# Motion Graphs

Teacher's Guide

## 1.0 Summary

"Motion Graphs" is the third activity in the Dynamica sequence. This activity should be done after Vector Motion. Motion Graphs has been revised for the 2004-2005 school year. Students should take approximately 45 minutes to complete this activity. The activity includes a six-question assessment.

## 2.0 Learning Goals

**Driving Question:** How can graphs be used to describe motion?

Graphs are a powerful representation of the relationships between distance, velocity, and acceleration. Graphs provide another way to show kinematic relationships expressed by formulas. This activity is the computer-modeled version of a sonar ranger lab, which measures your motion and shows it as a real-time graph of either distance vs. time or velocity vs. time. As a graph plots the position and speed of a ball on the screen, students can add forces to the ball and see the resulting changes of its motion in the graph.

Step 1: **Position vs. Time Graphs:** Introduces the students to the tools used in this activity. Students run models and observe the motion of objects on a grid. In addition, they observe the graph of the motion of the object on a Position vs. Time graph. Students are asked to interpret the graphs and answer questions.

Step 2: **Velocity vs. Time Graphs:** Teaches students to calculate velocity based on values on the Distance vs. Time graph. Students also observe the motion of objects and corresponding velocity graphs. Students are introduced to the "force booster," which instantaneously increases an object's velocity.

Step 3: **Acceleration vs. Time Graphs:** Examines the relationship between acceleration graphs and velocity graphs. Students practice calculating acceleration using information from the Velocity vs. Time graph. Students are shown examples contrasting instantaneous vs. gradual acceleration.

Step 4: **Quiz:** Provides a quick assessment of student learning in this activity. The quiz contains 6 multiple-choice questions. At the end of the quiz, the student will be presented with her/his score and given the opportunity to review the questions/answers. Teachers can view student responses on the MAC Web Portal. Quiz answers are provided at the end of this guide.

**Learning Goals**

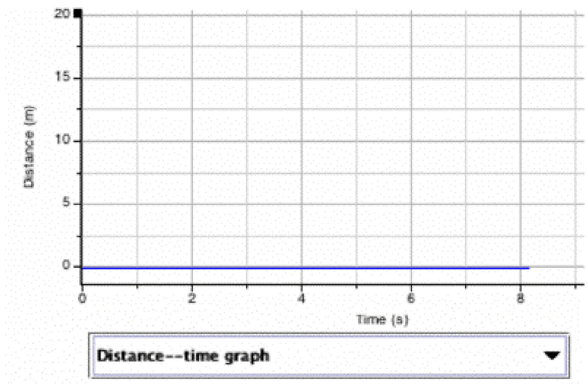
- Students will develop an understanding of the relationship between the motion of an object and a graph that represents change in position.
- Students will develop an understanding of the relationship between the motion of an object and a graph that represents velocity.
- Students will develop an understanding of the relationship between the motion of an object and a graph that represents acceleration.

- Students will practice calculating velocity from information given on a position vs. time graph.
- Students will practice calculating acceleration from information given on a velocity vs. time graph.

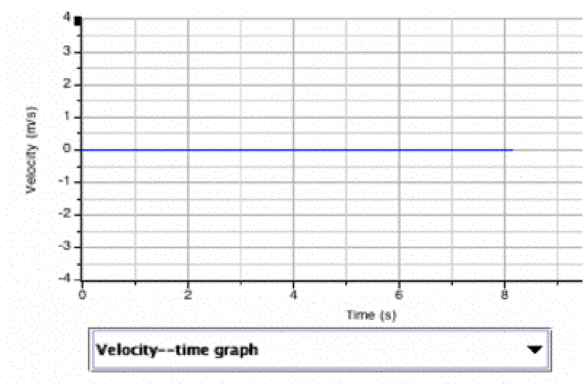
## Additional Teacher Background

Displacement and velocity-time graphs of the same motion appear different, even though they are a record of the same motion. Going from one to the other, and understanding how each corresponds to the motion of an object, is very challenging! But it's an excellent way to learn to read graphs and understand slope. It is also fundamental to understanding the physics of motion.

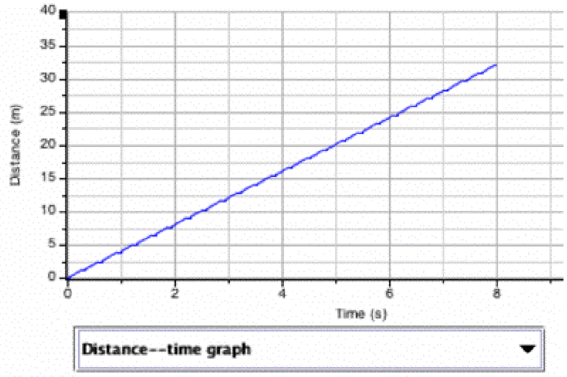
**<u>Example 1:</u>** If the object is **not moving**, the displacement-time graph will be a horizontal flat line.



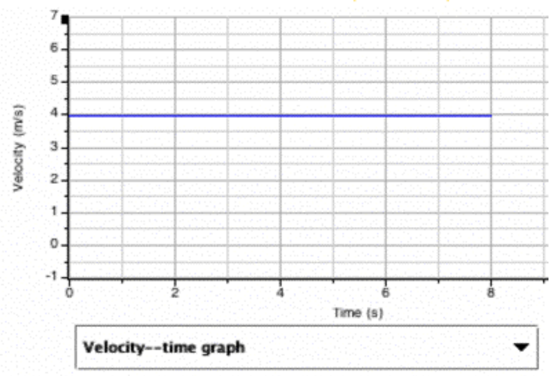

The velocity is zero.



