Advanced Collisions

Teacher's Guide

1.0 Summary

Advanced Collisions is the seventh activity in the Dynamica sequence. This activity should be done after *Collisions and Momentum in 1D* and should take students approximately 30 minutes. This is a more challenging activity that includes collisions in two-dimensions. Students may want to use a calculator during this activity.

2.0 Learning Goals

Driving Question: When objects collide in different situations, what happens?

This activity presents models of two balls colliding, three balls colliding, sticky collisions and offset collisions.

Step One: **Calculating Momentum** reviews the concept of total momentum of a system. Students practice calculating p_{total}.

Step Two: **Three Ball Game** presents the students with a mystery event that can be understood by using what they learned about conservation of momentum.

Step Three: **Inelastic Collisions** displays an inelastic collision, where the two balls stick together. Students are encouraged to test their existing momentum rules.

Step Four: **Collisions in Two Dimensions** allows students to observe that the same rules can be applied to the X and Y directions independently.

Additional Teacher Background

Momentum is of central importance in physics and working with it may be the first time that students work with a **derived** quantity, which is not measured directly. Rather, momentum is the product of two measurable quantities - mass and velocity. The activity helps them pay attention to the value of the product (mv) rather than the values of the components.

The reason momentum is so important is that momentum is **conserved**, meaning that the amount of momentum in a given direction is the same before and after an event. This rule helps with the solution to a great number of problems.

Momentum often seems to disappear. For instance, when a ball bounces on the ground it appears to change from mv to -mv because it reverses direction. Where did the 2mv go? In fact, the earth moved a little bit, but imperceptibly because it's so massive! When a car slows down, its decrease in momentum is exactly matched by an increase in the earth's momentum in the opposite direction. We trust the conservation of momentum to be true even when we can't measure it.

Energy and momentum are related, but they are not the same thing. Momentum (mv) is a vector in the same direction as the velocity. Kinetic energy ($1/2\ m\ v^2$) depends on the square of the velocity. It is a scalar quantity. It is not a vector and does not have direction. It also has other forms, such as potential energy and heat (see the *Energy* activity).

Students may be surprised that momentum is conserved even in inelastic collisions, such as when two balls stick together (step six). This may be confusing because the kinetic energy of the balls ($1/2\ m\ v^2$) is **not** conserved. Some of the energy is converted to heat when the balls collide. If this energy is included, total energy **is** conserved.

Another surprising thing is that both balls can have momentum but the **total** momentum of the system is still zero. Momentum is a vector, like force and velocity; the momentum of different objects can cancel each other.

Additional Activities

Collisions and momentum: Use two sonar rangers to explore the before-and-after velocities of low-friction carts. Try changing their relative masses and calculating the total momentum before and after the collision. Is momentum conserved? Try inelastic collisions, where the two carts stick together. Is momentum conserved then?

3.0 Standards Alignment

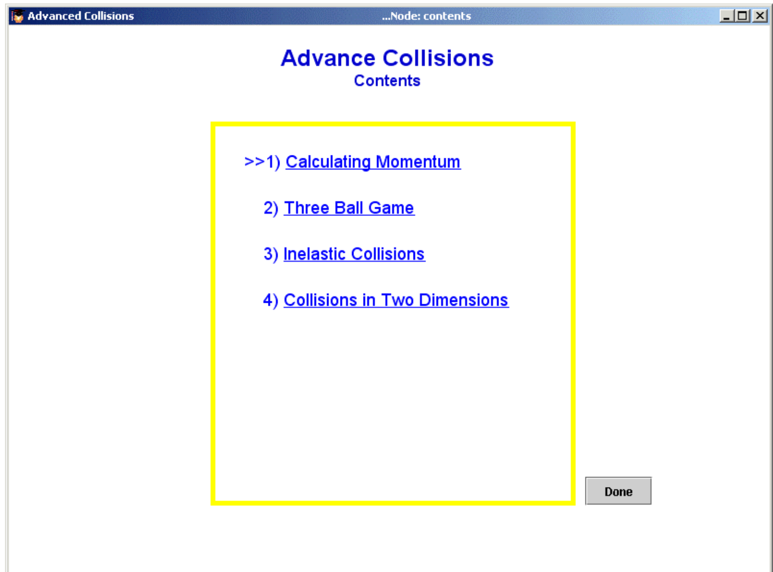
Alignment to National Math and Science Standards (NCTM or NSES)

