1.0 Summary

"Balancing Forces" is the eighth activity in the Dynamica sequence. This activity should be done after Advanced Collisions and it should take students approximately 45 minutes. This activity has been shortened and revised for the 2004-2005 school year.

2.0 Learning Goals

Driving Question: What happens when many forces act on the same object?

This activity models several situations where there are multiple forces acting on an object at the same time.

Step One: **Introduction** provides simple situations for students to add force vectors to objects that are supposed to be at rest. For example, a ball that is sitting on a table has the force of gravity acting upon it, but it also has the force of the table pushing up.

Step Two: **Balanced forces** gives students multiple opportunities to apply forces on the same object so that the object will remain still. The magnitude of each force vector is recorded in table format to scaffold the student's understanding.

Step Three: **Unbalanced forces** illustrates what happens when the net force on an object is not zero. Students manipulate forces to achieve different goals.

Step Four: **Tip To Tail** allows students to find the resultant of several forces by using a standard geometric representation of vector addition by drawing vectors tip to tail and observing the total displacement.

Step Five: **Real World Examples** presents opportunities for students to compose free body diagrams of real situations, such as someone on a swing and a boat moving through the water. In each case, the solution can be tested immediately and modified if necessary. In the boat example, students see how forces can be balanced while an object is moving at a constant velocity.

Additional Teacher Background

This activity is built around force diagrams. The key concept is **net force**, which is the sum of all the external forces acting on an object. If the net force is zero, the object will stay at a constant velocity (including zero velocity). If the net force is not zero, the object will accelerate in the direction of the force. To predict an object's motion, one doesn't need to know what or how many forces there are; only the net force matters.

In order to find the net force, force vectors are summed just like displacement and velocity vectors. The math is exactly the same, even though the quantities seem quite different.

They can be added geometrically (tip to tail) or by summing the X and Y components separately.

Students often want to include both internal and external forces in their diagrams. For example, a soda bottle may have a large internal pressure resisted by the walls, but neither of these are external forces that would cause the soda bottle to move. Since this model only deals with external forces, it is an opportunity to explore the distinction and ask whether the model is legitimate if it "leaves things out."

Although Newton's Third Law (for each action there is an equal and opposite reaction) isn't explicitly displayed in this model, it is important to bring up a key distinction. "Action = reaction" refers to the forces that two **different objects** exert on each other. If object A and object B interact, the force object A exerts on B is equal and opposite to the force object B exerts on A. These two forces are on two different objects (A and B). The Balancing Forces activity puts external forces on the **same object**, adds them up, and looks at the result of the net force.

For example, if I push on a cart, the cart pushes back on me with exactly the same force (opposing forces on two different objects). If the force I exert on the cart is greater than the resisting friction force, the net force on the cart is not zero (sum of forces on the same object), and the cart will accelerate. If my pushing force exactly equals the force of friction, the net force on the cart is zero, and the cart will move at a constant speed.

Additional Activities

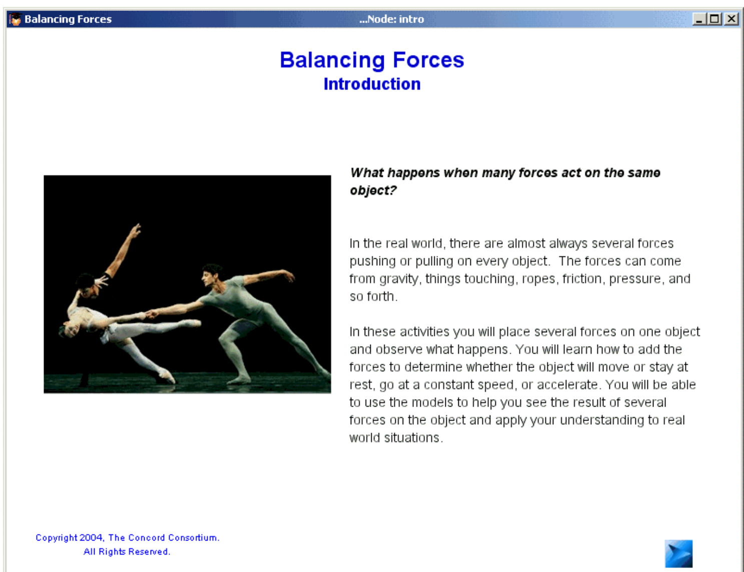
Force Table - This is a common piece of equipment in physics labs, but it could be improvised. A circular table has pulleys mounted at the edges, with weights on strings. The strings are joined in the middle, and the goal is to have them be balanced so that the central knot stays in the same place. The 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.

3.0 Standards Alignment

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

Objective	Standards
Students will be able to combine vectors both geometrically and numerically.	• Students should understand the properties of, and representations for, the addition and multiplication of vectors. • 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 should use Cartesian coordinates to analyze geometric situations.
Students will understand the meaning of "balanced" and "net" forces.	• Students should recognize and apply mathematics in contexts outside of mathematics. • Students should understand that objects change their motion only when a net force is applied.
Students will understand why force vectors that make a closed figure add up to zero.	• Students should judge the meaning, utility, and reasonableness of the results of symbol manipulations, including those carried out by technology. • Students should recognize reasoning and proof as fundamental aspects of mathematics. • Students should use geometric models to gain insights into, and answer questions in, other areas of mathematics.
Students will determine the net force resulting from several other forces.	• Students should develop fluency in operations with real numbers and vectors using mental computation or paper-and-pencil calculations for simple cases and technology for more-complicated cases.
Students will understand that objects with balanced forces do not change velocity and objects with unbalanced forces accelerate.	• Students should understand that objects change their motion only when a net force is applied.

Students will analyze the forces acting on everyday objects.	• Students should understand whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object. • Students should judge the meaning, utility, and reasonableness of the results of symbol manipulations, including those carried out by technology. • Students should recognize and apply mathematics in contexts outside of mathematics.

