Forces in Two Dimensions

Teacher's Guide

1.0 Summary

"Forces in Two Dimensions" is the sixth activity in the Dynamica sequence. This activity should be done after Balancing Force and it should take students approximately 45 minutes.

2.0 Learning Goals

Driving Question: How do forces in more than one direction affect the motion of objects?

The previous activities looked at the effect of forces along only one dimension, that is, just to the left or right. But forces act in all directions. For example, when you kick a ball through the air, you hit it sideways, gravity pulls it downward, and air resistance pushes against it. This activity will illustrate how the motion and forces along each axis can be studied independently in order to understand a two-dimensional trajectory. For instance, forces in the X direction do not affect motion in the Y direction.

Step One: **Introduction** has a ball that makes distance and velocity graphs in both the X and the Y directions. It demonstrates that forces in the Y direction affect the Y velocity but not the X velocity.

Step Two: **Sideways Forces** is another exercise in observing that motion graphs in the X direction and the Y direction can be studied independently.

Step Three: **Frisbee Practice** is a game section where students figure out the direction of velocities and forces.

Step Four: **Turning Corners** is a challenge where students must apply a force to an object so that it turns 90 degrees.

Step Five: **Basketball** is a game section where students supply the velocity vectors needed to launch a ball into a basket.

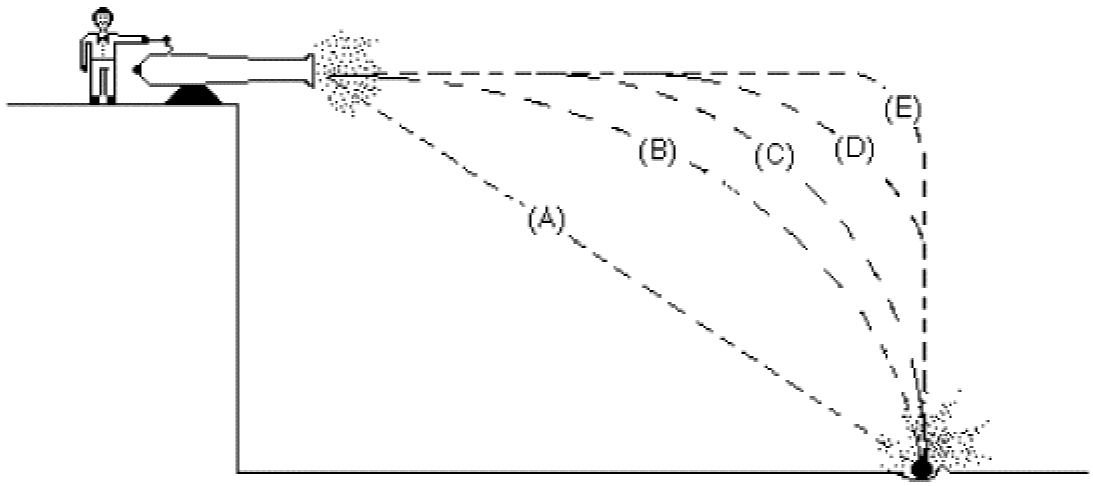
Step Six: **Hidden forces** challenge students to infer forces from the appearance of graphs.

Step Seven: **Lab** provides a "space" where students can experiment on their own or complete exercises provided by the teacher.

Additional Teacher Background

This activity is like the motion graphs activity but in two directions. The independence of X and Y, whether for displacement, velocity, or force, is a powerful tool in physics because it simplifies the analysis. The pair of graphs encourages the student to distinguish between motion in the Y direction and motion in the X direction.

Many students think that if a rolling ball is hit sideways, it will make a right turn, rather than going at a diagonal; the **same** X velocity and some **new** Y velocity. Another common misconception (which will be addressed again in **Gravity**) is that a ball that is rolled off a table edge will go at a diagonal (A), or straight out, then down (E).



In fact, it goes in an arc (D), which is the combination of its continuing, unchanged horizontal velocity and its gravitational acceleration downward.