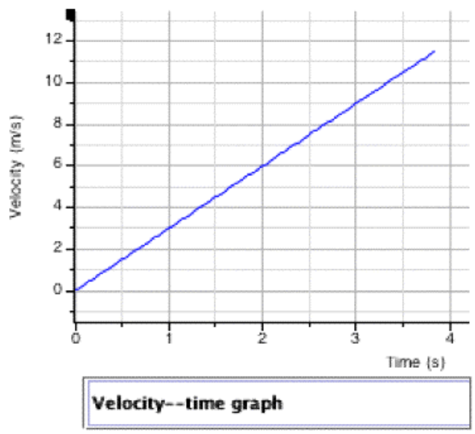
**<u>Example 2:</u>** If the object is moving at a **constant velocity**, the displacement-time graph will be a sloping straight line, because the displacement is changing at a constant rate. The slope can be either positive or negative. A negative slope means the velocity is negative, that is, the displacement is decreasing and the object is moving "backwards."



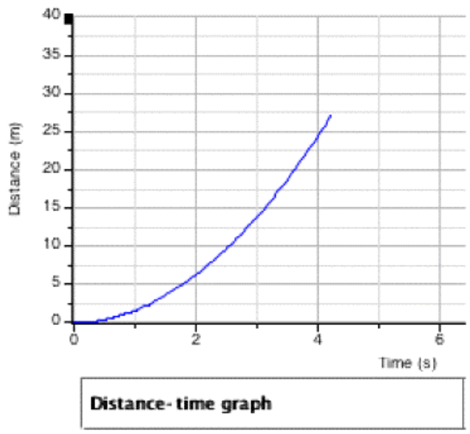

The velocity-time graph will be a flat horizontal line with a value equal to the velocity.




**<u>Example 3:</u>** If the object is **accelerating** or **decelerating** (deceleration is the same as negative acceleration), the velocity-time graph will be a sloping straight line, because the velocity is changing at a constant rate. Again, the slope can be positive or negative, depending on whether the object is speeding up or slowing down.



The relationship between displacement and acceleration is a two-step process. If an object is accelerating, that means the velocity is changing. Since the **slope** of the displacement-time graph is equal to the velocity, this slope must also be changing, and the displacement-time graph is **curved**.




The fundamental physics idea embedded in this activity is that **external forces cause a change in velocity** (i.e. acceleration). The other side of the coin is that if the velocity is constant (or zero), there are no external forces. Many people believe that a constant velocity requires a constant force. On the earth, where friction is always present, a constant velocity may require a force, but it balances the force of friction and the **net external force is zero**. This idea is also dealt with in “Balancing Forces” and “Friction.”

The velocity booster represents a sharp impulse -- a big force for a short time -- such as a bat hitting a ball. The force booster represents a steady constant force, such as a car accelerating or braking, or a ball rolling down a hill.

## Additional Activities

*Tracking Motion:* There are various probes, such as the sonar ranger, that can be used by students to turn their body motion into graphs of distance, velocity, and acceleration. The experience of creating a real-time graph with your own physical movement is a very powerful means for grasping the meaning of these quantities and their relationships to each other and to real-world motion. Activities can include creating graphs of a specified shape, writing a motion "story" and predicting what the graph will look like, and interpreting what story a given graph tells.

# 3.0 Standards Alignment

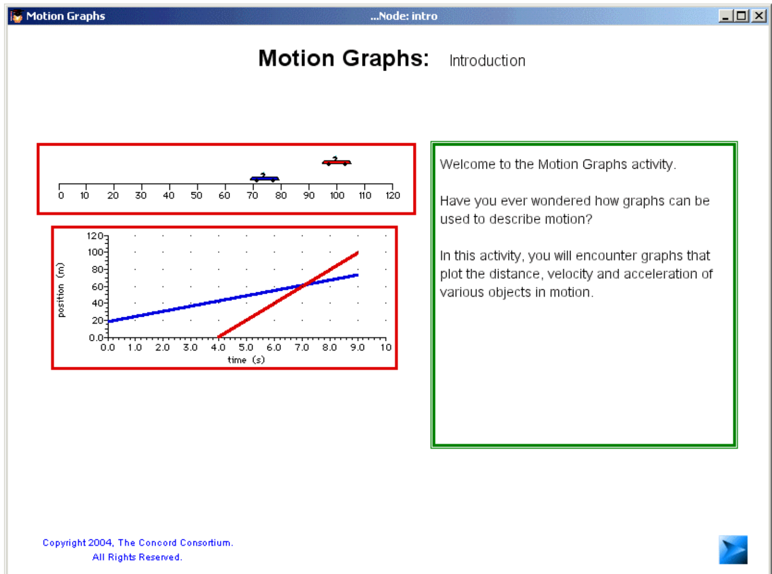
### Alignment to National Math and Science Standards (NCTM or NSES)