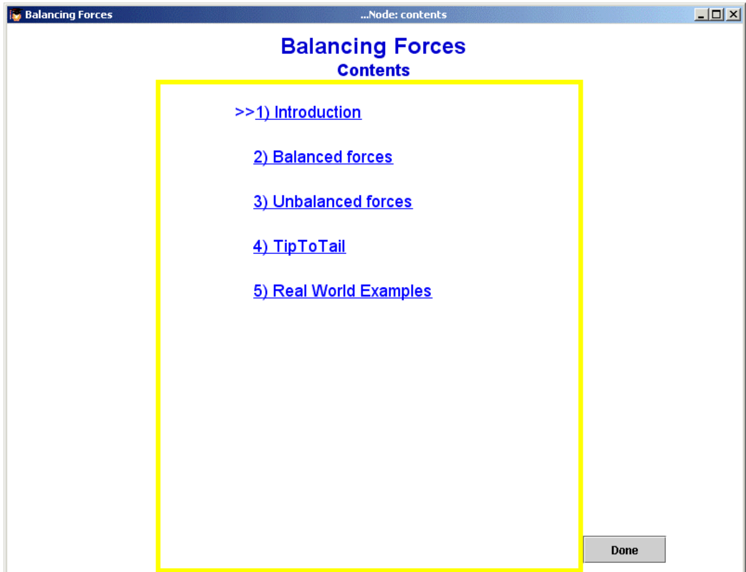


Introduction Screen

4.0 Activity Sections

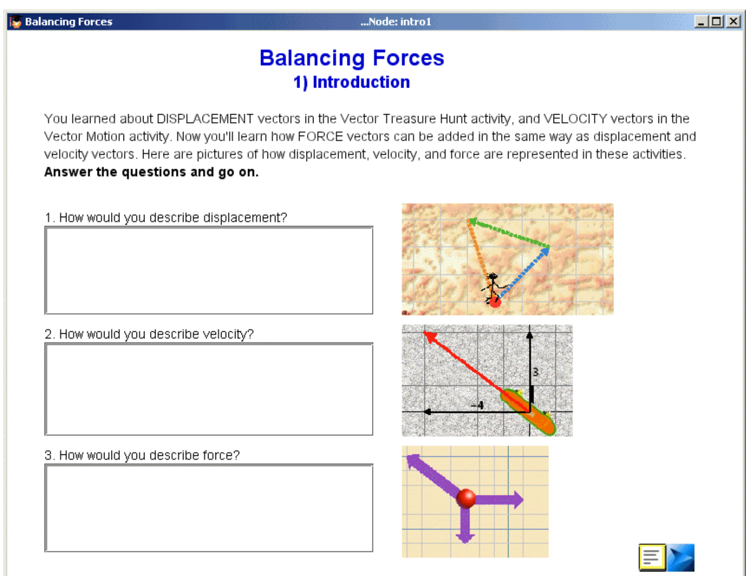
4.1 Table of Contents

This activity has 5 sections.



4.2 1) Introduction

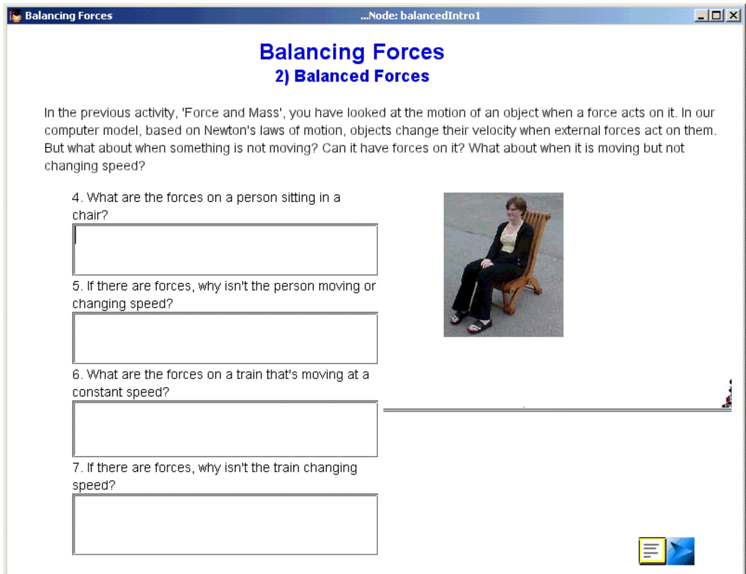
Students review vectors and displacement with examples from prior activities.



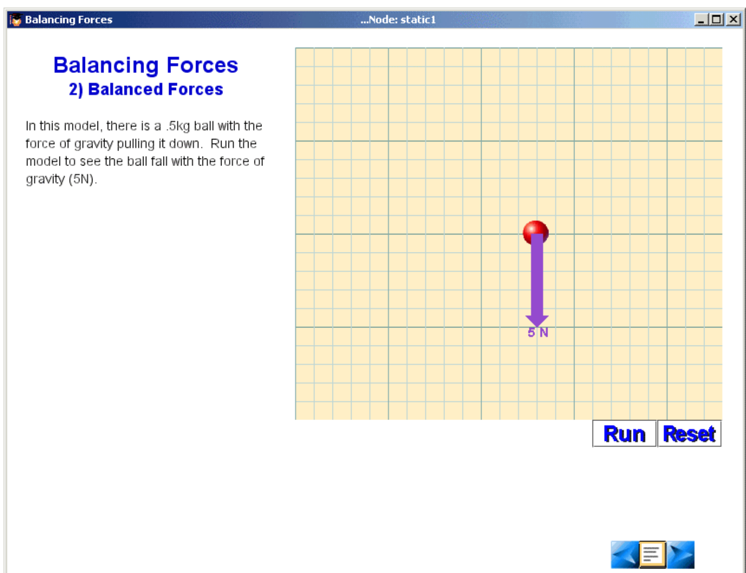
Review of vectors

4.3 2) Balanced Forces

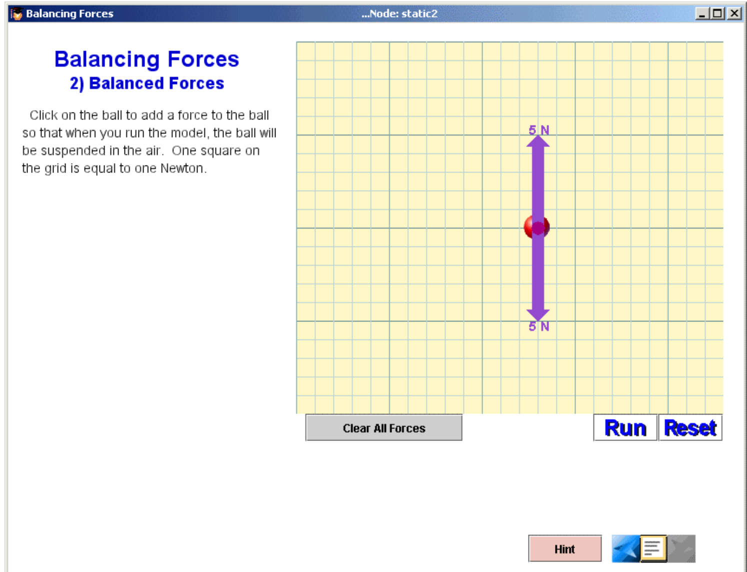
The introduction to Balancing Forces builds on the student's practical knowledge of the force of gravity. This section introduces the concept of equal and opposite forces such as a ball resting on a table. The ball has multiple forces acting upon it, but it is not moving. That is because the forces are balanced, or the net force is equal to 0 Newtons.