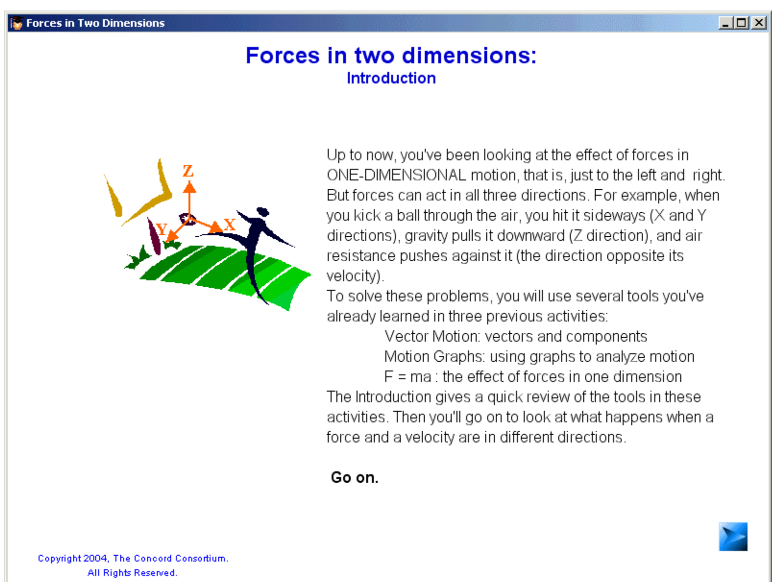
Additional Activities

Force Table - This is a common piece of equipment in physics labs, but it could be improvised. A circular table has pulleys mounted at the edges, with weights on strings. The strings are joined in the middle, and the goal is to have them be balanced so that the central knot stays in the same place. The weights and angles can be adjusted to match the computer activity, or the computer activity can model the physical experiment. Spring scales or force probes can replace weights. The forces become more vivid if students can use force probes to pull on strings connected to a central point.

3.0 Standards Alignment

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

Objective	Standards
Students will analyze two-dimensional forces in terms of independent X and Y components	• Students should understand vectors as systems that have some of the properties of the real-number system. • Students should select, apply, and translate among mathematical representations to solve problems;
Students will predict the forces that are needed to make objects follow various trajectories	• Students should use the language of mathematics to express mathematical ideas precisely. • Students should use Cartesian coordinates to analyze geometric situations.
Students will understand the correspondence between the motion of objects and velocity-time graphs	• Students should recognize and apply mathematics in contexts outside of mathematics.

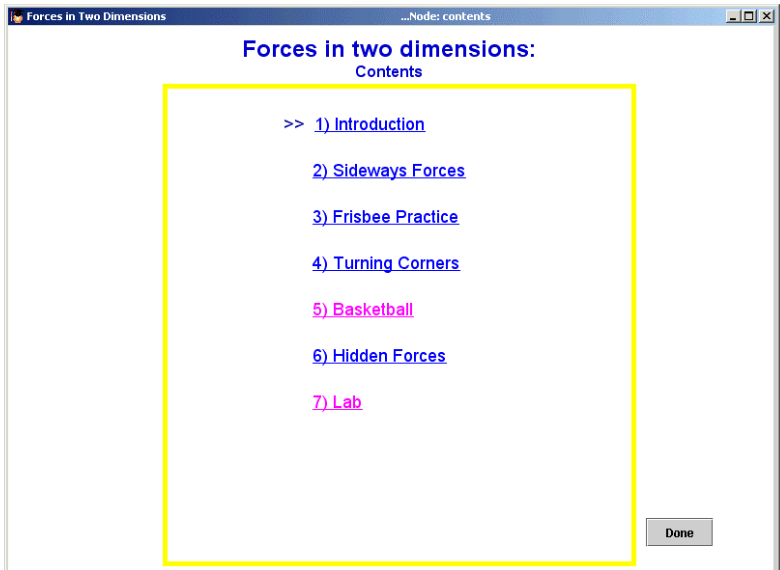


Opening screen

4.0 Activity Sections

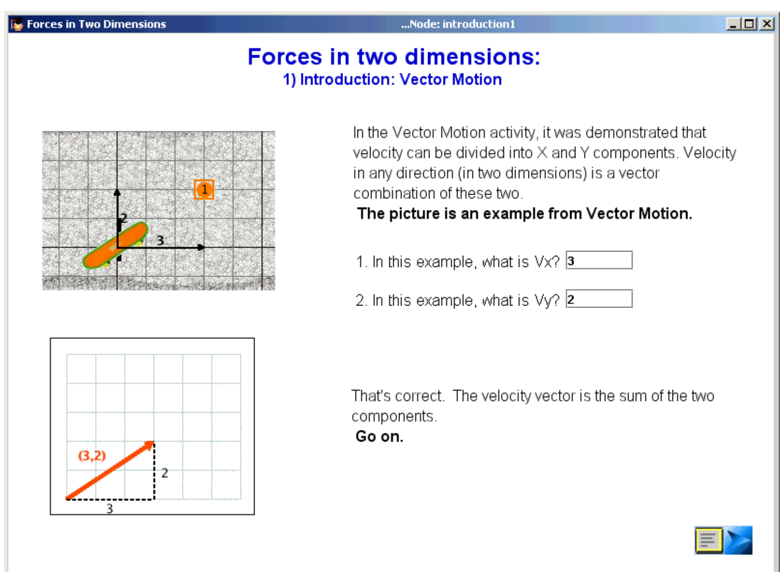
4.1 Table of Contents

This activity has 7 sections. The required sections of this activity are sections 1 through 6. The last section is a "Lab" where teachers may assign students custom experiments.