Objective	Standards
Students will learn the definition of momentum as a vector quantity.	• Students should develop an understanding of properties of, and representations for, the addition and multiplication of vectors.
Students will calculate the momentum of moving objects.	• Students should interpret representations of functions of two variables. • Students should develop fluency in operations with real numbers, vectors, and matrices, using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.
Students will predict the outcome of an event and compare it with data from a simulation.	• Students should draw reasonable conclusions about a situation being modeled. • Students should recognize reasoning and proof as fundamental aspects of mathematics.
Students will use conservation of momentum to predict what happens when objects collide.	• Students should identify essential quantitative relationships in a situation and determine the class or classes of functions that might model the relationships. • Students should use the language of mathematics to express mathematical ideas precisely.
Students will compare elastic and inelastic collisions.	• Students should recognize and apply mathematics in contexts outside of mathematics.
Students will analyze X and Y components independently in two-dimensional collisions.	• Students should analyze precision, accuracy, and approximate error in measurement situations. • Students should select, apply, and translate among mathematical representations to solve problems.

4.0 Activity Sections

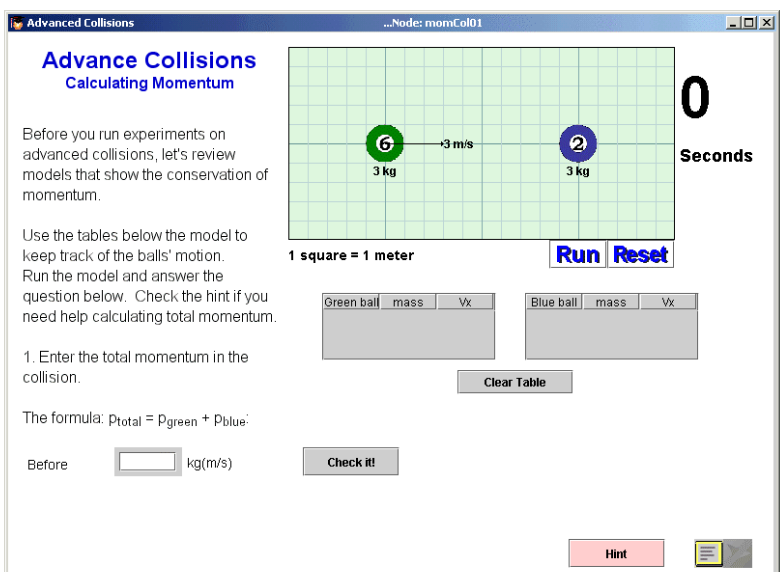
4.1 Table of Contents

This activity has 4 sections.

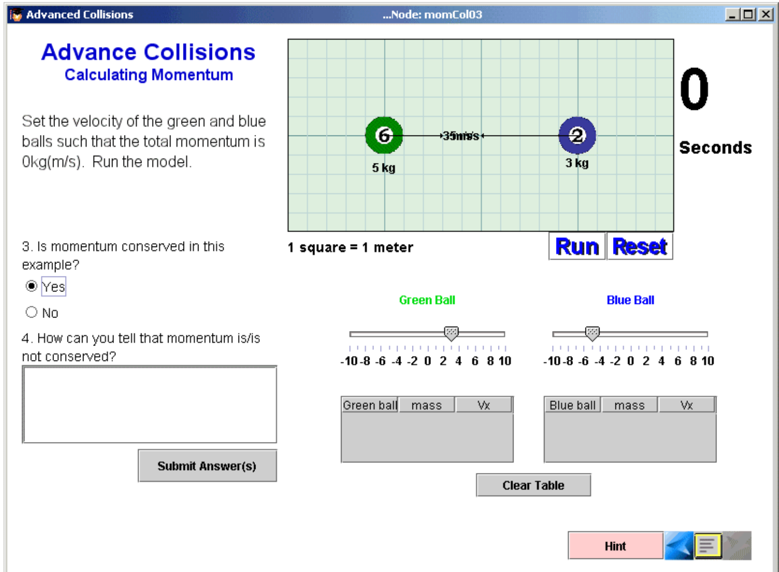


4.2 1) Calculating Momentum

In this section, students review how to calculate the total momentum of a system before and after a collision. Of course, the models depict a frictionless environment.