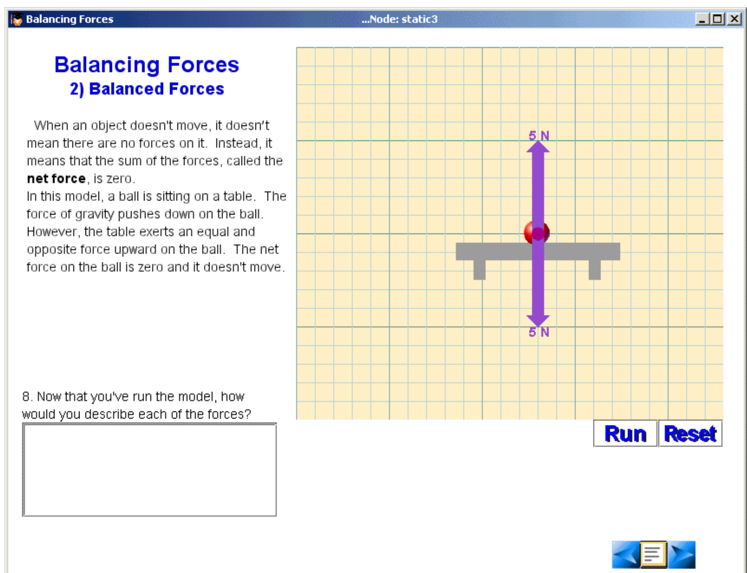
Thinking about balancing forces



Students are asked to predict what the graphs will look like

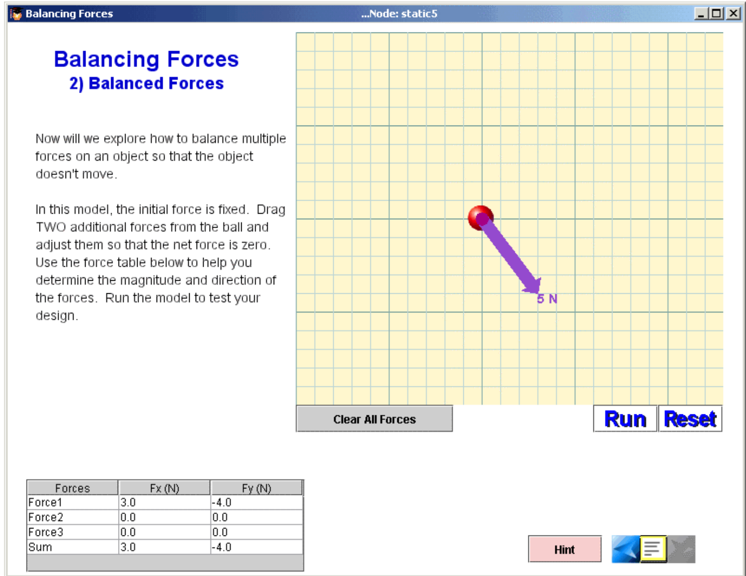


A force arrow of 5N to counteract the force of gravity

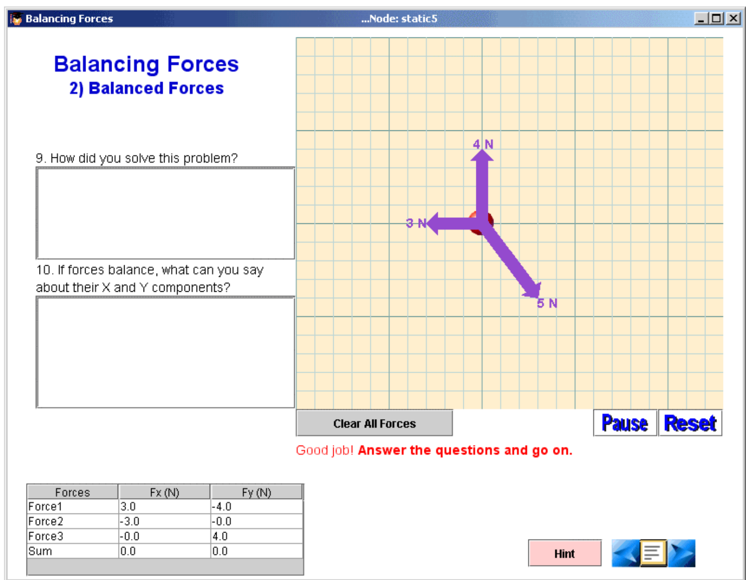


Equal and opposite forces in the model

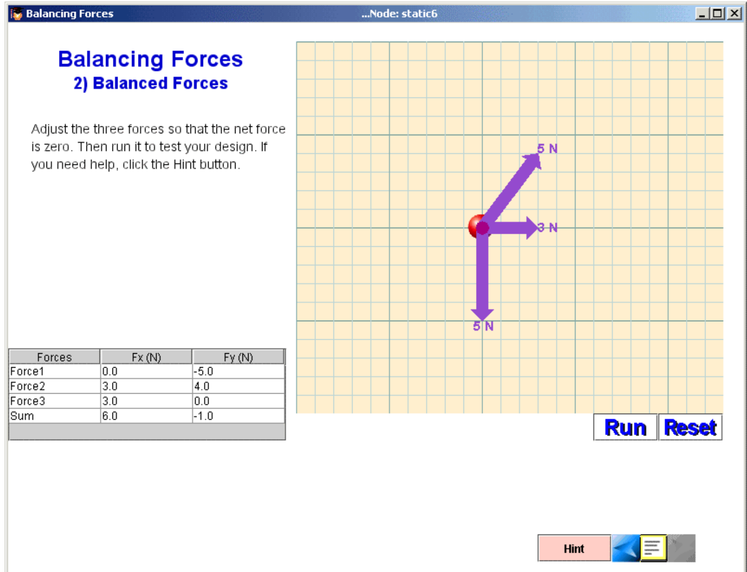
In the next set of models, a force table is provided to keep track of the force magnitudes. The student is asked to work with three forces on one object. The goal is to ensure that the sum of the forces is 0. First, the student is to add two additional forces to a ball with one fixed force. Later in this section, the student adds forces by typing in the x and y components for each force.