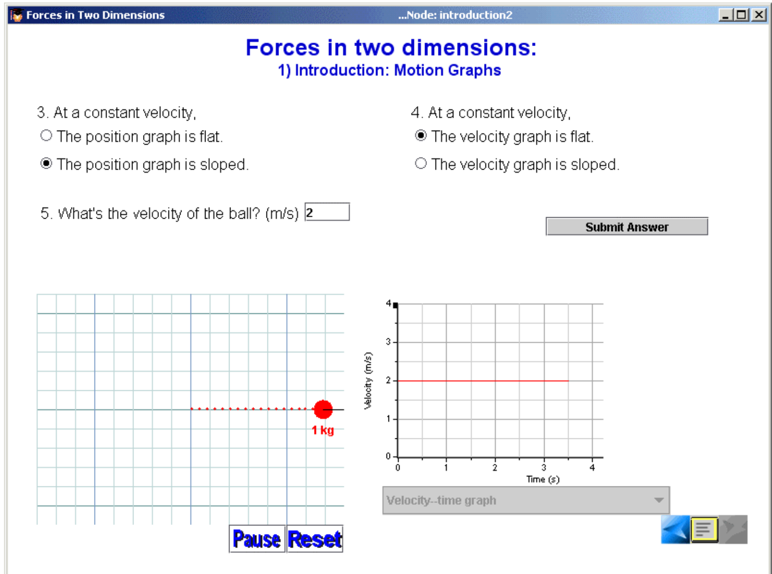


4.2 1) Introduction

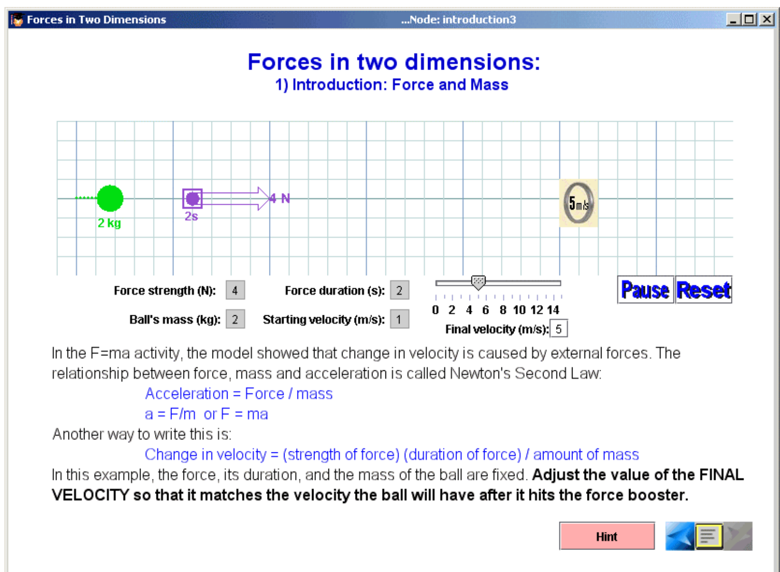
The introduction in Force in Two Dimensions is really a review of some of the concepts that students learned in the Vector Motion, Motion Graphs and F=ma activities.



