove balls. The third one has a lot of information in it. You can switch between more and less data. If you click on “More Data”, you will get a larger box which displays the mass, location, velocity, and momenta of each ball. This is also very important control to precisely locate and setting up the initial conditions of the system.
Running the simulation is obvious buttons found just under the screen. If you want to restart the simulation, click the “Rewind” button. In addition, you can speed up or slow down the interaction with the “Time Rate” slide bar.

Introduction:

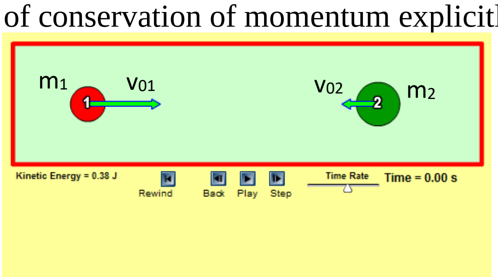
When the net external force (F_{net}) acting on a system of particles is zero (the system is isolated) and that no particles leave or enter the system (the system is closed), the total momentum (P) of the system is constant.

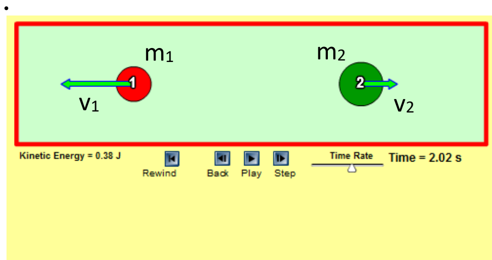
$F_{net} = 0 \;\Rightarrow\; \Delta P/\Delta t = 0 \;\Rightarrow\; \Delta P = 0$

Linear momentum is defined as, $P = mv$

$\Delta P = 0 \;\Rightarrow\; P - P_0 = 0 \;\Rightarrow\; P = P_0$ (The momentum after equals to the momentum before)

For example, let us consider two balls colliding to each other as shown below and rewrite the law of conservation of momentum explicitly.





Physics Lab 5 (Online Simulation)

Before Collision

$m_1 v_{01} + m_2 v_{02}$

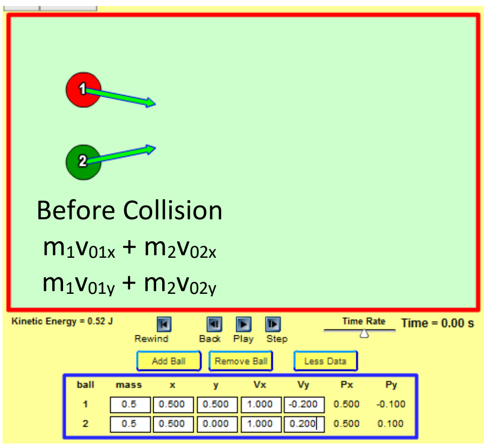
After Collision

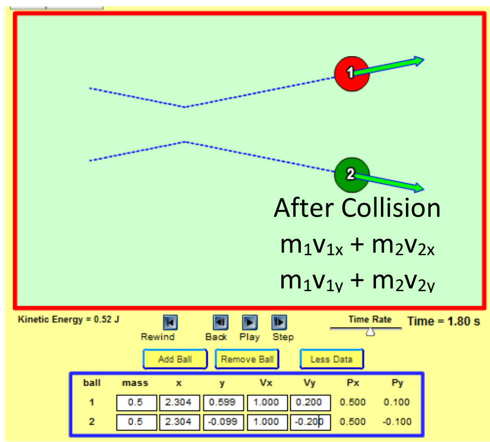
$m_1 v_1 + m_2 v_2$

The momentum before collision is equal to the momentum after collision:

$$m_1 v_{01} + m_2 v_{02} = m_1 v_1 + m_2 v_2$$

Since momentum is a vector quantity, we should pay attention to directions. If it is a one dimensional collision, the directions are right and left or positive and negative on the horizontal axis. In two dimensional motion, you have to resolve the momentum vectors in x and y directions before and after the collisions. Check out the figure below for the general case of collision in two dimensions for the two balls.





The total kinetic energy of the system may or may not be the same before and after the collision. Those collisions for which the total kinetic energy is conserved are called elastic collisions. Inelastic collisions are those which the total kinetic energy is not conserved.

