F=ma

Teacher's Guide

1.0 Summary

"F=ma" is the fourth activity in the Dynamica sequence. This activity should be done after Motion Graphs and it should take students approximately 30 minutes. This activity has been entirely rewritten for the 2004-2005 school year. It includes a four-question quiz at the end of the activity.

2.0 Learning Goals

Driving Question: How do forces affect the motion of objects with different masses?

This activity explores the relationships between force, mass, and acceleration. The model allows students to apply a force to an object and predict how its velocity will change.

Step One: **Force and Mass** demonstrates the difference in the magnitude of the force needed to move a more massive object than a less massive object.

Step Two: **Force in Newtons** explains the F component of the F=ma equation. Students will calculate the force needed to accelerate an object.

Step Three: **Mission 1: Flying** is a game that uses the arrow keys on the keyboard to represent force boosters applied to a space ship.

Step Four: **Mission 2: Target Practice** asks students to predict the force needed for a space ship to hit a target at a certain velocity. Students calculate the required force and adjust the force boosters as needed.

Step Five: **Mission 3: Landing Zone** requires that students apply forces in the opposite direction of the ship's motion in order to slow down or stop a ship.

Step Six: **Mission 4: Flight Commander** requires students to understand the F=ma equation. Students use the equation to complete various tasks, such as calculating acceleration.

Step Seven: **Quiz** is a four-question assessment. Students will receive a score and can review their answers at the end of the quiz.

Additional Teacher Background

The change in velocity depends on three simultaneous variables: the force, the length of time it is applied, and the mass. Force and duration are directly proportional to velocity change, and mass is inversely proportional. These relationships make sense intuitively, but working with all three at once can be challenging.

The common algebraic expression of Newton's Second Law, *F* = *ma*, is presented here in a slightly different but equivalent form:

Impulse = change in momentum

Since *impulse* is equal to the *force applied over a specified time*, you can rearrange this to be equivalent to Newton's Second Law because change in velocity divided by time equals acceleration.

Force x time applied = mass x velocity

Force = mass x (change in velocity / time applied)

Force = mass x acceleration

Additional Activities

Air carts: low friction carts with motor-driven propellers provide a constant force. Measure the force by letting the cart push against a force probe as it runs. Then add different masses to the cart and measure its acceleration with a Sonar Ranger. Since the force is constant, students can test the inverse relationship between mass and acceleration.

3.0 Standards Alignment

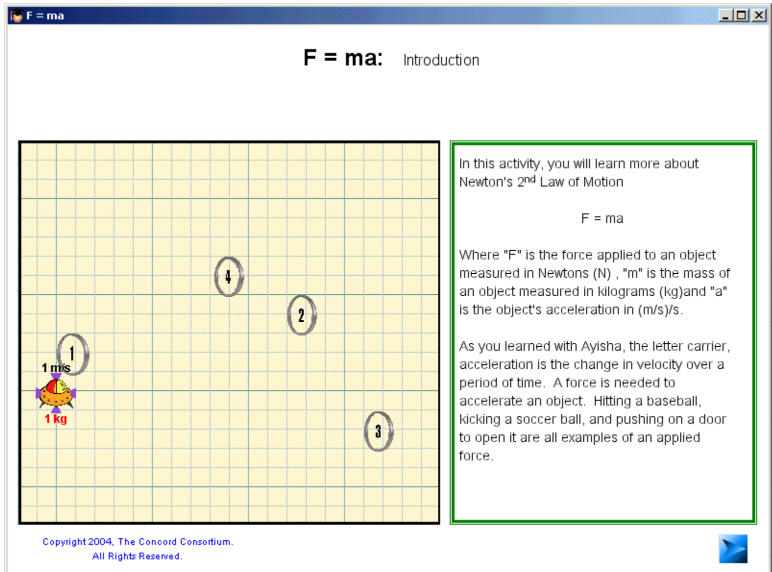
Alignment to National Math and Science Standards (NCTM or NSES)