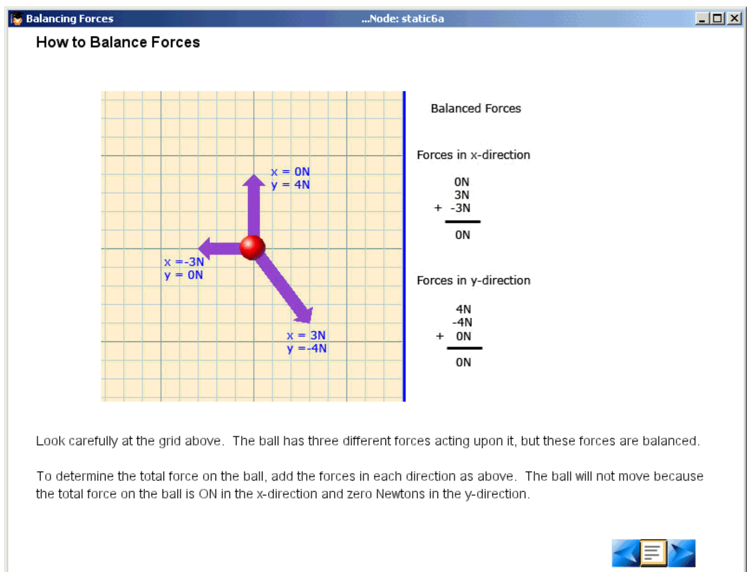
Click and drag on the ball to add a force arrow



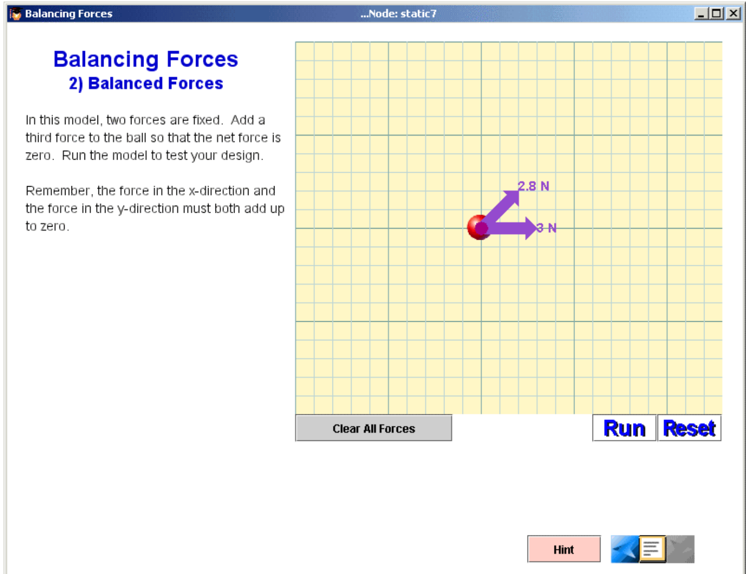
Possible solution to the problem



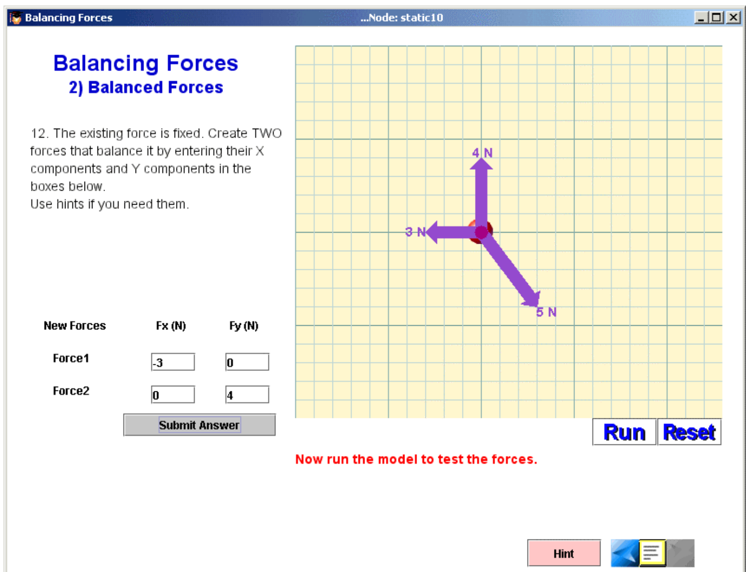
Adjust the three forces



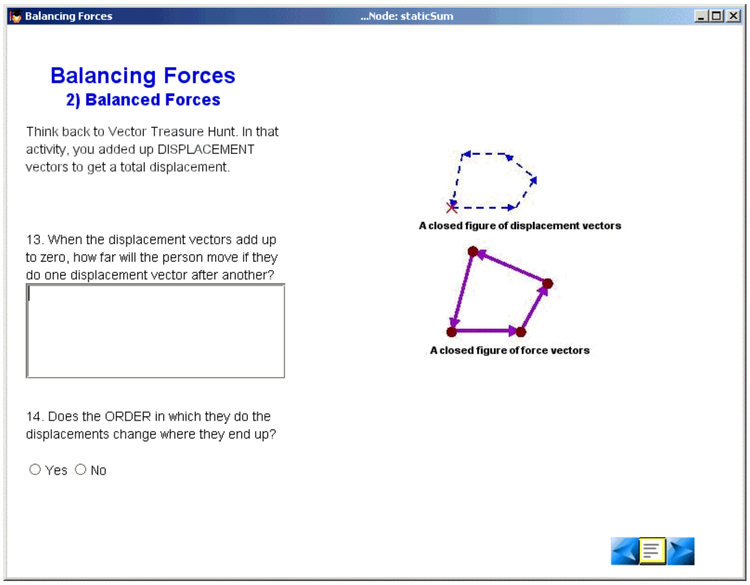
Add the x-components and the y-components to find the net force



Add a balancing force



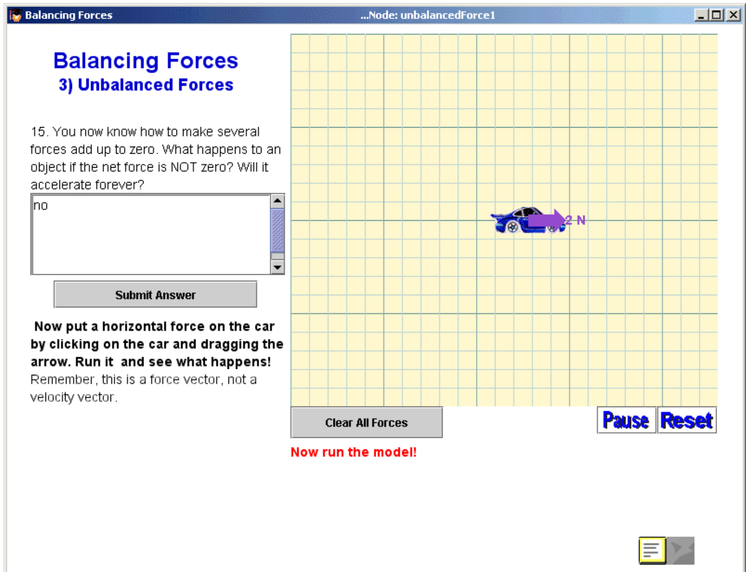
Add a force by typing the appropriate x and y components