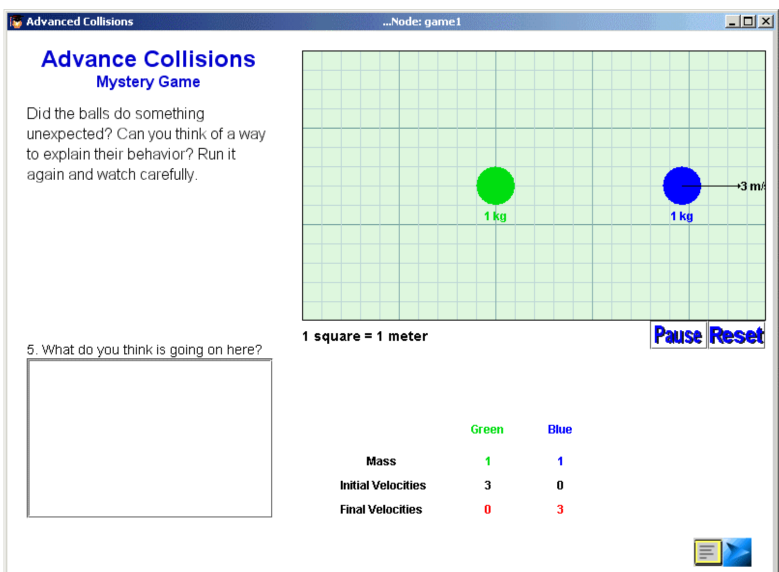
Calculate total momentum



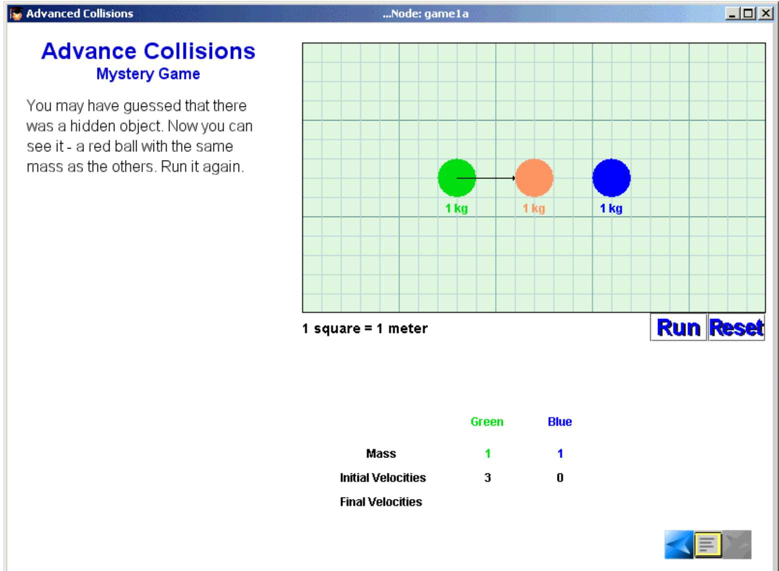
Setting the green ball to 3m/s and blue to –5m/s results in 0 momentum