Objective	Standards
Students will understand that change in velocity is proportional to the strength of the force and the length of time it is applied.	• Laws of motion are used to precisely calculate the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F = ma, which is independent of the nature of the force.
Students will understand that change in velocity is inversely proportional to mass.	• Students will interpret representations of functions of two variables.
Students will calculate the unknown quantity in an equation with three variables (F = ma).	• Students will use the language of mathematics to express mathematical ideas precisely. • Students will write equivalent forms of equations and solve them with fluency -- mentally or with paper and pencil in simple cases and using technology in all cases.
Students will learn the definitions of impulse and momentum.	• Students will recognize and apply mathematics in contexts outside of mathematics.
Students will predict the outcome of an event and compare it with data from a simulation.	• Students will use the language of mathematics to express mathematical ideas precisely. • Students will draw reasonable conclusions about a situation being modeled.
Students will understand the equivalency of the two statements of Newton's Second Law: (F=ma) and (impulse = change in momentum).	• Students will write equivalent forms of equations and solve them with fluency -- mentally or with paper and pencil in simple cases and using technology in all cases • Students will recognize and apply mathematics in contexts outside of mathematics.

4.0 Activity Sections

4.1 Table of Contents

This activity has 7 sections. The last section is a 4 question quiz to assess student understanding of the material. Students will receive a score after completing the quiz. They will also be able to review their answers.



Opening screen

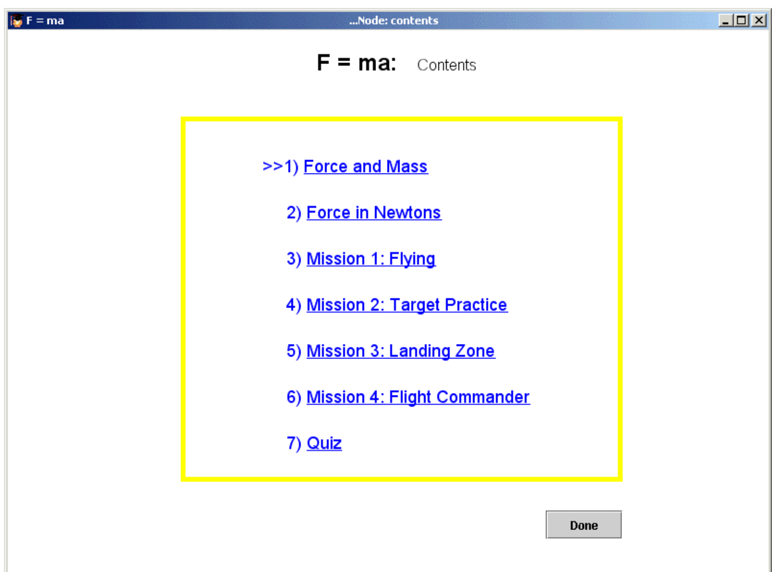
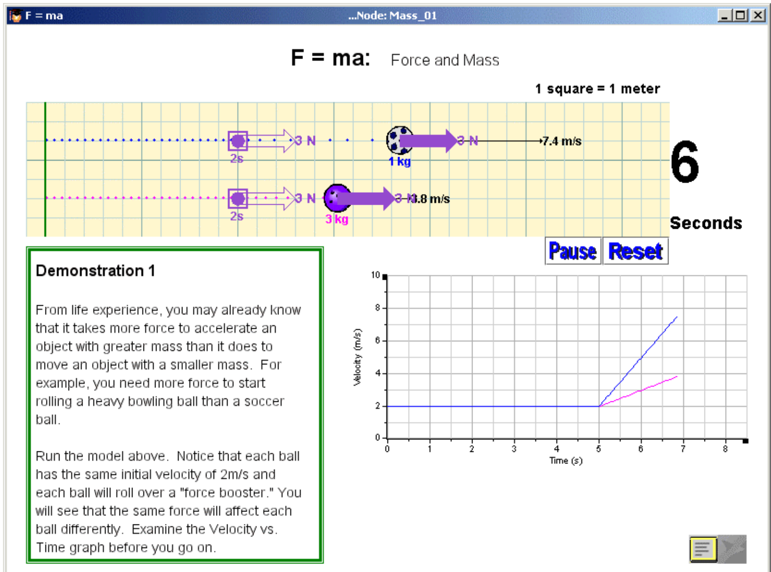