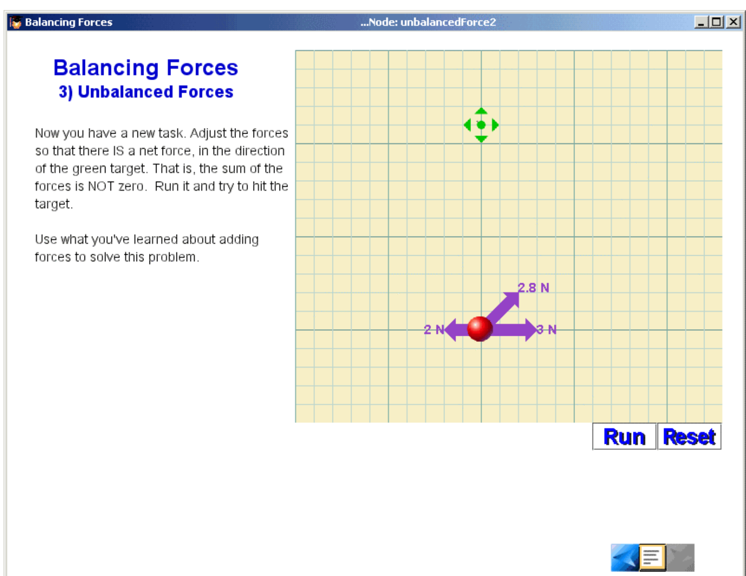
Comparison of 0 displacement with 0 net force

4.4 3) Unbalanced forces

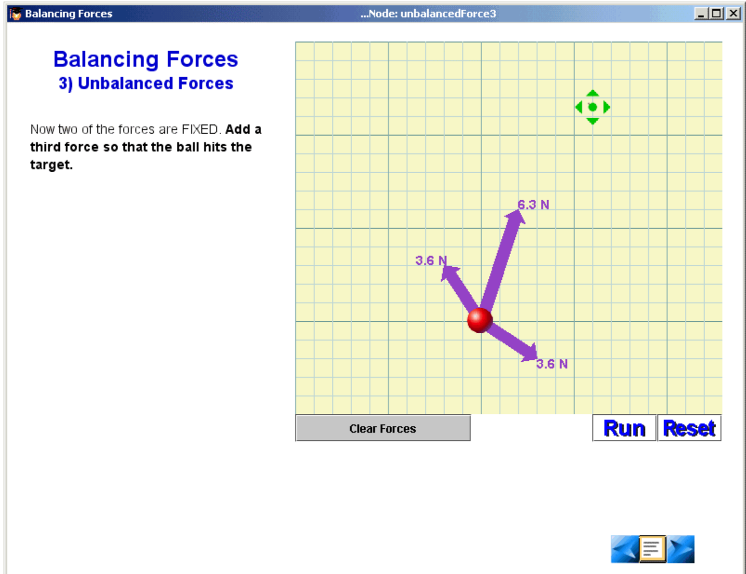
In this section, students experiment with the effects of unbalanced forces. In the first model, students see what happens when a single force is applied to a car—it accelerates forever. In other models, students manipulate multiple forces in order to hit a target.



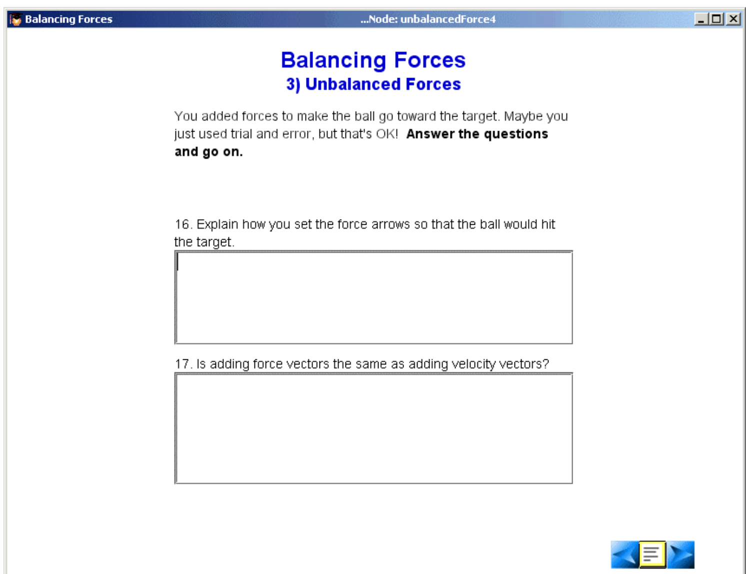
The car will accelerate forever!