4.3 2) Three Ball Game

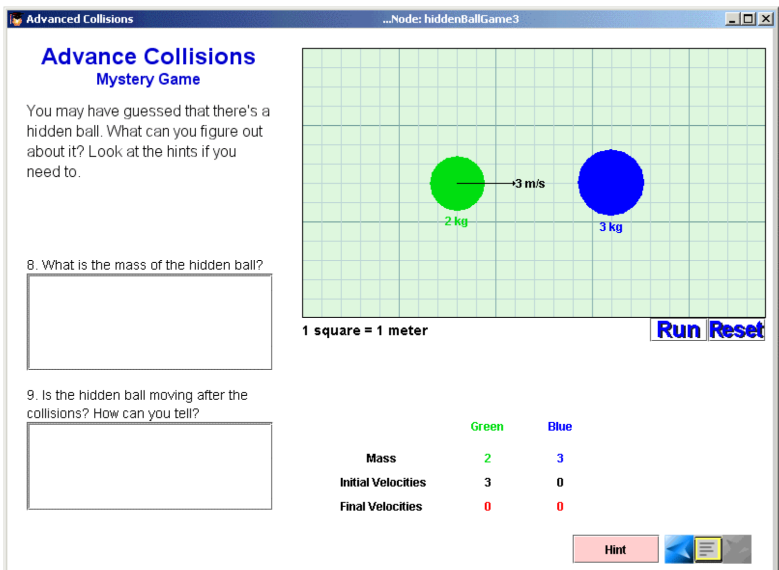
In this section, students run models of collisions with a "mystery" ball. This is a third, invisible ball.



Run the model and answer the question.



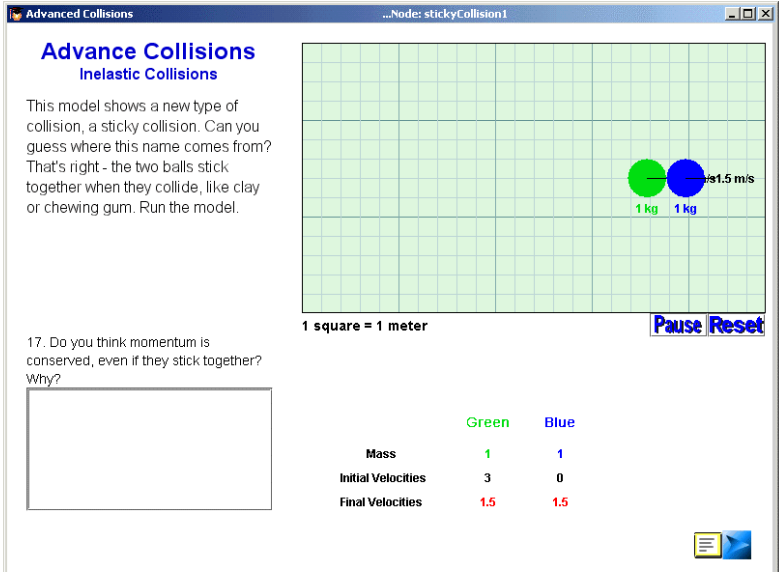
The mystery ball is revealed.