| Objective | Standards |
| --- | --- |
| **Students will use real-time graphs to analyze the motion of objects.** | • Students should interpret representations of functions of two variables.<br>• Students should select, apply, and translate among mathematical representations to solve problems. |
| **Students will be able to describe the motion of an object by looking at the graph.** | • Students should use the language of mathematics to express mathematical ideas precisely.<br>• Students should recognize and apply mathematics in contexts outside of mathematics. |
| **Students will be able to describe a motion graph by observing the motion of an object.** | • Students should recognize and apply mathematics in contexts outside of mathematics. |
| **Students will understand the relationship between displacement and velocity.** | • Students should approximate and interpret rates of change from graphical and numerical data.<br>• Students should recognize and apply mathematics in contexts outside of mathematics. |
| **Students will calculate velocity as the slope of the displacement-time graph.** | • Students should approximate and interpret rates of change from graphical and numerical data. |
| **Students will understand the relationship between velocity and acceleration.** | • Students should approximate and interpret rates of change from graphical and numerical data.<br>• Students should recognize and apply mathematics in contexts outside of mathematics. |

# 4.0 Activity Sections

## 4.1 Table of Contents

This activity has 4 sections: three steps and one summary.




Opening Screen

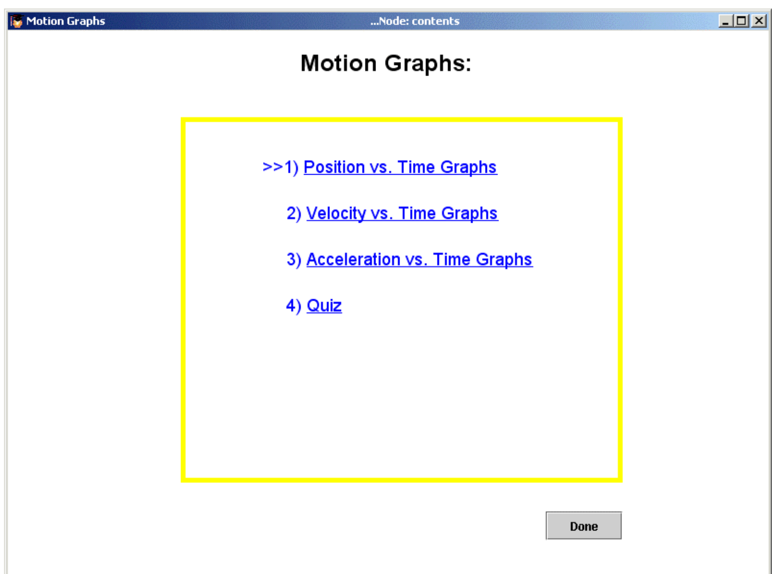
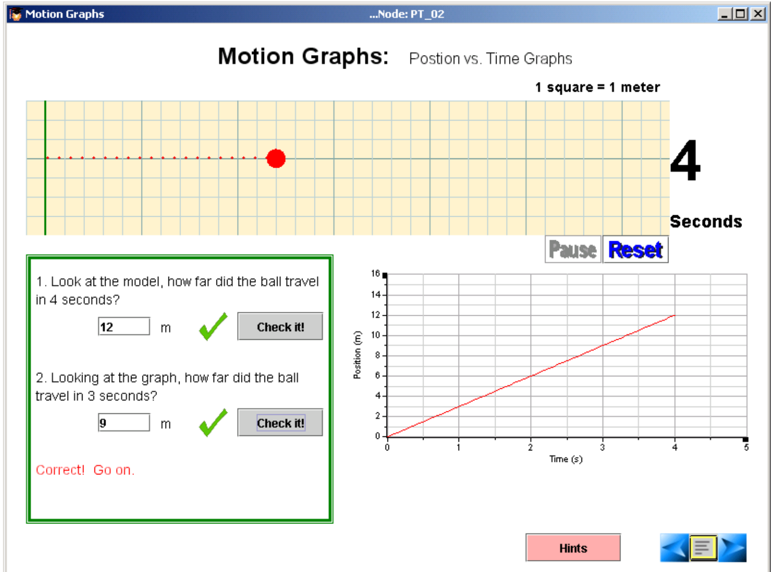