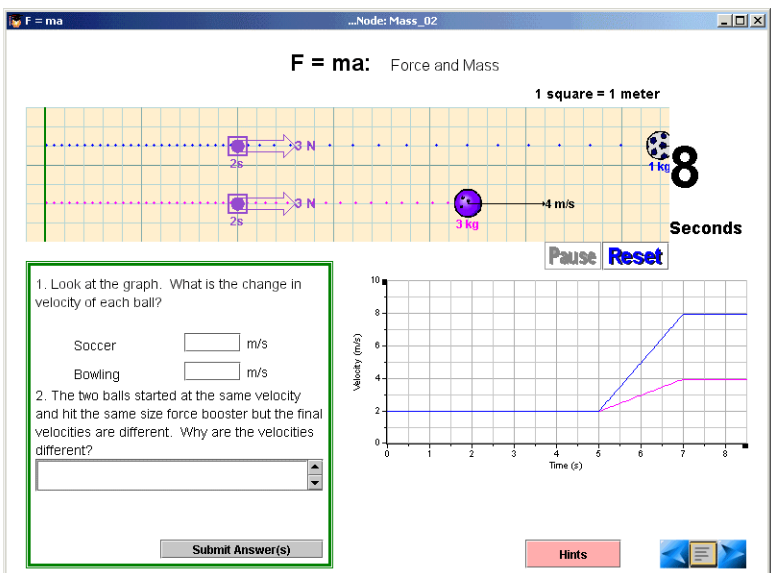
Table of Contents

4.2 1) Force and Mass

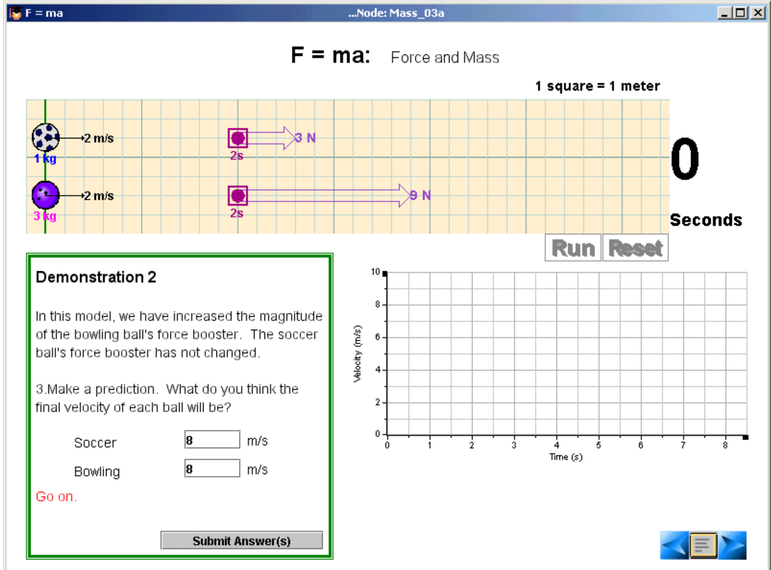
To understand the equation F=ma, students must understand the components of force, mass and acceleration. In this section, students are introduced to the relationship between a model showing the difference in the force needed to roll a soccer ball and a bowling ball.



Equal force is applied to objects with two different masses



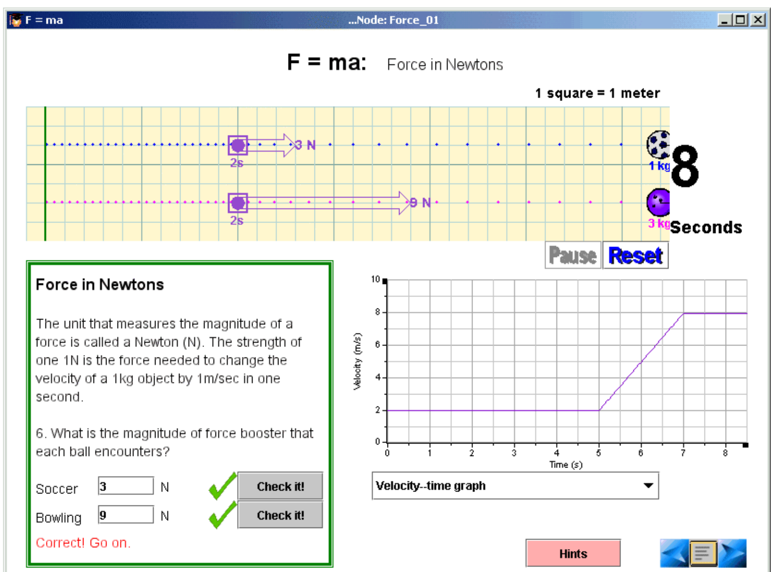
Using the graph, find the velocity of each object.