Review of Vector Motion



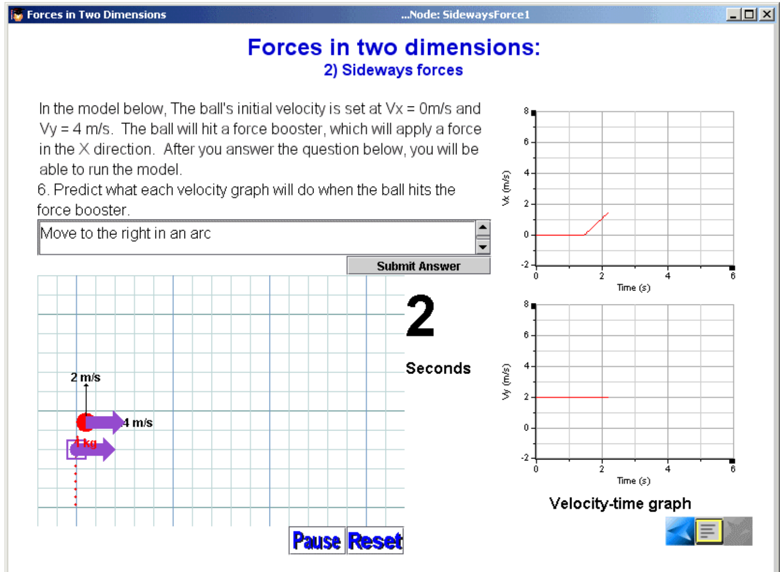
Review of Motion Graphs



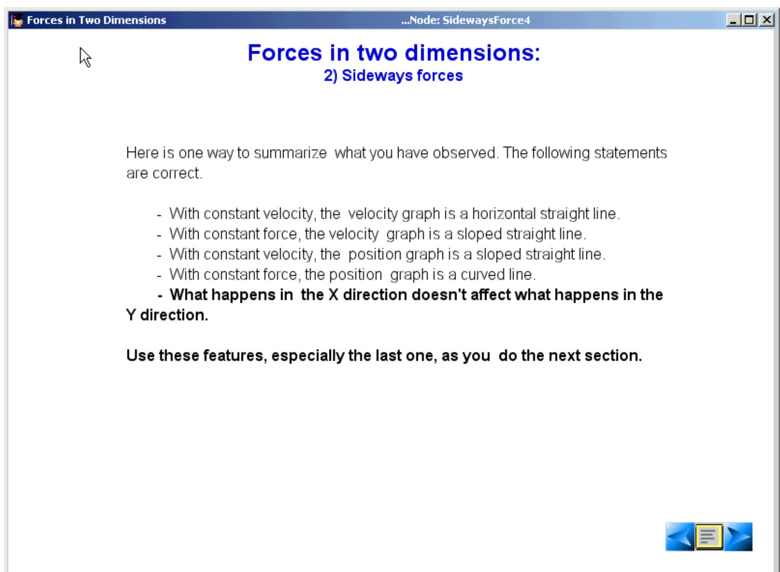
To move past this screen, students must set the slider to 5

4.3 2) Sideways Forces

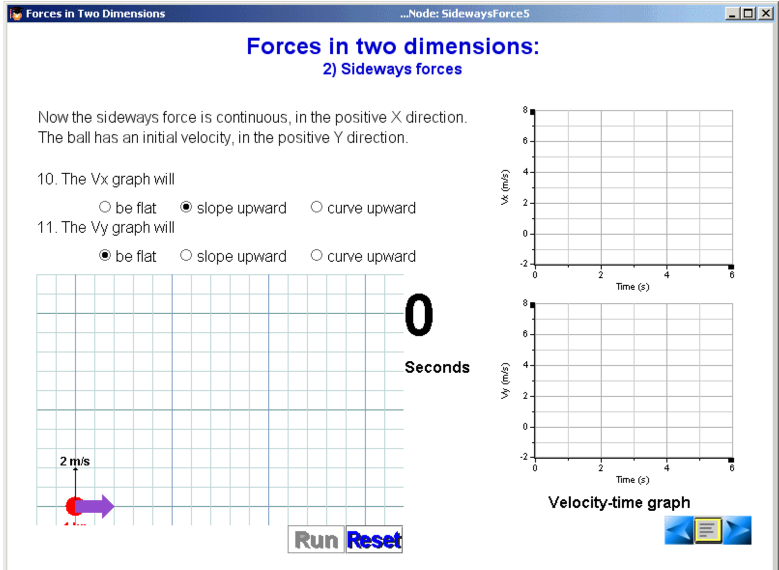
In this section, students are introduced to objects moving in one direction that encounter a force that moves them in a different direction. There are two additional examples in this section that emphasize the independence of the velocity in each direction. For example, in the peashooter game, a shot pea and a dropped pea have the same y velocity but a different x velocity.



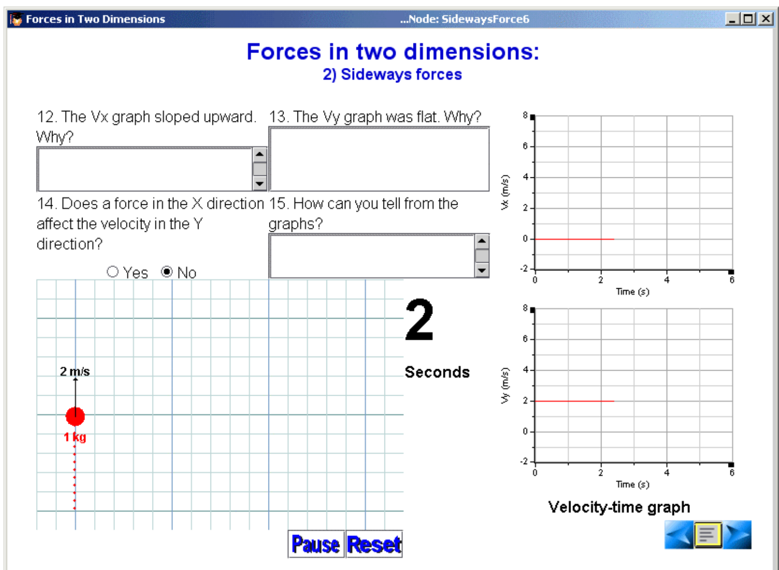
Run the model and examine the graphs



Students should think about the independence of
forces and velocities in each direction for the remainder of this section