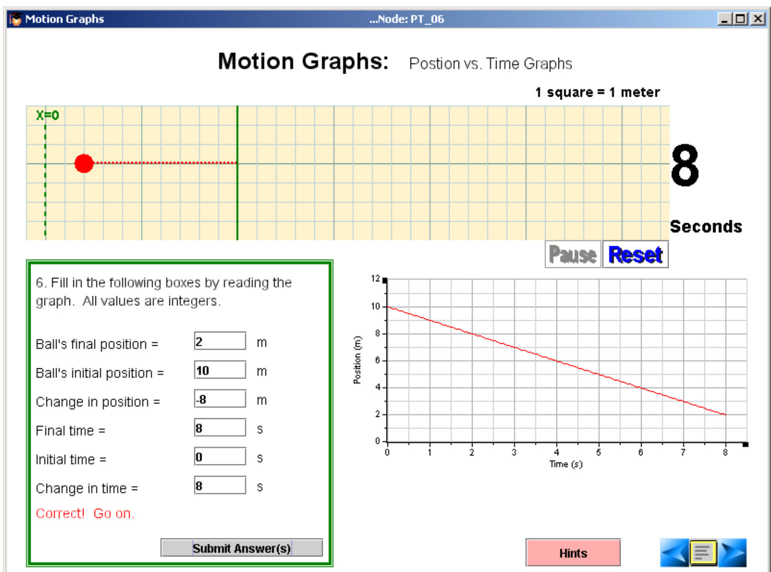

Table of Contents

## 4.2 1) Position vs. Time Graphs

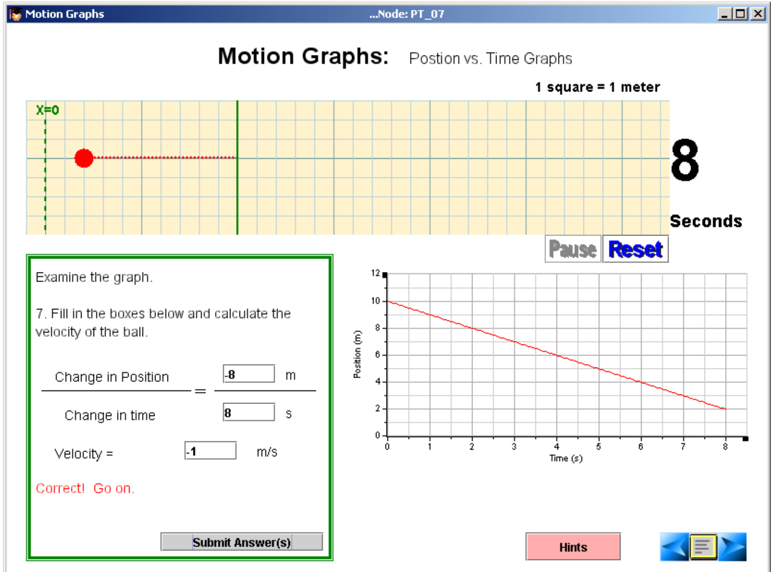
The first section introduces students to the model tools to be used in the remainder of this activity. The Run/Pause and Reset buttons control the model. A timer and graph is also provided. The Hints in this activity are fairly extensive. Please remind your students that it is OK to look to the hints for more information on how to answer the questions.




Students receive automatic feedback on the "Check it!" questions.