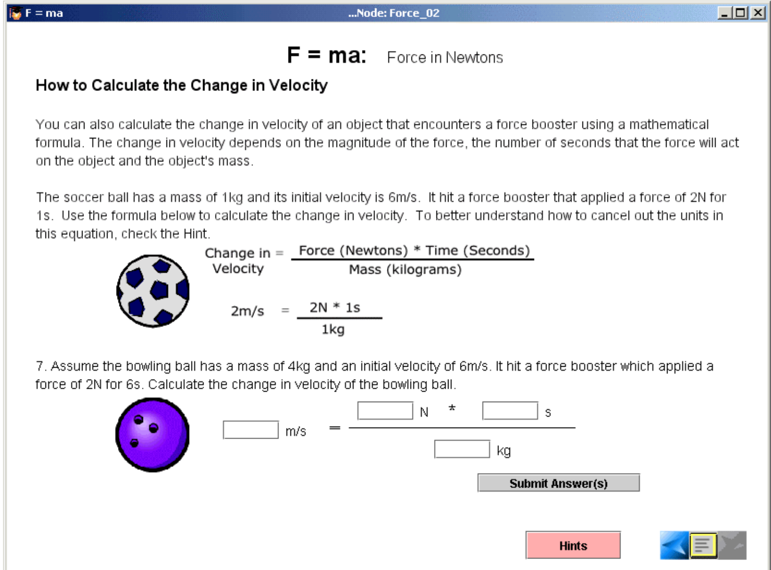
Predict the final velocity of each ball (8m/s).

4.3 2) Force in Newtons

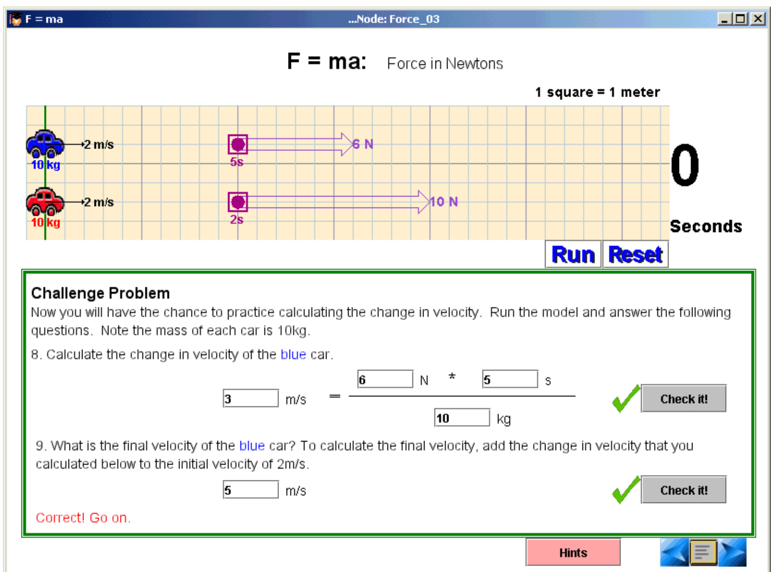
In this section, students run models of collisions with two balls of different mass. First, they are asked to predict what will happen after the collision. Then, they are guided though various scenarios.



Run the model and examine the graphs.



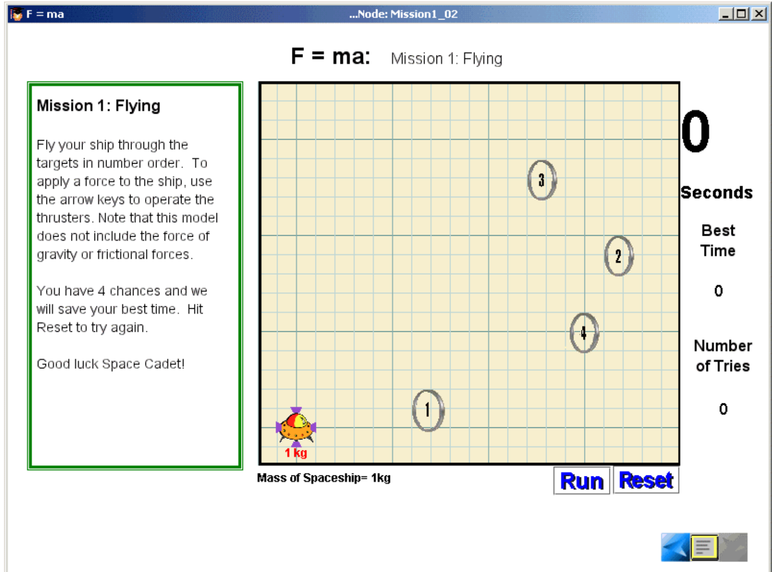
Example of formula for calculating the change in velocity