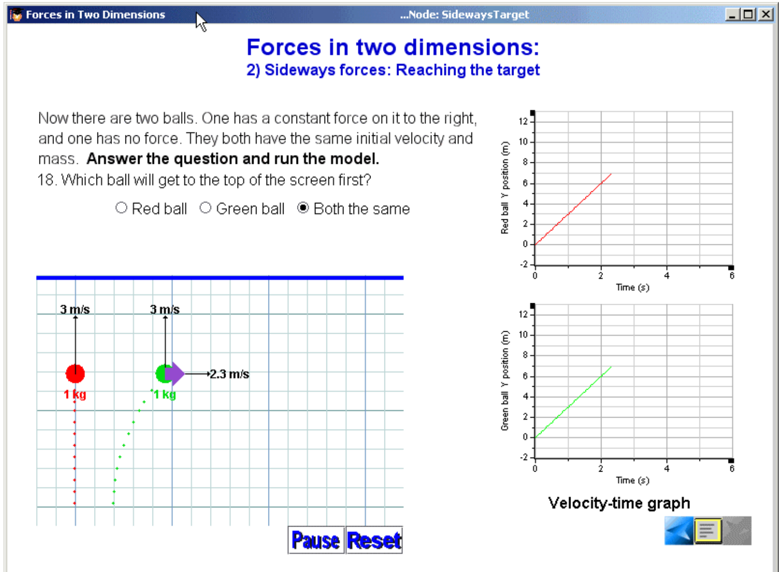


Students are asked to predict what the graphs will look like

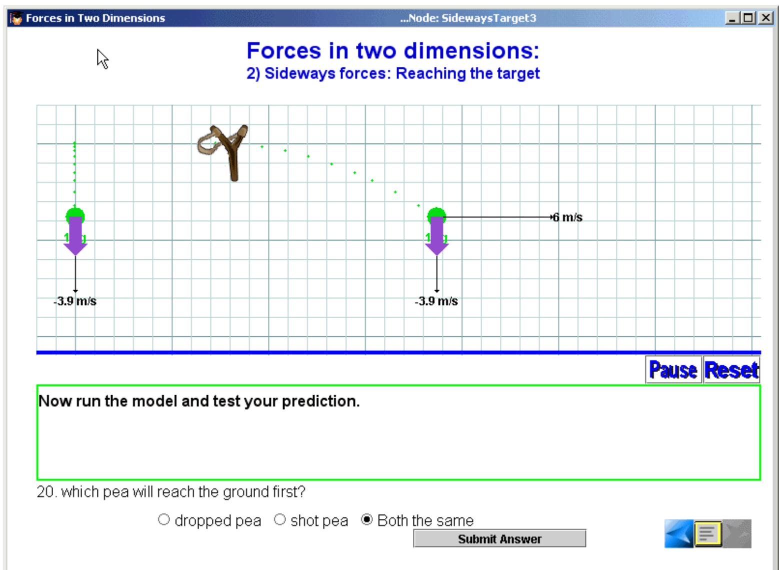


Students are asked to explain the relationship between the model and the resulting graphs

In the next two games, students are asked to predict the action of two objects. In the first game, students are asked to predict if both balls, each with the same Vx but a different horizontal force will reach the top at the same time. In the second game, the peashooter, students drop a pea and shoot a pea from the same height. They are asked to predict which pea will hit the ground first.



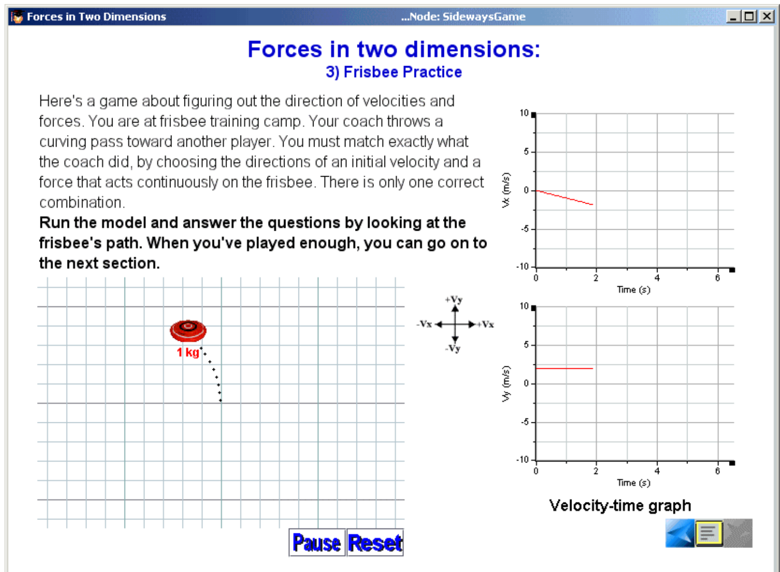
The student can adjust the force of the green ball