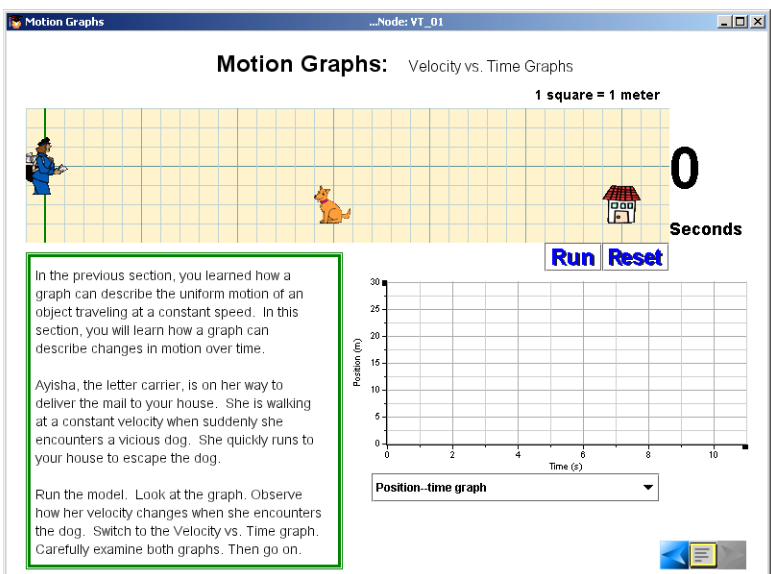

Questions on change in position and change in time



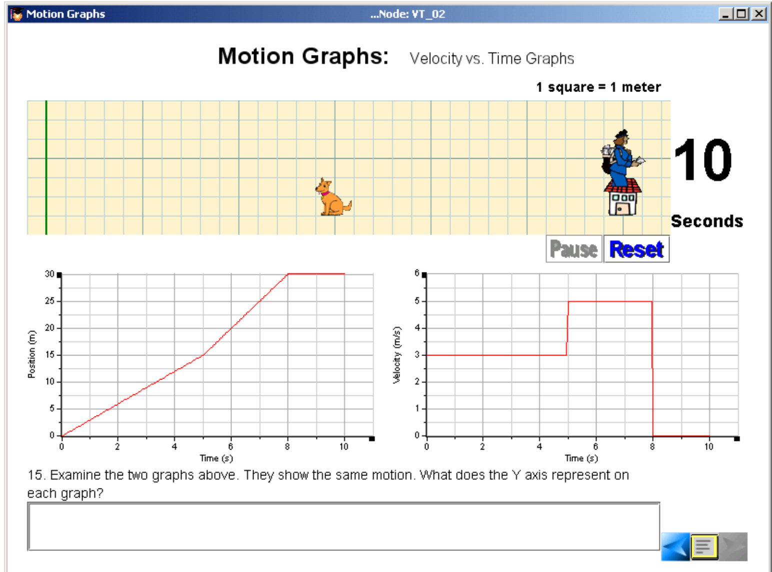

Takes student step-by-step through calculating velocity

## 4.3 2) Velocity vs. Time Graphs

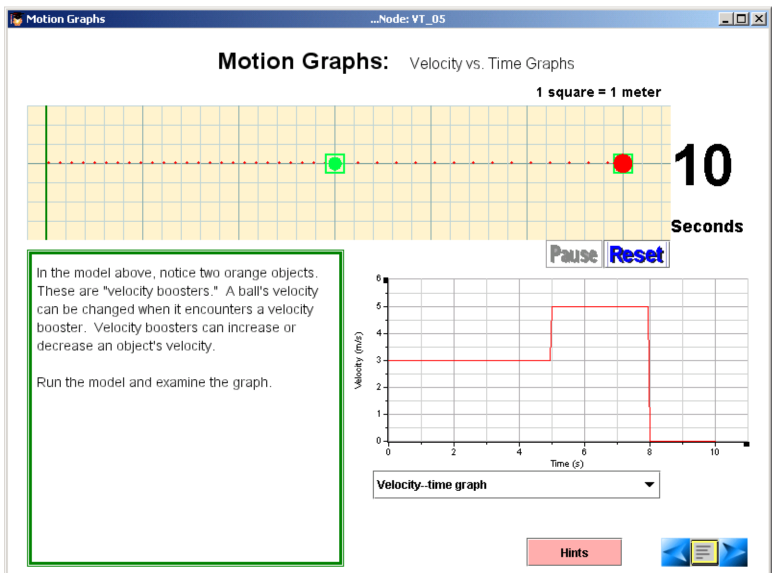
This section of the activity introduces students to a real world situation. Ayisha, the letter carrier, runs into a dog on the way to delivering the mail. She changes her velocity to run from the dog. The models in this section use “Velocity Boosters” to change the velocity of the moving objects. Velocity Boosters can increase or decrease velocity and they work instantaneously. In the next section, we will contrast instantaneous and gradual changes in velocity.