Final velocity = change in velocity * initial velocity

4.4 3) Mission 1: Flying

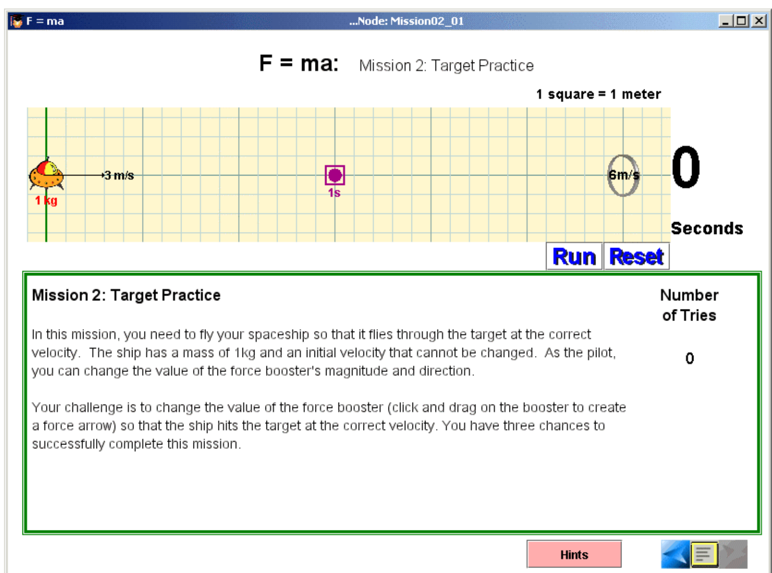
The student will be led through a series of short “missions” with the goal of becoming a Flight Commander on planet Erehwon. In the first mission, students are introduced to their space ship and the targets that they will need to fly through in subsequent missions. Students use the arrow keys on the keyboard to fly their ship through the targets in numerical order. Every time an arrow key is hit, a force of 1N in that direction is added to the ship.



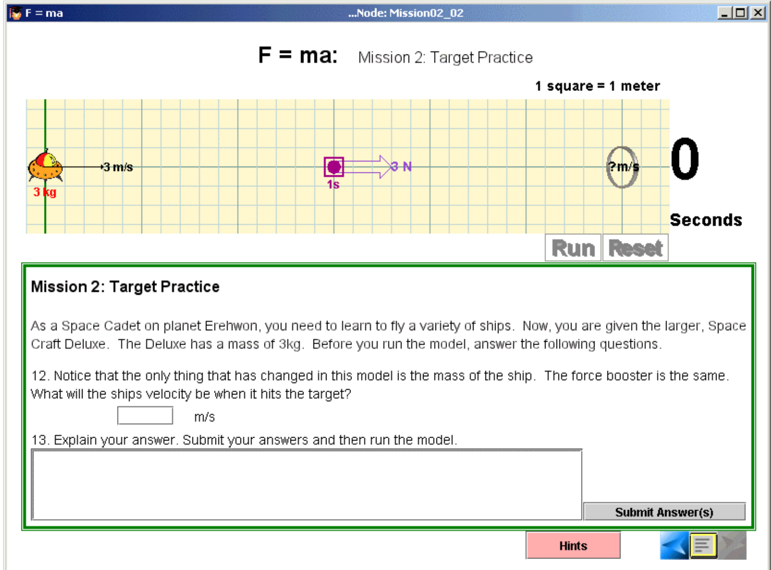
The law as applied to objects of the same mass

4.5 4) Mission 2: Target Practice

In this mission, students must fly the ship through the target at the velocity indicated within the target. To do this, students must adjust the force on the force booster by clicking and dragging on the force booster.



Students have three chances to adjust the booster to 3N.