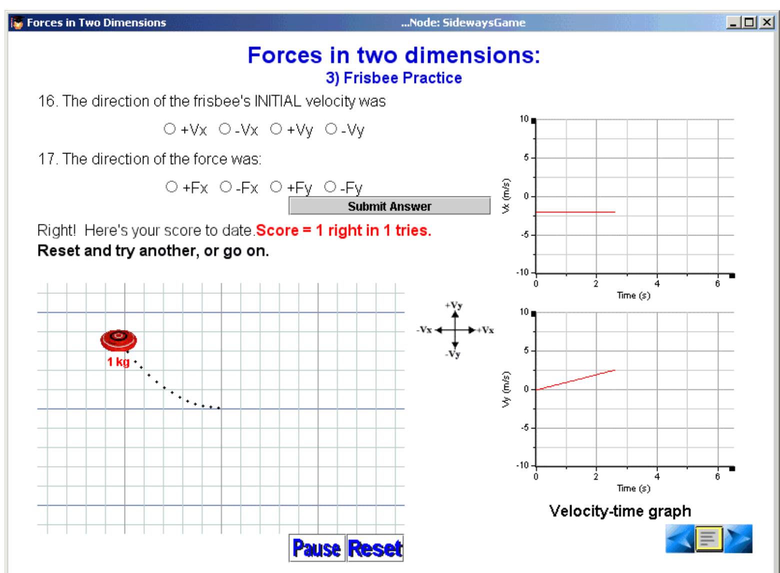
Both peas will hit the ground at the same time

4.4 3) Frisbee Practice

This section helps students better understand the relationship between the initial velocity of an object and a force acting in a different direction. Students indicate the direction of a frisbee's initial velocity and the direction of the force. The direction and velocity of the Frisbee is chosen randomly so each student will have a slightly different model.



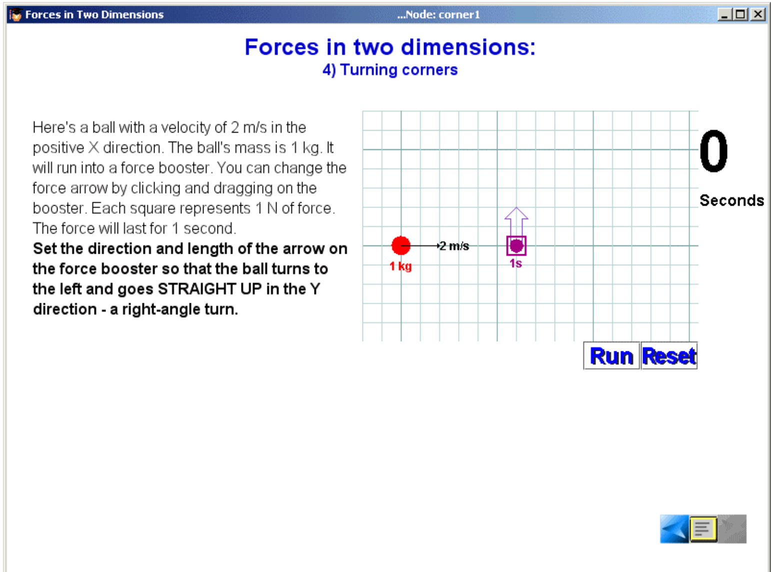
Students run graph of a frisbee being thrown



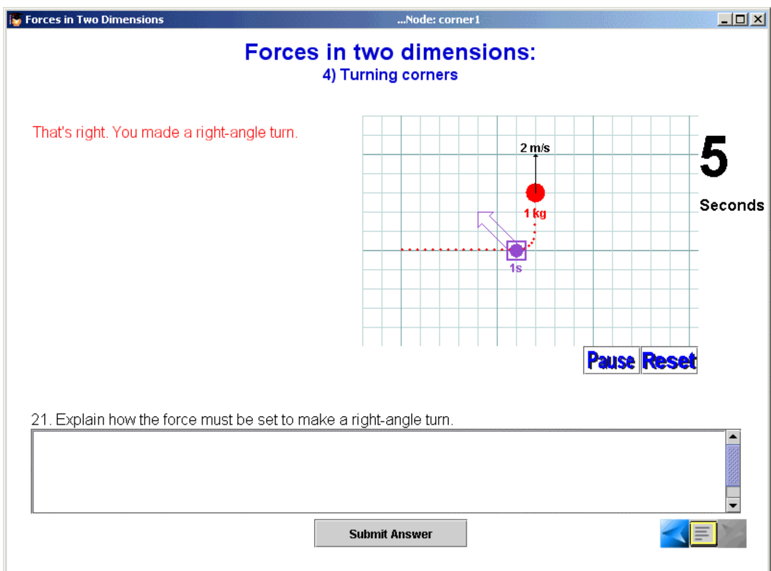
Student selects the direction of the frisbee's initial velocity and the applied force

4.5 4) Turning Corners

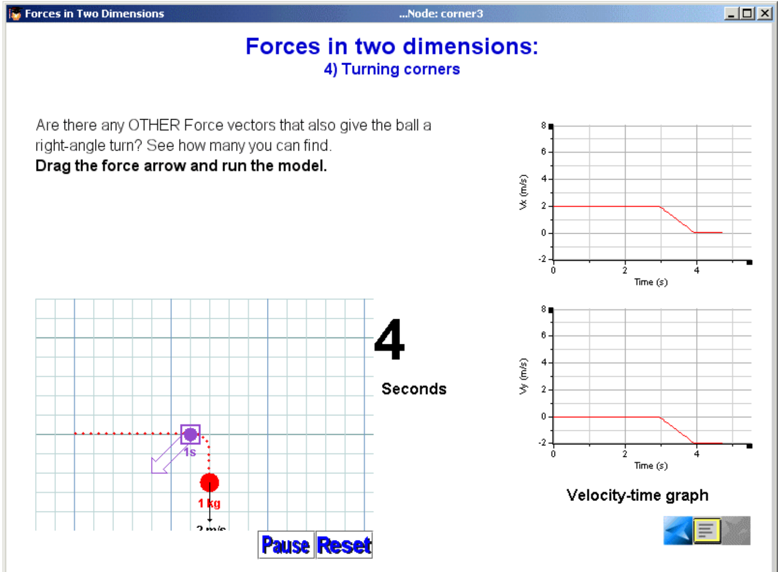
Turning Corners asks students to apply a force such that a ball turns and moves 90 degrees from the original path. The student must find two different forces that allow this to occur.