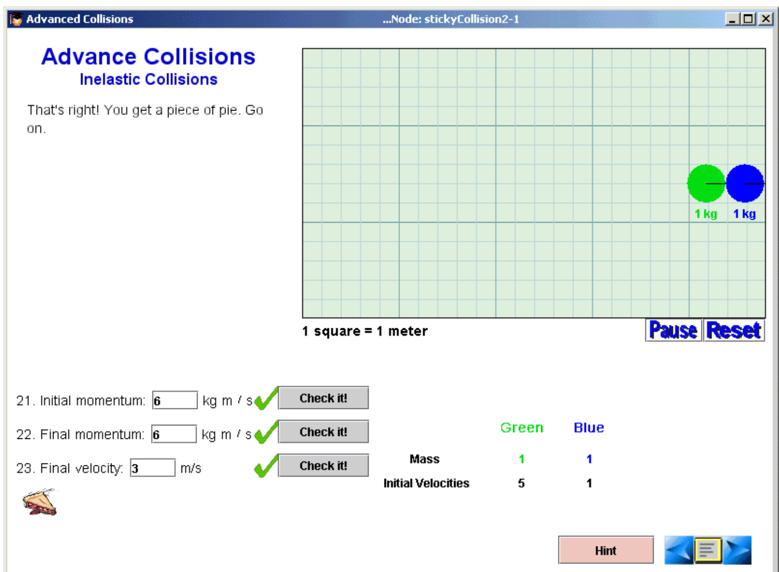
Another hidden ball example

4.4 3) Inelastic Collisions

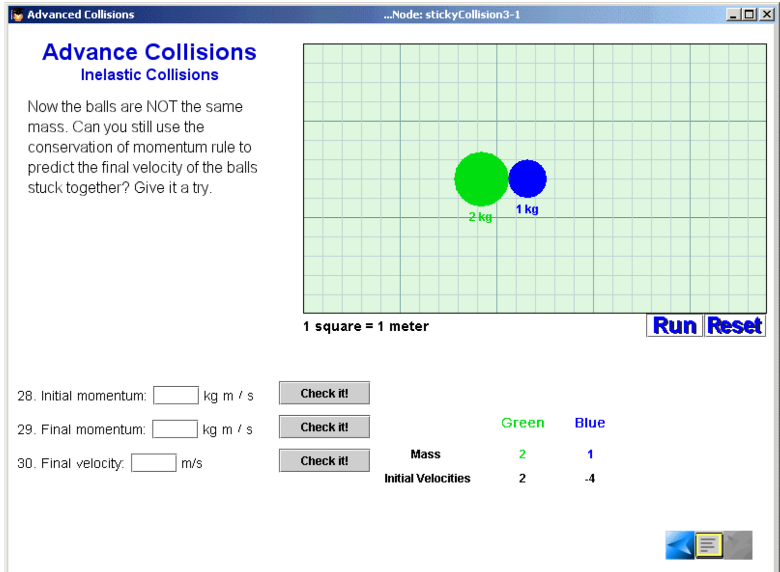
This section introduces students to totally inelastic collisions, or sticky collisions. Students are presented with a few different examples and are asked to calculate the initial and final momentum in a collision as well as the final velocity of the collision.



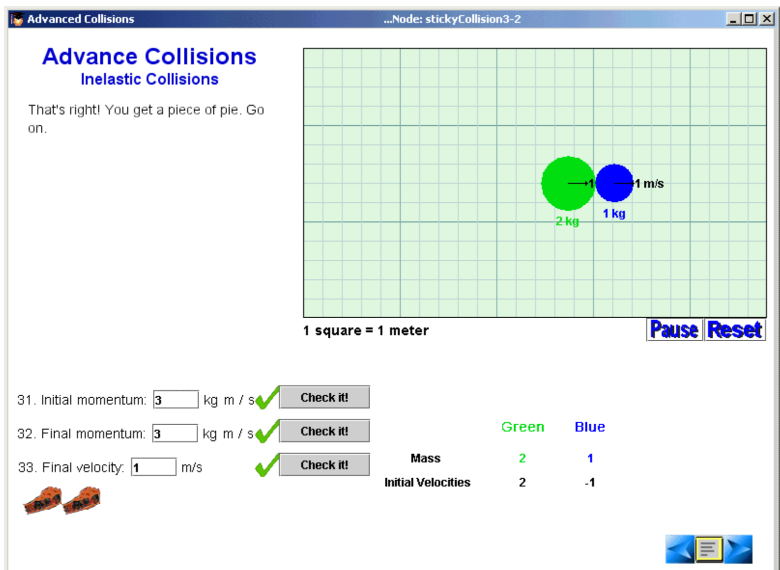
Conservation in a sticky collision



Calculate the final velocity.