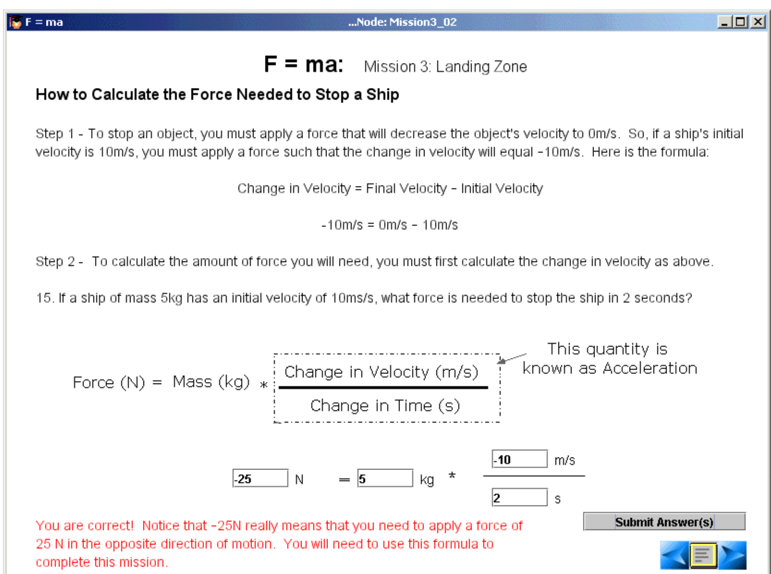


Students predict the final velocity of the Space Craft Deluxe (4m/s).

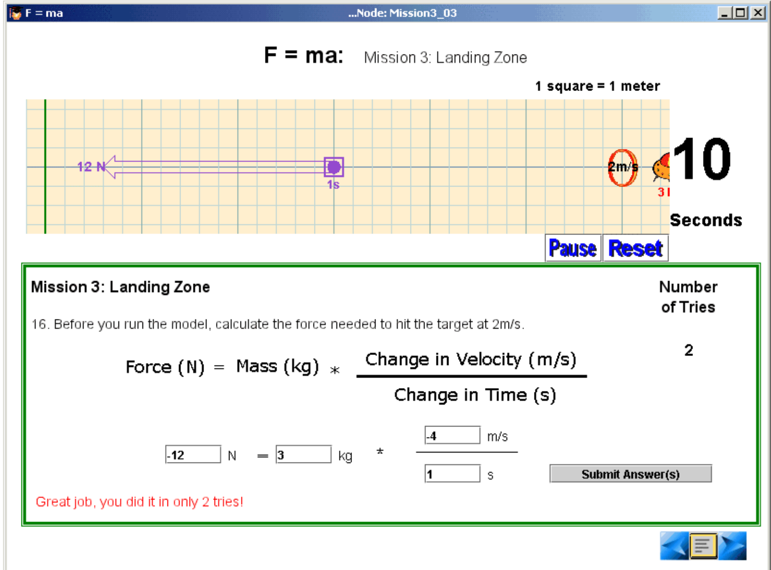
4.6 5) Mission 3: Landing Zone

Up to this point, students have used force boosters to increase the velocity of a ship. Now, students will need to apply an opposing force in order to slow a ship down. In the last part of this section, students will need to apply a force in the opposite direction of the ship's motion in order to stop the ship on the landing zone.

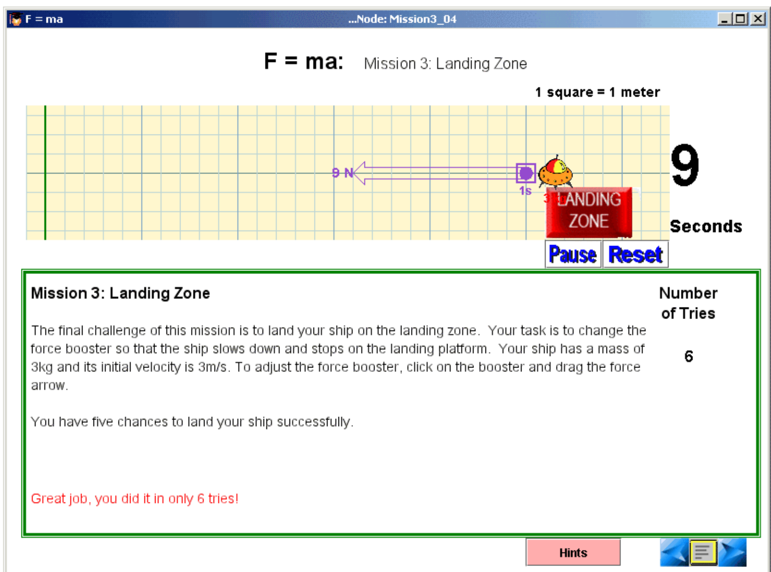
Note that in the following screen the answer is –25N, meaning that the force needed is 25N; the negative sign indicates that the force is in the opposite direction.