Students are asked to adjust the force arrow such that the ball makes a 90 degree turn



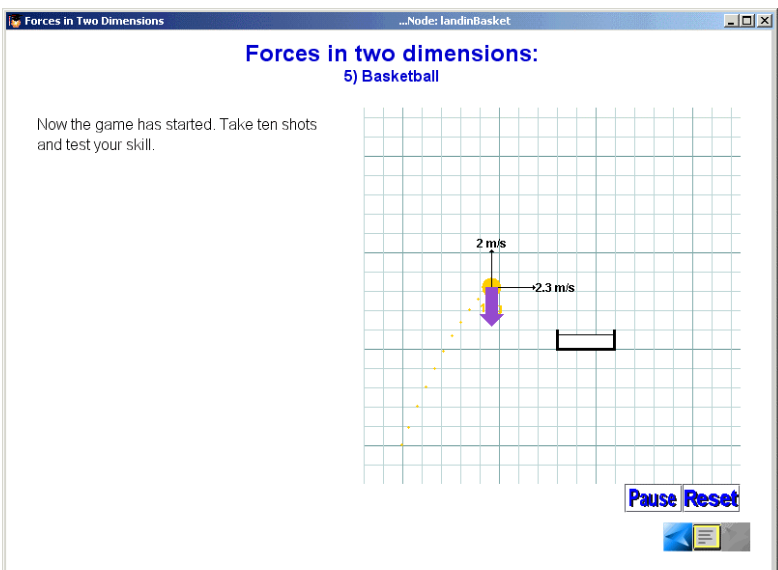
Free response question to assess understanding



Student must then solve the problem in a different way

4.6 5) Basketball

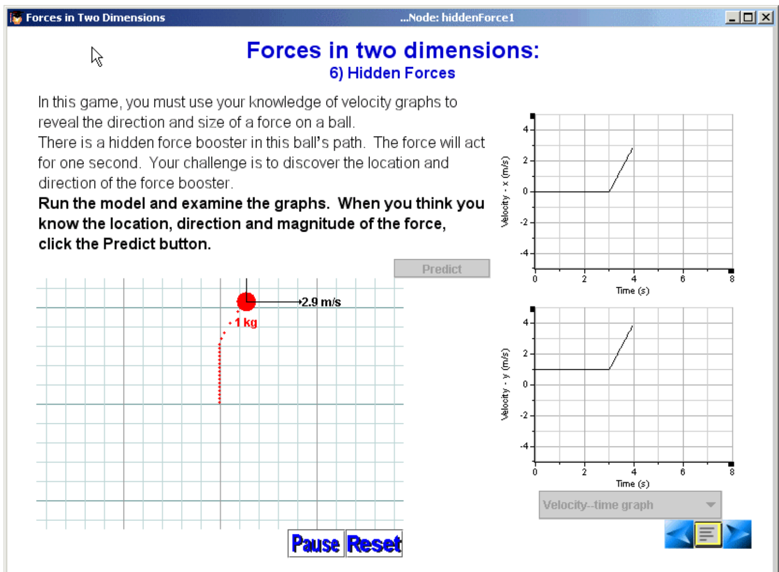
The Basketball game gives students 10 tries to shoot a basket. Students apply an initial velocity in the x and y directions to the ball. The ball also has the force of gravity acting upon it (there is a force arrow already on the ball). The basket location is generated randomly, so each student will have a different solution to this game. In fact, multiple solutions will work with each basket location.