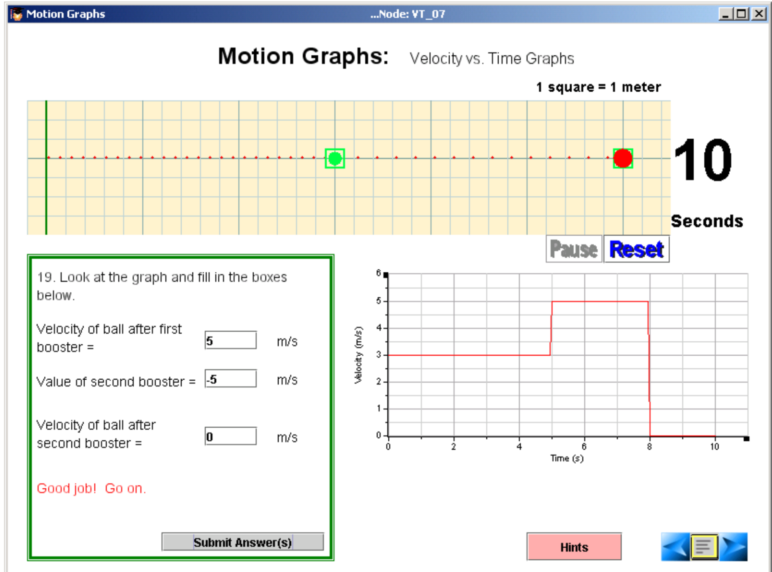

“Real world” scenario model for students



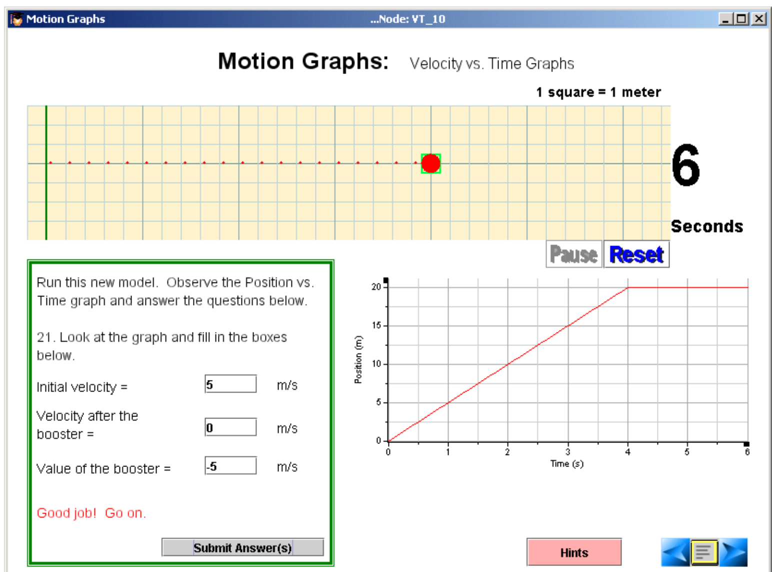

Comparing the Position and Velocity graphs



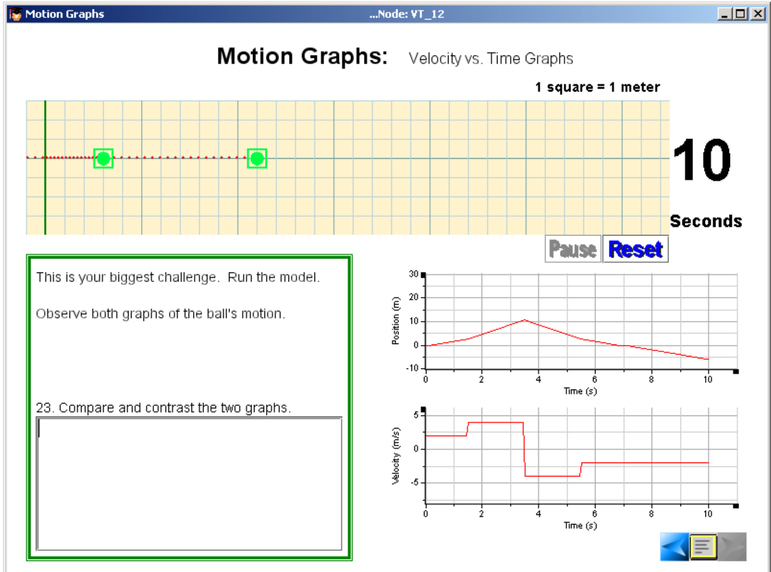

Graphical representation of change in velocity




Calculate change in velocity with Velocity graph



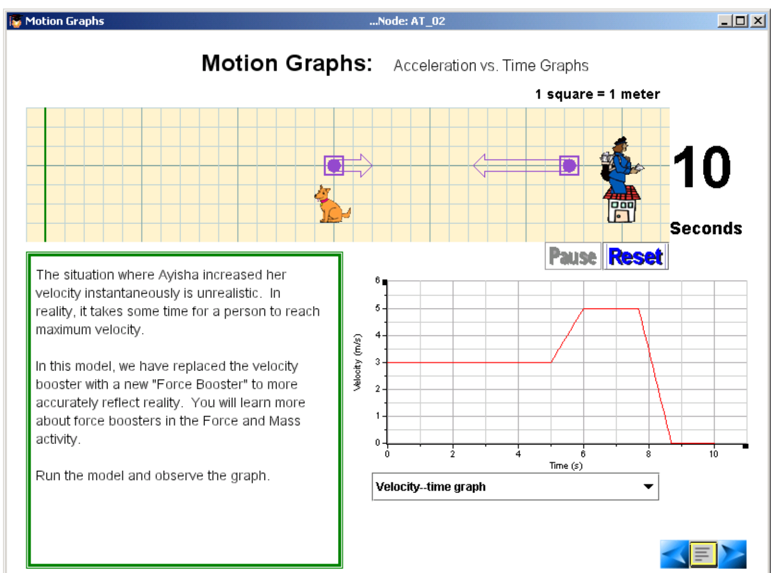

Calculate change in velocity with Position graph



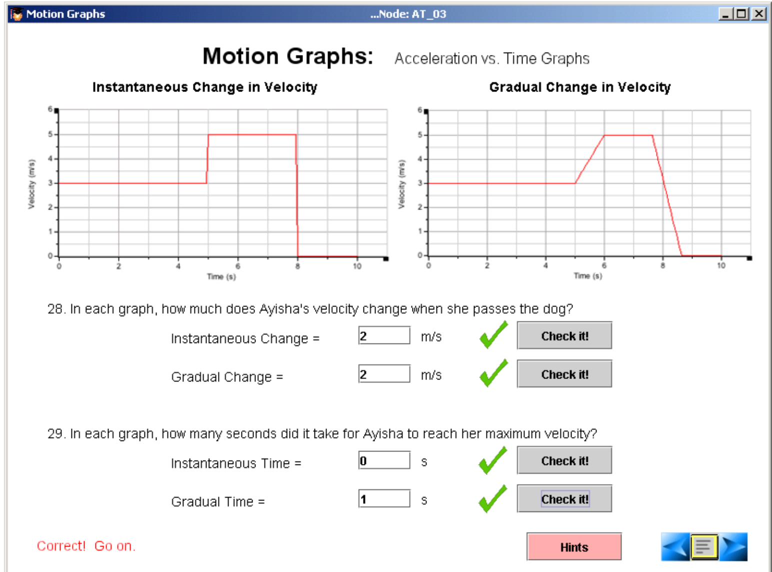

Challenge Problem: Students analyze velocity and position graphs

## 4.4 3) Acceleration vs. Time Graphs

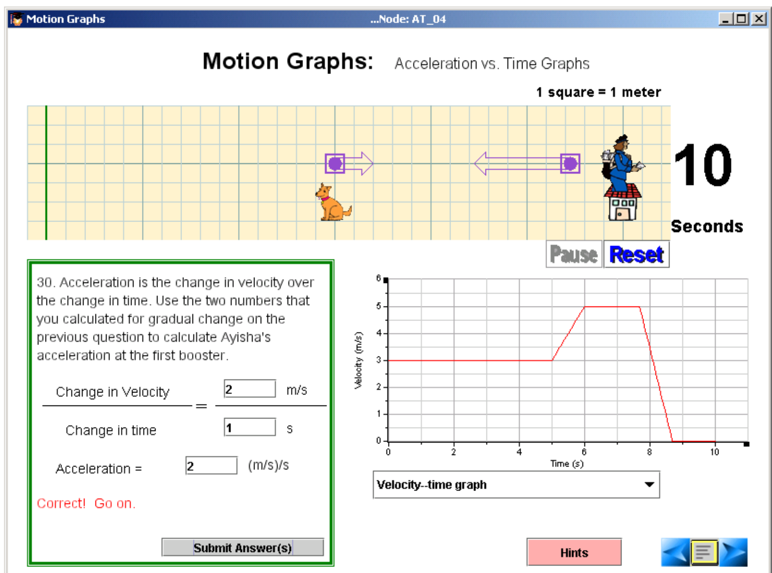
In this section, students are introduced to acceleration, or the change in velocity over a period of time. At the beginning, they contrast instantaneous and gradual change in velocity. Then, they run models using Acceleration vs. Time graphs. A new real world situation is also introduced.