Calculating the force needed to stop a ship



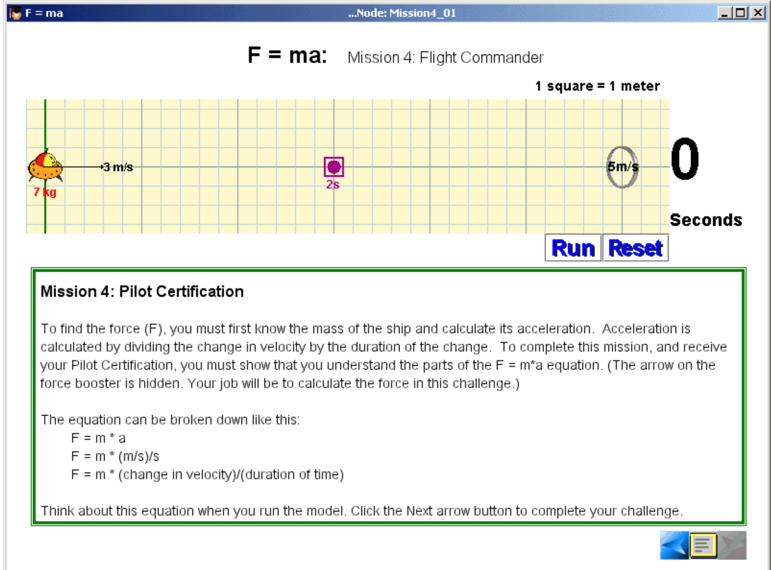
Student must complete the equation before running the model.



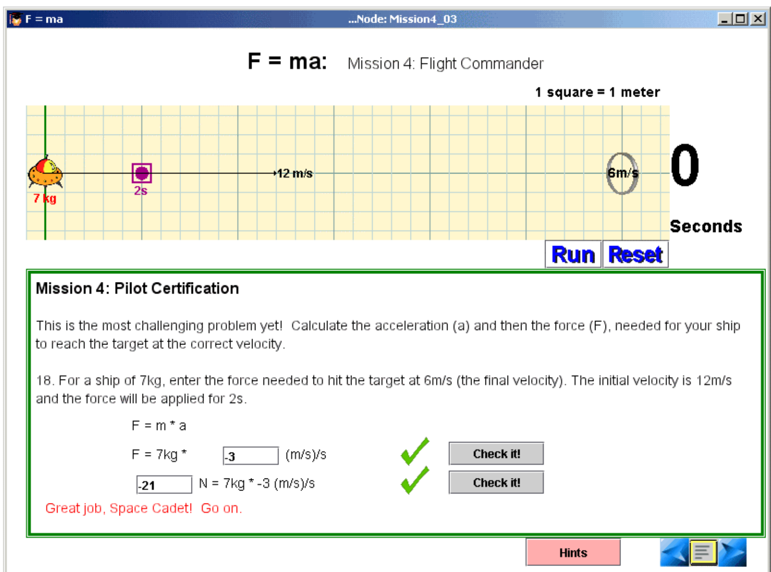
Set the booster to 9N to reduce the ships velocity to 0m/s.

4.7 6) Mission 4: Flight Commander

This is the final mission in the space cadet sequence. In this mission, the force booster arrow is hidden. Students must use the F=ma equation to calculate the magnitude of the force.