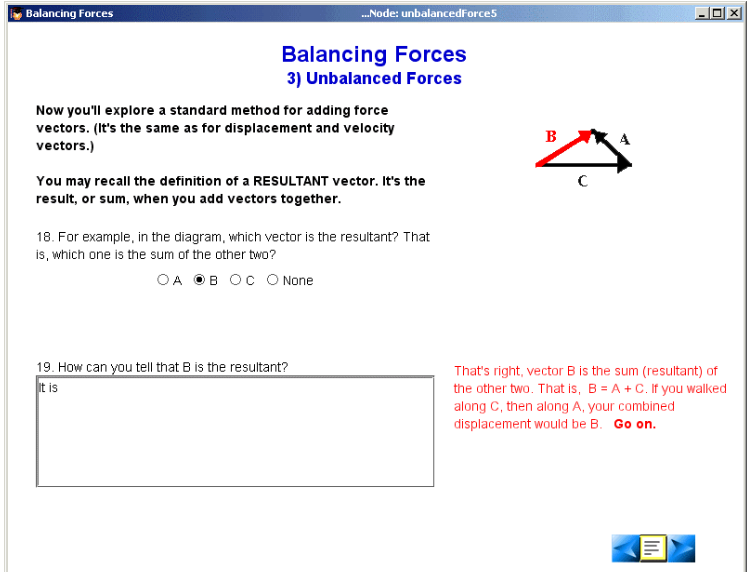
Hit the target



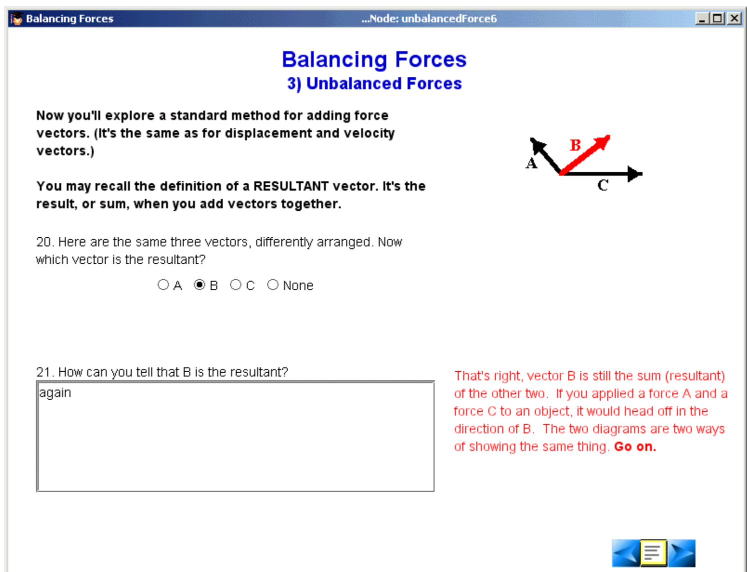
Once the student hits the target, Reset will provide additional problems



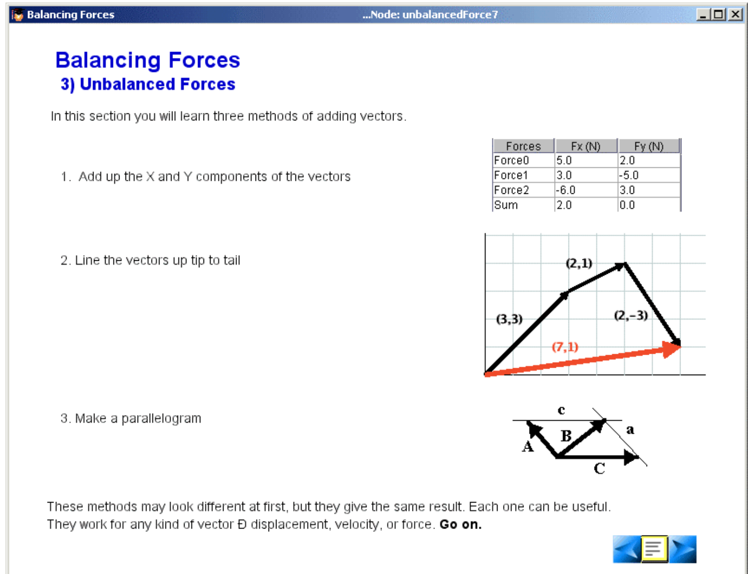
Questions for understanding



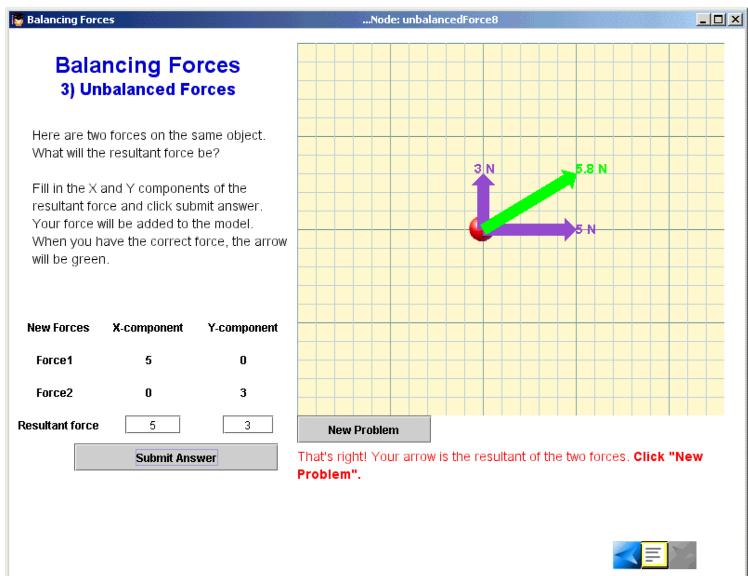
Select the resultant force (B)



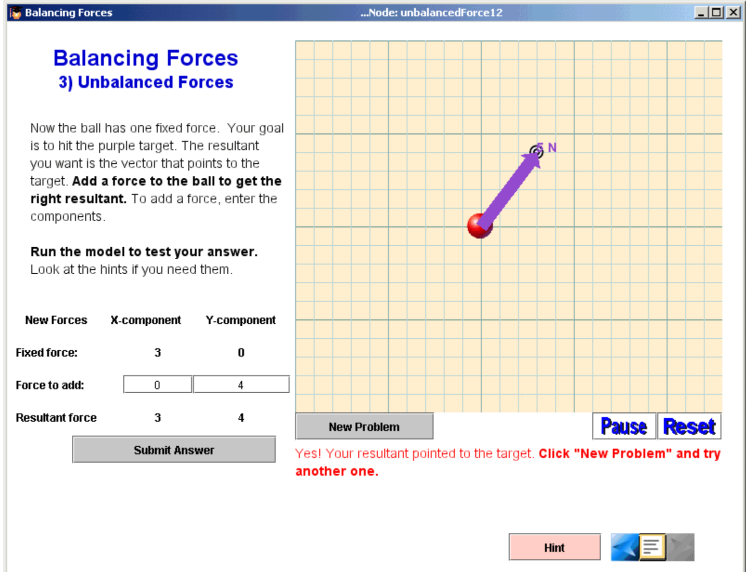
Select the resultant force (B)