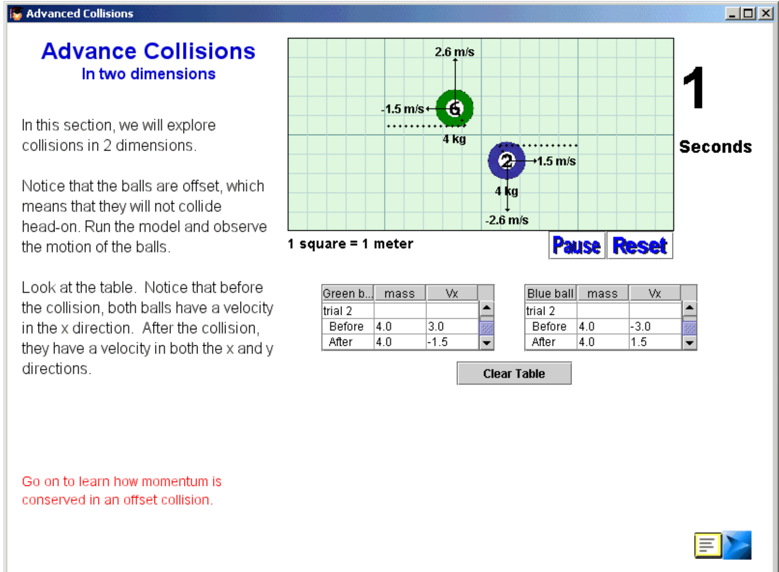
Balls of different mass



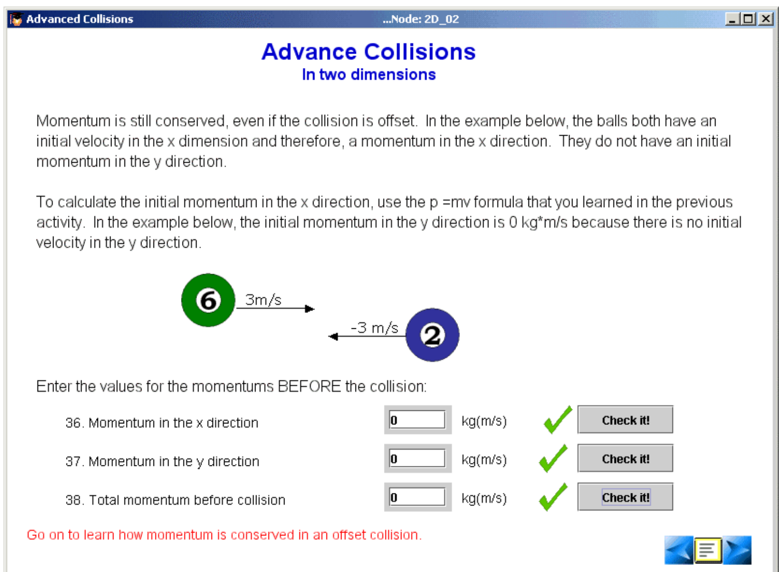
Final velocity is 1 m/s

4.5 4) Collisions in Two Dimensions

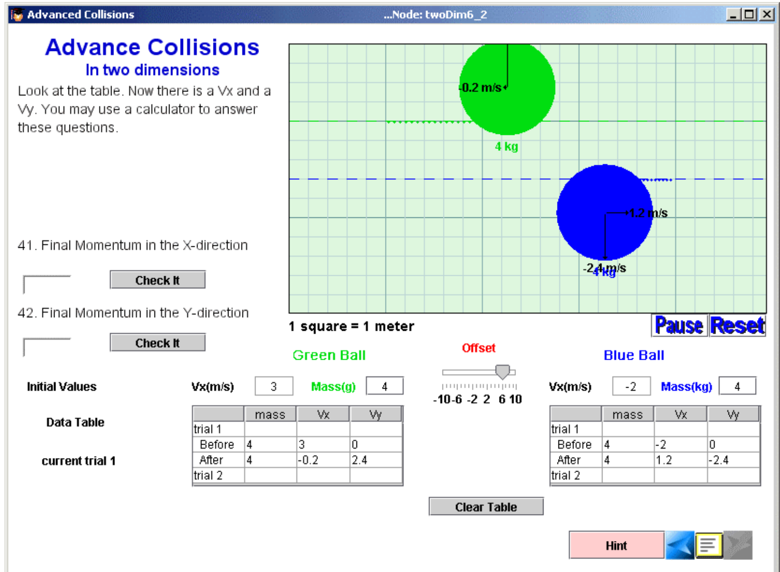
Offset collisions adhere to the Law of Conservation of Momentum. In this section, students will run models of 2D collisions where they can adjust the offset as well as the mass and velocity of the balls. Students are asked to compute momentum in both the x and y directions. A calculator may be used in this section. Students can also use the built in Windows calculator found in the Start menu, under Programs and Accessories.