Breakdown of the F=ma equation



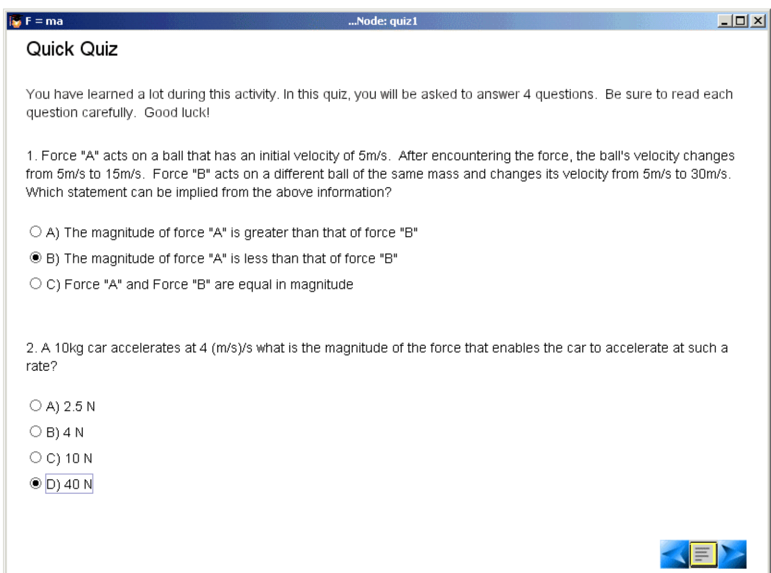
Calculate the acceleration and then the force.

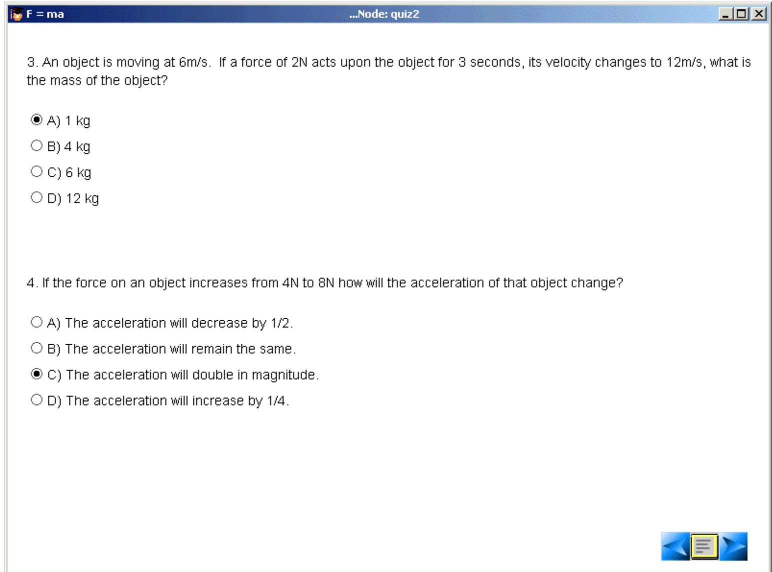
Flight Commander Certificate

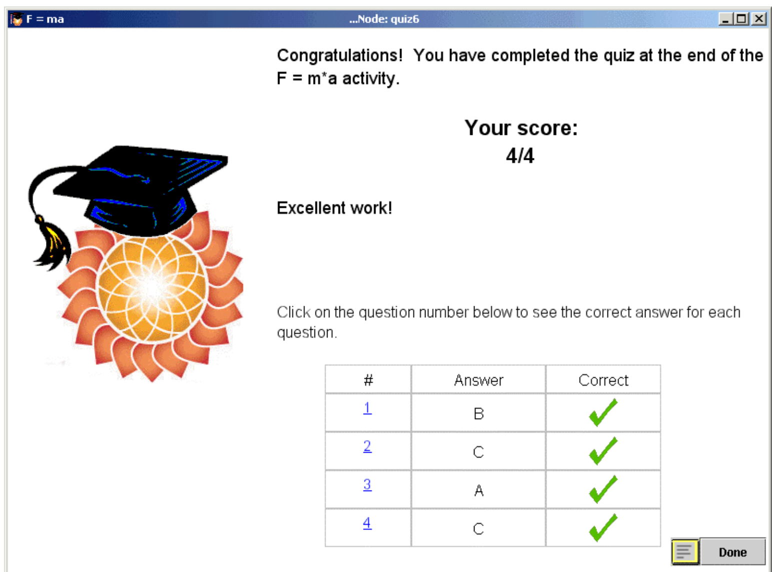
4.8 7) Quiz

This quiz has four questions. Students will be able to review their answers at the end of the quiz.

Answers: 1-B, 2-C, 3-A, 4-C







To review the quiz questions and answers, click on the question number links.

5.0 Student Reports

Your students' work with the F=ma 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.

Students should now attempt the Forces in 2D activity.