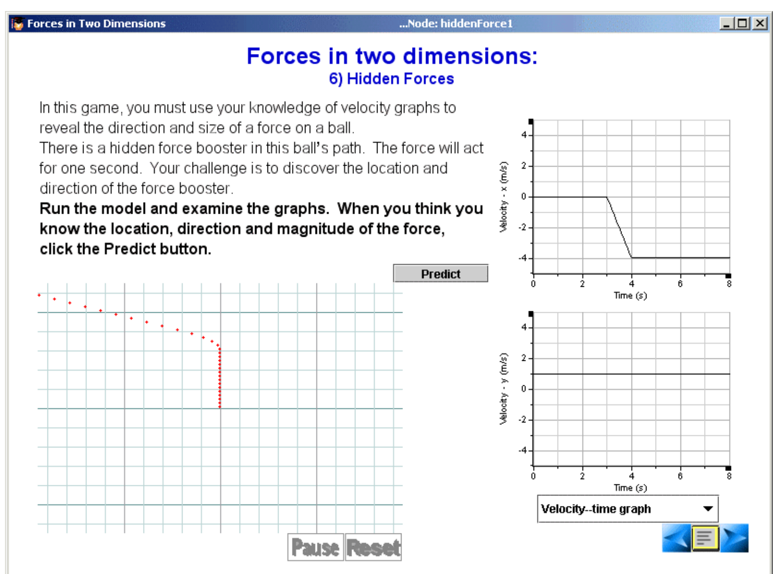
The student has 10 chances to make a basket

4.7 6) Hidden Forces

Students run a model where a ball encounters a hidden force and is moved from its original path. Using the model and the graphs as a guide, students must determine the location, magnitude and direction of the force. This model is generated randomly, so each student will have a different force location and magnitude. The force booster is hidden but the student can gather information from the graphs

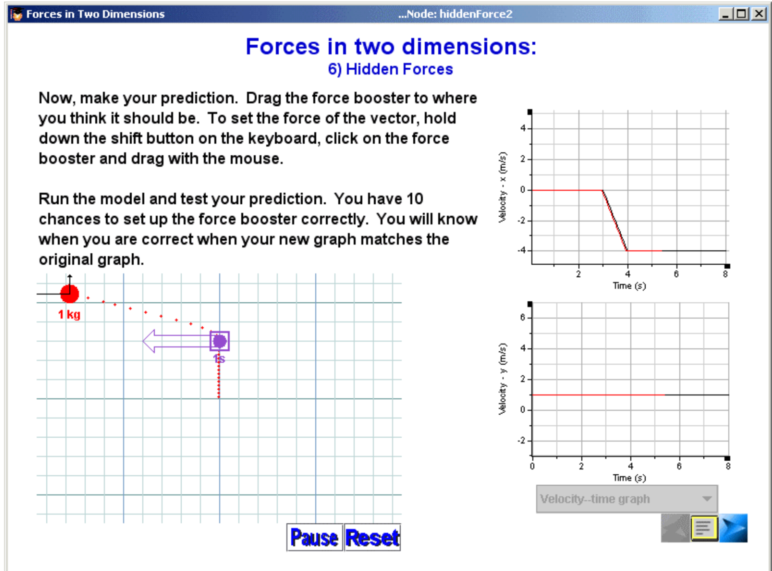


The ball moves as though it encountered a booster



A different booster configuration

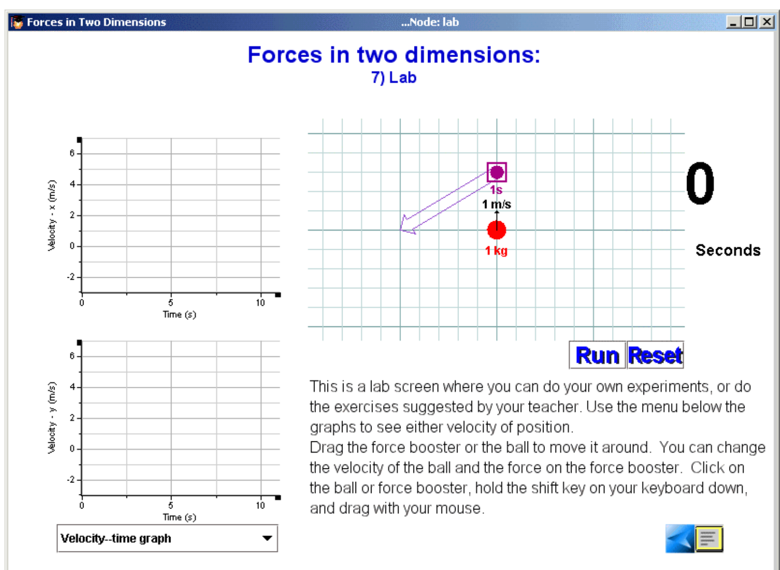
The student should click the Predict button to move to the next screen. Once the student is in the prediction screen, s/he should adjust the booster to replicate the action of the hidden force. The student can click and drag on the graphs to move them around and see how the velocity of the ball changes over time. To add force to the booster, shift-click and drag on it. The following is a successful run as illustrated by the red line on the graph following the original black line.



Successful attempt at matching the hidden force

4.8 7) Lab

The Lab section of the Force in Two Dimensions activity allows students to set up their own experiments using one ball and one force booster. The student can move and adjust the objects on the screen. Clicking and dragging on the force booster will change the force arrow. Velocity vectors can be added to the ball by holding the shift key down while clicking and dragging on the ball.



Move the force vector and drag the force arrow,
shift-click on the ball to add a velocity vector

5.0 Student Reports

Your students' work with the Forces in Two Dimensions 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 Collisions and Momentum in 1D.