Vector addition methods



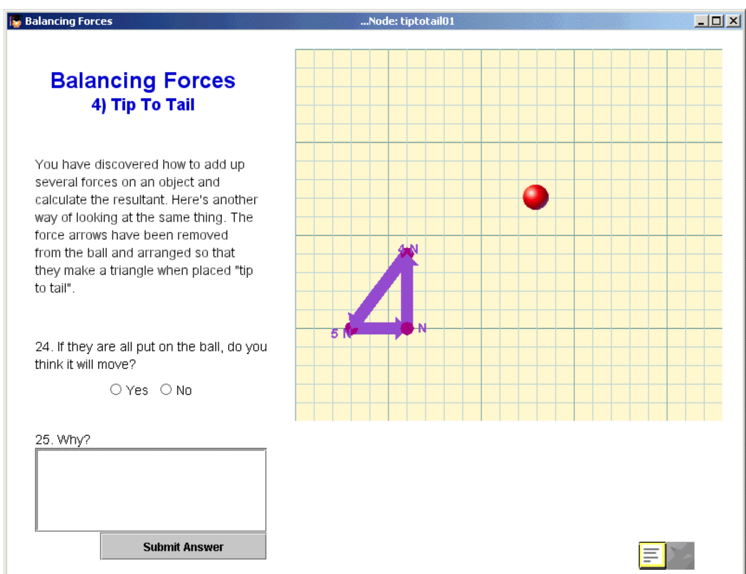
Add the force vectors to find resultant



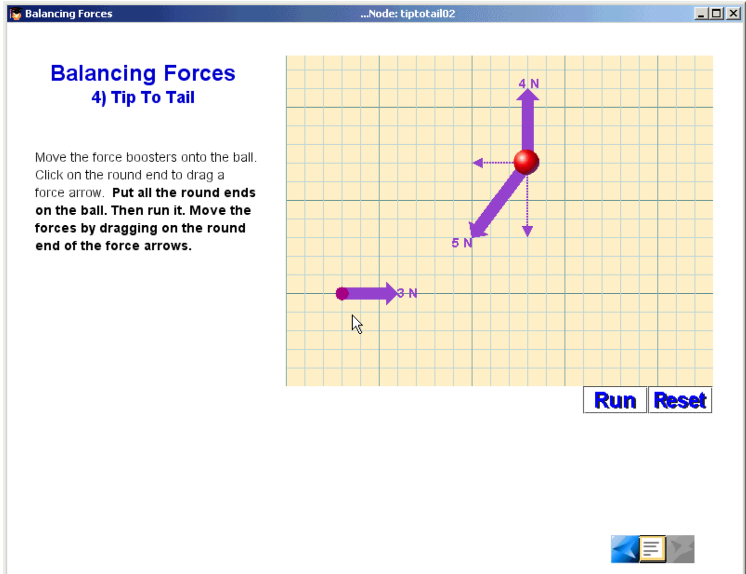
Add a force vector to hit the target

4.5 4) Tip To Tail

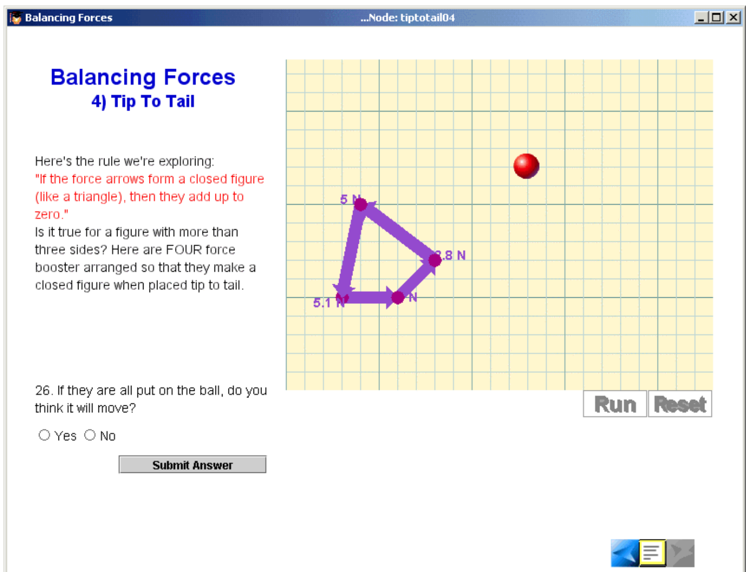
This is a short section that gives students another method for balancing forces, the Tip-to-tail method. Here, students drag the forces arrows from a closed figure onto the ball by dragging the non-arrow end of the arrow (a pink dot).



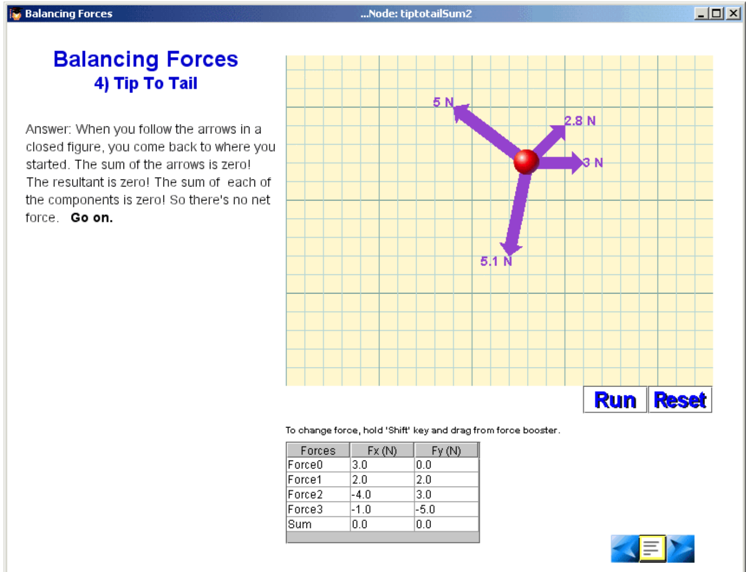
Is the net force of these three forces 0? Yes.



Move the force arrows by clicking and dragging with the mouse



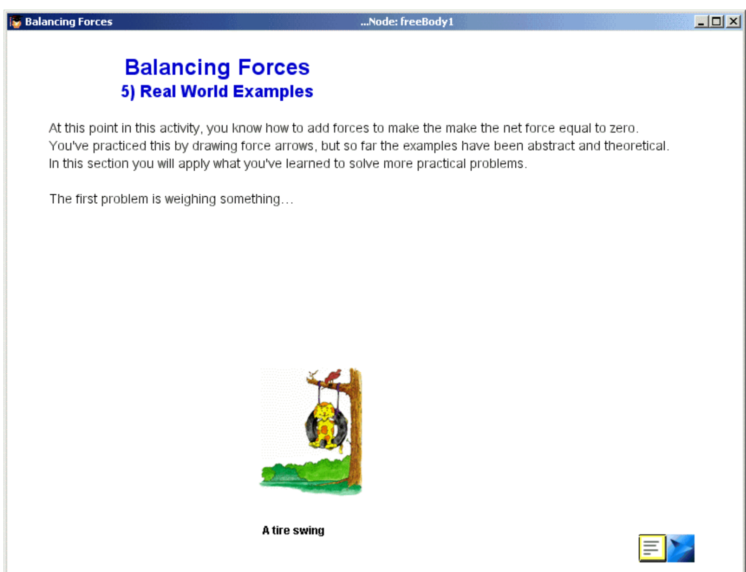
Will all closed figures have a net force of 0? Yes.