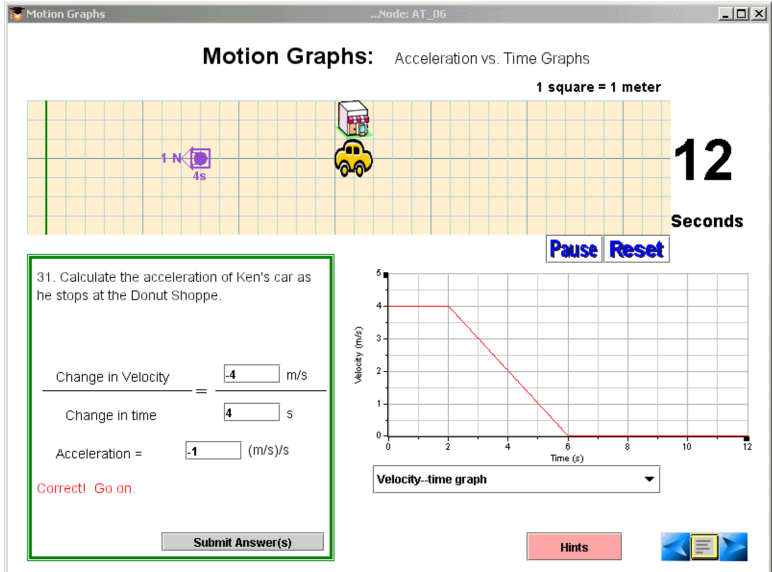

Student must translate vectors to map coordinates.



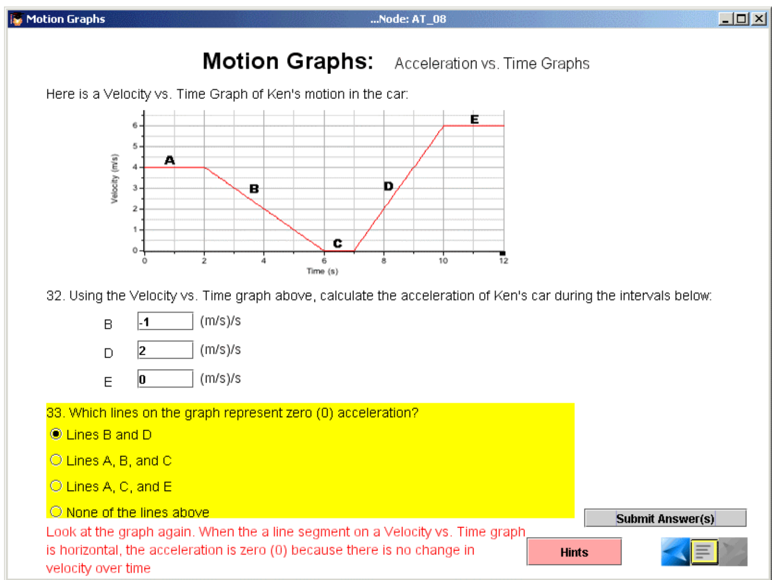

Check It! questions provide instant feedback




Acceleration is introduced.




Donut shop acceleration problem




Feedback on calculating acceleration from velocity graphs

## 4.5 4) Quiz

This quiz contains questions from a standardized test on motion graphs. There are 6 questions and all three graph types are tested. At the end of the quiz, the student will see his or her score. Once a student is done with the quiz, s/he cannot go back to change her/his answers.

Answers:

1- D 2- D 3- C 4- B 5- C 6- E

Quiz Questions:

Motion Graphs ...Node: quiz1

### Quiz time!

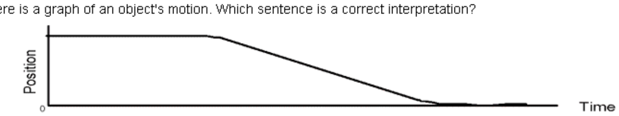
You have learned a lot during this activity. You have explored a number of different models and tracked an object's motion on Position vs. Time graphs, Velocity vs. Time graphs and Acceleration vs. Time graphs. In this quiz, you will be asked to answer six questions on interpreting graphs. Be sure to read each question carefully. Good luck!

1. To the right is a graph of an object's motion. Which sentence is the best interpretation?


- ○ A) The object is moving with a constant, non-zero acceleration.
- ○ B) The object does not move.
- ○ C) The object is moving with a uniformly increasing velocity.
- ◉ D) The object is moving with a constant velocity.
- ○ E) The object is moving with a uniformly increasing acceleration.

Motion Graphs ...Node: quiz2

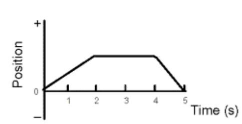
2. Here is a graph of an object's motion. Which sentence is a correct interpretation?




- ○ A) The object rolls along a flat surface. Then it rolls forward down a hill, and then finally stops.
- ○ B) The object doesn't move at first. Then it rolls forward down a hill and finally stops.
- ○ C) The object is moving at constant velocity. Then it slows down and stops.
- ◉ D) The object doesn't move at first. Then it moves backwards and then finally stops.
- ○ E) The object moves along a flat area, moves backwards down a hill, and then it keeps moving.