Procedure: Open collision lab
http://phet.colorado.edu/en/simulation/collision-lab

Part I: Collisions in one dimension

1. Create a scenario so that the interaction is between a ball and a wall
   a. If the ball's initial velocity be is 2m/s and the system's elasticity is 100%,
      i. What is the velocity of the ball after rebounds from the wall? V = -2.0m/s
      ii. What is the change in momentum of the ball? ΔP = -2.0kgm/s
   b. If the ball's velocity is unchanged but the elasticity is reduced to 50%,
      i. What is the velocity of the ball after rebounds from the wall? V = -1.0m/s
      ii. What is the change in momentum of the ball? ΔP = -1.5kgm/s
   c. If the ball's velocity remains the same but the elasticity is reduced to 0%,
      i. What is the velocity of the ball after rebounds from the wall? V = 0.0m/s
      ii. What is the change in momentum of the ball? ΔP = -1.0kgm/s

2. Now add another ball so that the collision is going to be between these two balls. Let the masses are equal and ball 1 and ball 2 are located at (0.5,0) and (1.5,0) respectively.
   a. If you run the simulation with elasticity of 100% and initial velocities of ball 1 and ball 2 are 1 m/s and at rest respectively,

i. the velocities of the two balls after collision are v_1 = 0m/s and v_2 = 1.0m/s
ii. the momenta of the system before and after collisions are equal to .5kgm/s and .5kgm/s
iii. the kinetic energies of the system before and after collisions are equal to .25Jules and .25Joules

b. If you run the simulation with elasticity of 50% and initial velocities of ball 1 and ball 2 are 1 m/s and at rest respectively,
   i. the velocities of the two balls after collision are v_1 = -.25m/s and v_2 = .75m/s
   ii. the momenta of the system before and after collisions are equal to .5kgm/s and .5kgm/s
   iii. the kinetic energies of the system before and after collisions are equal to 0.25Jules and 0.156Joules

c. If you run the simulation with elasticity of 0% and initial velocities of ball 1 and ball 2 are 1 m/s and at rest respectively,
   i. the velocities of the two balls after collision are v_1 = .5m/s and v_2 = .5m/s
   ii. the momenta of the system before and after collisions are equal to .5kgm/s and .5kgm/s
   iii. the kinetic energies of the system before and after collisions are equal to .25Jules and 0.125Joules

3. Let ball 1 has a mass twice that of ball 2 and ball 1 and ball 2 are located at (0.5,0) and (1.5,0) respectively,
   a. If you run the simulation with elasticity of 100% and initial velocities of ball 1 and ball 2 are 1 m/s and at rest respectively,
      i. the velocities of the two balls after collision are v_1 = -.33m/s and v_2 = 1.33m/s
      ii. the momenta of the system before and after collisions are equal to 1kgm/s and 1kgm/s
      iii. the kinetic energies of the system before and after collisions are equal to .5Jules and .5Joules
   b. If you run the simulation with elasticity of 50% and initial velocities of ball 1 and ball 2 are 1 m/s and at rest respectively,
      i. the velocities of the two balls after collision are v_1 = .50m/s and v_2 = 1m/s
      ii. the momenta of the system before and after collisions are equal to 1kgm/s and 1kgm/s
      iii. the kinetic energies of the system before and after collisions are equal to .75Jules and .375Joules
   c. If you run the simulation with elasticity of 0% and initial velocities of ball 1 and ball 2 are 1 m/s and at rest respectively,
      i. the velocities of the two balls after collision are v_1 = .67m/s and v_2 = .67m/s
      ii. the momenta of the system before and after collisions are equal to 1kgm/s and 1kgm/s
      iii. the kinetic energies of the system before and after collisions are equal to .75Jules and .333Joules

Part II: Collisions in two dimensions

1. Apply the following settings for the simulation
   a. Mass: $m_1 = m_2 = 0.5$ kg.
   b. Location: (0.5m, 0.5m) and (0.5m, 0m) for ball 1 and ball 2 respectively
   c. Initial velocities: v_{01x} = 0.4m/s v_{01y} = -0.2m/s v_{02x} = 0.4m/s v_{02y} = 0.2m/s
2. Calculate the angles for initial velocity vectors
   Ball 1: -26.565 degrees
   Ball 2: 26.565 degrees