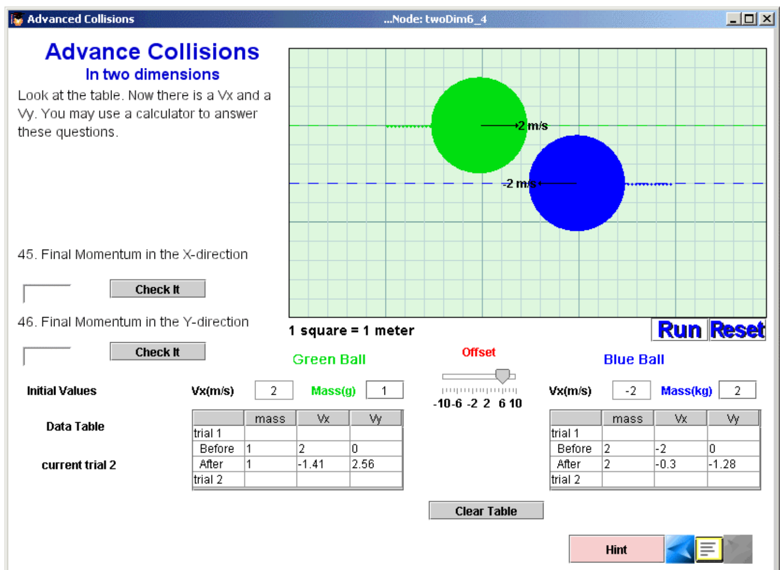
Data tables show velocity before and after the collisions.



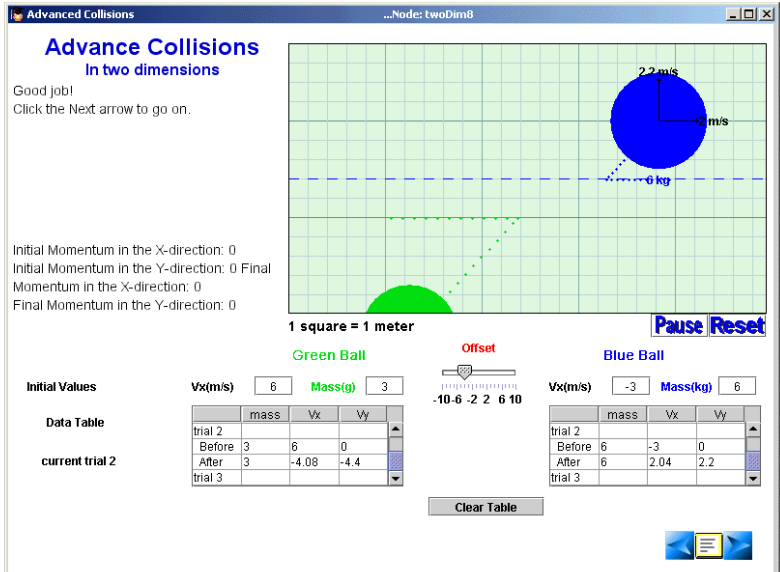
Introduction to momentum in the y-direction



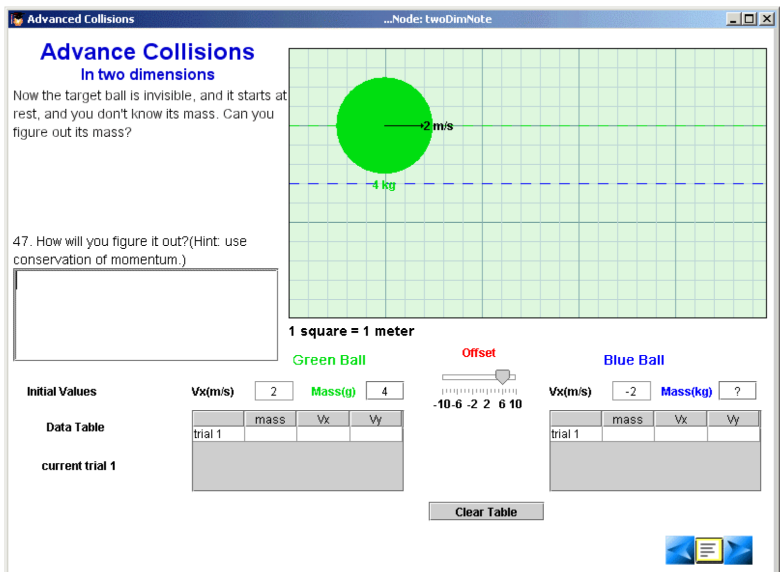
Use tables to calculate momentum in x and y directions.