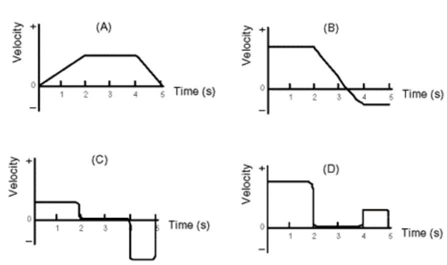
Motion Graphs ...Node: quiz3

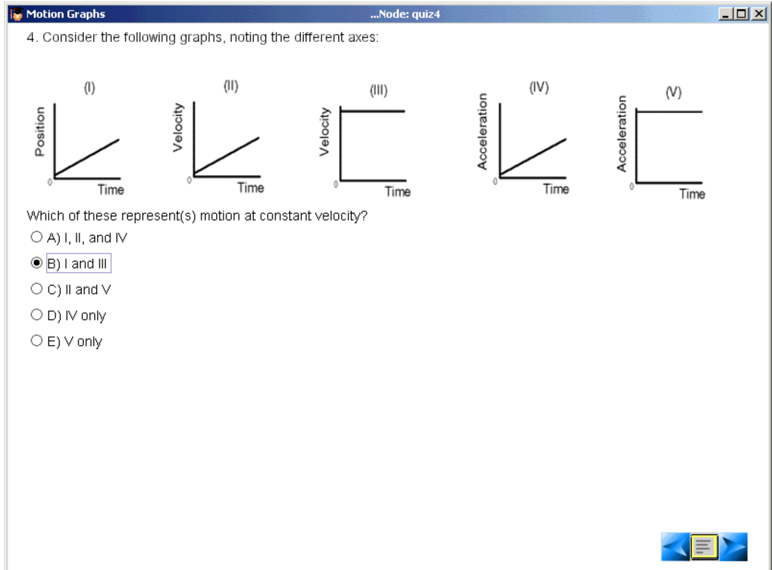
3. The following is a position-time graph for an object during a 5 s time interval.

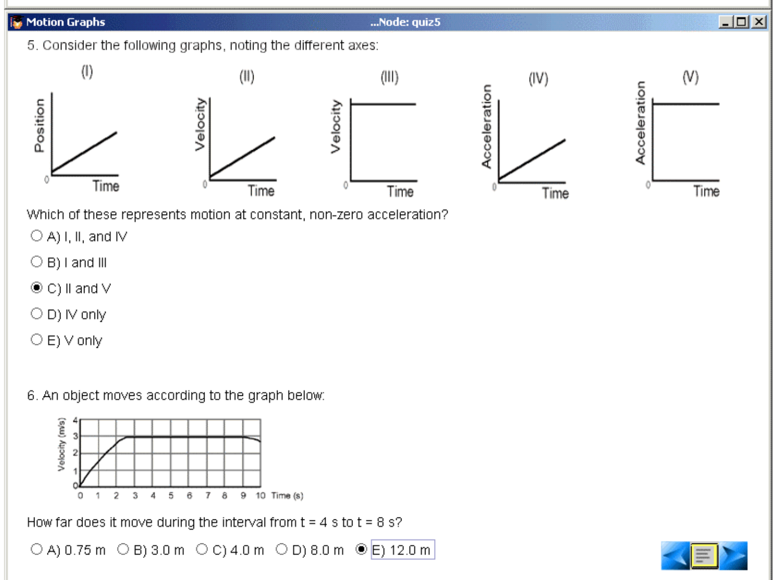


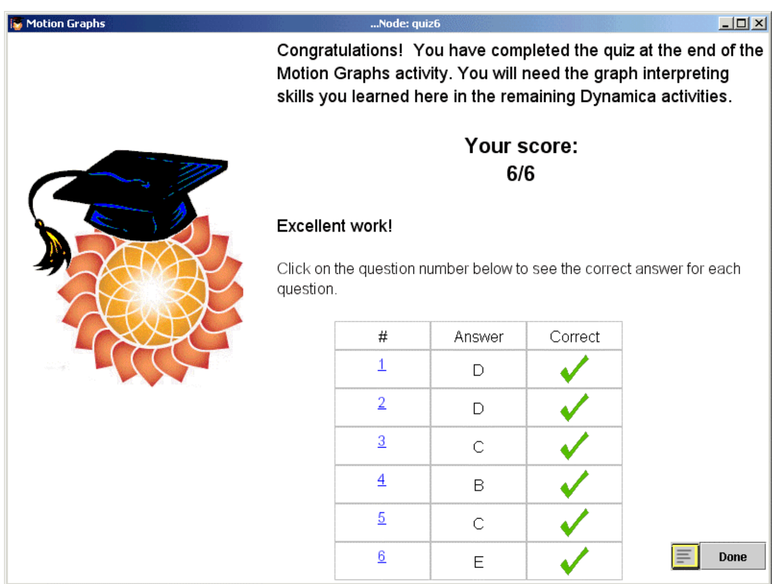

Which one of the following graphs of velocity versus time would best represent the object's motion during the same time interval?

○ A ○ B ◉ C ○ D






Quiz review: Click the question number to see the correct answer

## 5.0 Student Reports

Your students' work in Motion Graphs is logged and viewable on the MAC Project Web Portal at http://mac.concord.org. You will see all your students' responses for each screen in the activity as well as their responses for the Quiz.

The next activity in the Dynamica sequence is F=ma.