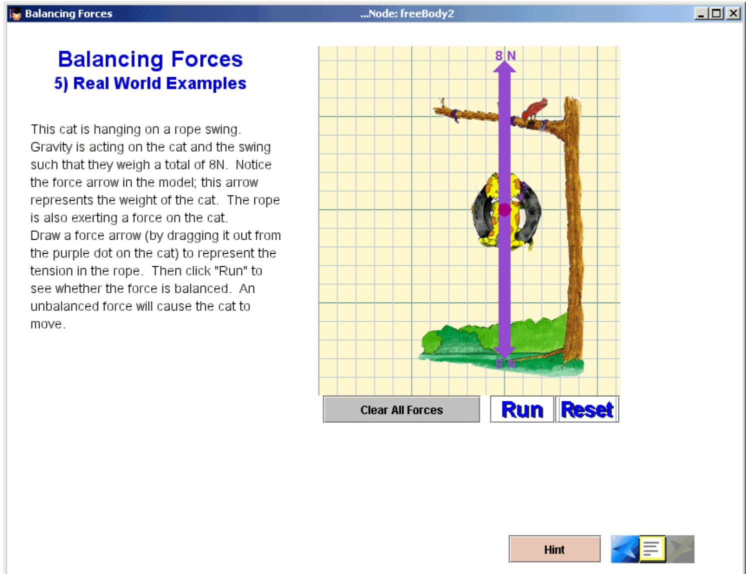
Hold the shift key down to change the magnitude and direction of the forces

4.6 5) Real World Examples

In this section, students experiment with two real world models. The first is a cat hanging on a swing. First, the cat is suspended by one rope, then by two. In the second example, a boat is traveling on the water. Students will observe that multiple forces on the boat (gravity, buoyancy, motor and water resistance) have a net force of zero; however, while the forces are balanced, the boat is moving at a constant velocity.

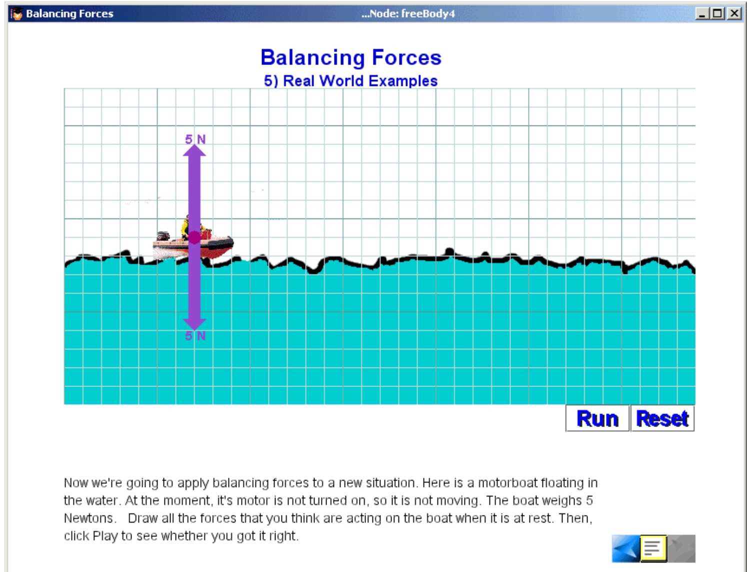


Introduction to real world examples section

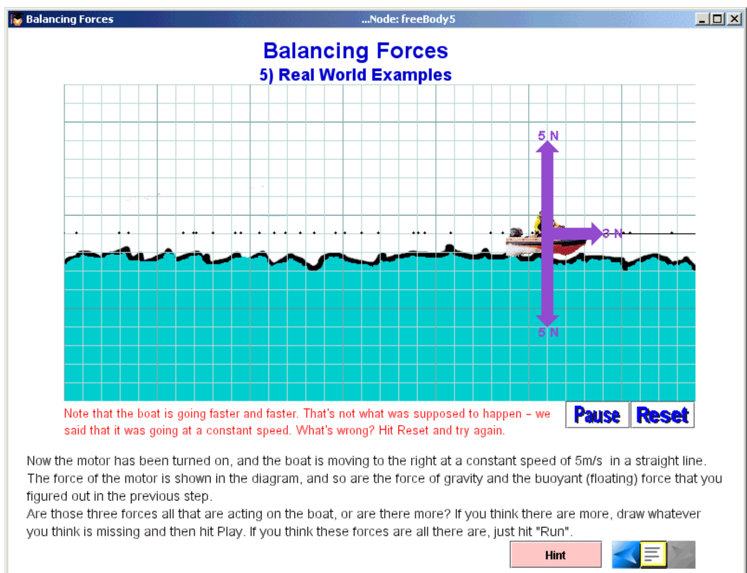


Apply an upward force, equal and opposite to the rope

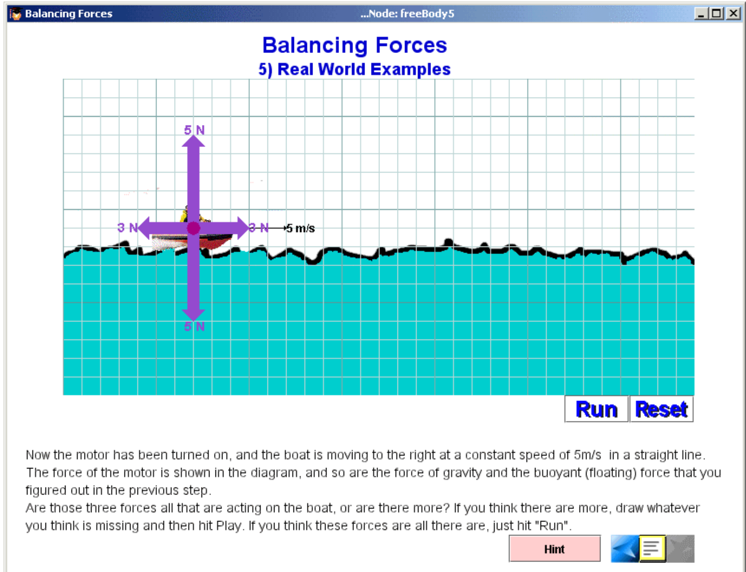
Add force arrows along both ropes



Apply forces to a boat at rest



Without the friction force of the water, the boat will accelerate forever



With an additional force, the boat moves at a constant speed

5.0 Student Reports

Your students' work with the Balancing Forces 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, and final, activity in the Dynamica sequence is Gravity.