Adjust the mass of the balls and calculate the final momentum.

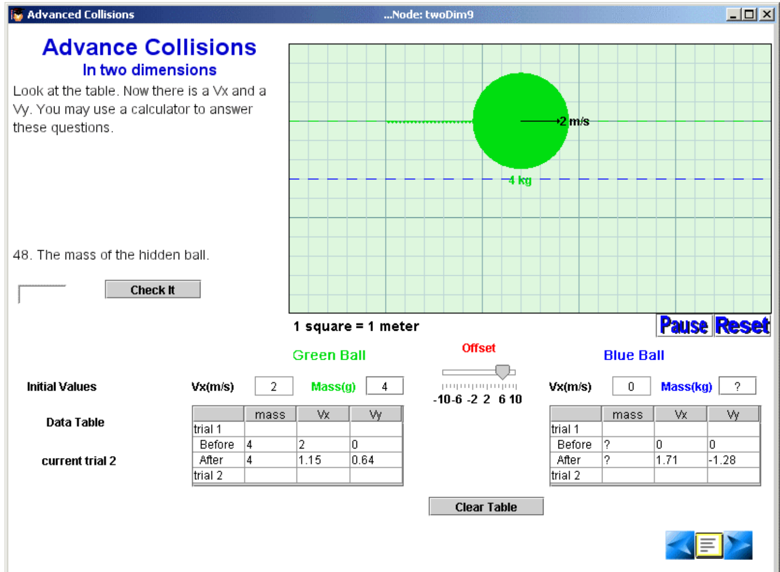


Set the model to have the same

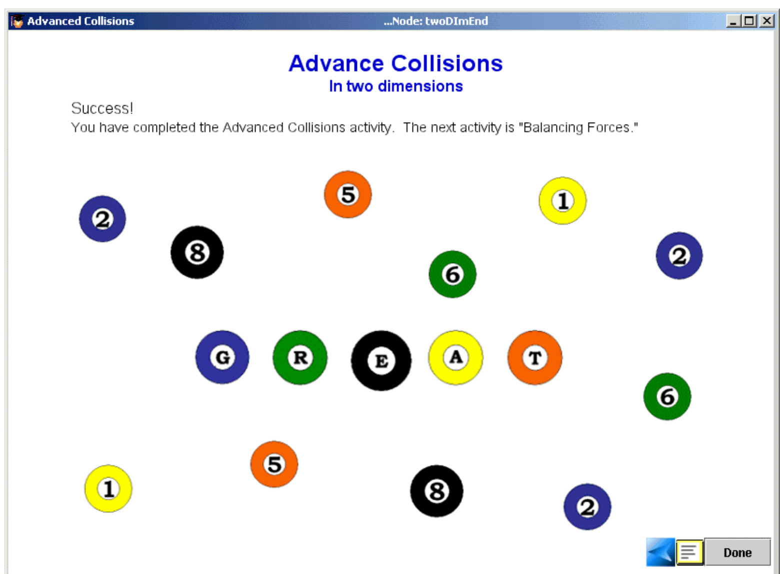


Now, the second ball is invisible with a mystery mass

The next problem is the biggest challenge. Students must calculate the mass of a ball based on the fact that the total momentum of the collision is the same before and after. In this example, the total initial momentum is 8. Use $p = mv$ to find that the mystery ball is 2kg.



Use the p=mv formula to calculate the mass.



Final screen of activity

5.0 Student Reports

Your students' work with the *Advanced Collisions* activity is logged and viewable on the MAC Project Web Portal at http://mac.concord.org. For each student, you can view a report containing questions and student answers.

The next activity in the sequence should be *Balancing Forces*.