WALKING FEET

Students form an understanding of how time and distance are related to the average velocity and acceleration of an object.

A set of Phantom Feet® in action

GRADE LEVELS

Science activity appropriate for grades 7–9

KEY SCIENCE TOPICS

- acceleration
- kinematics
- motion
- velocity

STUDENT BACKGROUND

Students should know how to use a stopwatch and produce graphs and should be familiar with metric measurement. Before the start of the activity, review the definitions of velocity and acceleration.

KEY PROCESS SKILLS

• collecting data	Students collect time and distance data for the walking toy.
• making graphs	Students construct position-time graphs to investigate velocity and acceleration.

TIME REQUIRED

Setup	5–10 minutes
Performance	20–40 minutes
Cleanup	5–10 minutes

Materials

For the "Procedure"

Per pair of students

- Phantom Feet® by TOMY Corp. or similar wind-up walking toy
- meterstick
- 20–30 colored toothpicks
- stopwatch

➤ *It's not vital to the activity that each pair of students have a stopwatch. For example, if you have one stopwatch, you can call out time intervals for the class.*

For the Variation

- duct tape
- stop watch

Safety and Disposal

No special safety or disposal procedures are required.

Procedure

1. Choose a time increment to use during the activity, for example, 1-second or 5-second intervals.

➤ *The time interval you choose will depend on the speed of the toy. You may wish to experiment or have students experiment in advance to determine the most appropriate time interval.*

2. Tell students that they will be placing a colored toothpick on or next to the meterstick to mark the position of the walking toy as each time increment is called out.

3. Have each pair of students place the walking toy by the meterstick and mark the starting position.

➤ *Each team should experiment to see if their toy veers from a straight path. If it does, they should put their meterstick on the side to which the toy veers.*

4. Tell them to start the walking toy and the stopwatch and mark the positions until the toy stops.

5. Have students work in pairs to collect data. One student will read the positions that were marked at time intervals. The other will record the information in table form.

6. Instruct students to make position-time graphs.

➤ *Walking toys typically maintain a constant velocity for a while and then decelerate to a stop.*

7. Have the students calculate average velocities from either their tables or graphs, for example, average velocities for the entire trip, for the time interval from the start until the toy begins to slow down, for the interval of highest velocity, or for each of the recorded time intervals. If the average velocities for each time interval are obtained, these velocities can be used as the velocities at the midpoints of the time intervals to make a velocity-time graph. The velocity-time values can then be used to calculate average accelerations.

8. (optional) Have one team of students put its data, graph, and calculations on the overhead projector or the board for classroom discussion. For example, the highest average velocities obtained by the groups can be compared.

Variation

An interesting way to introduce these kinematic quantities is the Hallway Walk. Pairs of students attempt to walk at a constant velocity down a hallway where marks have been made at equal position intervals. Time is recorded at each mark during the walk. After the walk, the position and time data can be used to calculate average velocities as in the "Procedure." The marks can be made by

placing duct tape across the hallway; a useful interval is 5 m. One member of the team carries a stopwatch, maintains a constant velocity, and calls out the time at each mark using the lap timer feature of the stopwatch. The other member walks alongside and records the times as they are called out. The students can be advised to try a slow walk first, and later, after calculations have been done, they can be asked to try to double or halve the previous velocity. The average velocities for each interval and for the entire trip can be calculated. Prizes can be given for the most constant pace over all the intervals and for the best attempt at doubling the velocity.

Explanation

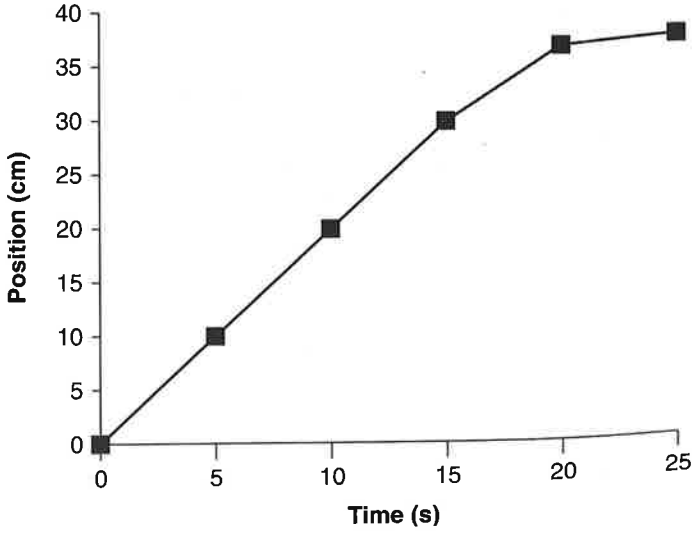
The following explanation is intended for the teacher's information. Modify the explanation for students as required.

In this activity, students collect time and distance data that enable them to calculate the two quantities defined in the study of motion, or kinematics: average velocity and average acceleration. Velocity is the rate of change of position, and acceleration is the rate of change of velocity. The quantities used in the definition of average velocity are displacement and time interval. Displacement is change in position or difference in final and initial positions. The time interval is the difference in final and initial times. Average velocity is defined as

$$v_{avg} = \frac{x_f - x_i}{t_f - t_i}$$

If position is graphed vertically and time horizontally, the graph is referred to as a position-time graph. According to the definition of average velocity, the slope of the line joining any two points is the average velocity over that time interval. A typical position-time graph for a walking toy is shown in Figure 1. The data points have been connected by straight lines that extend over the 5-second time intervals. In this example, the velocity is constant at 2 cm/s over the first 15 seconds of the trip, and then the toy slows down over the final 10 seconds.

Figure 1: Position-Time Graph for a Walking Toy

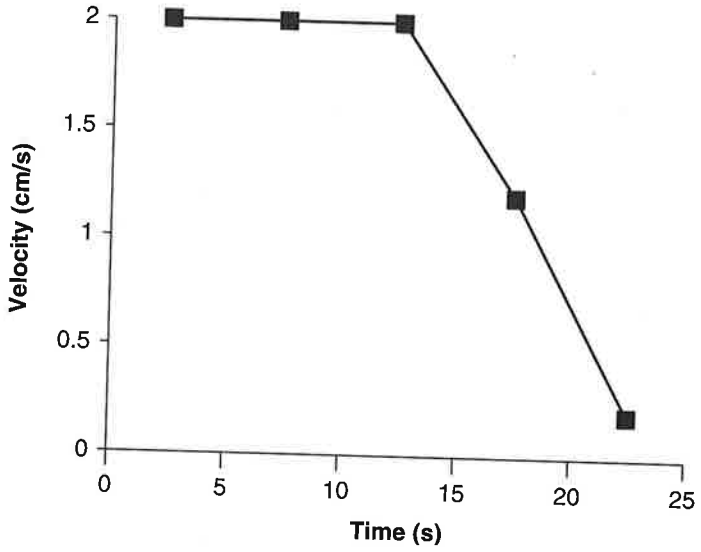


The two quantities used in the definition of average acceleration are velocity change, or difference in final and initial velocities, and time interval. Average acceleration is defined as

$$a_{avg} = \frac{v_f - v_i}{t_f - t_i}$$

If velocity is graphed vertically and time horizontally, the graph is known as a velocity-time graph. According to the definition of average acceleration, the slope of the line joining any two points is the average velocity over that time interval. A velocity-time graph for the walking toy in Figure 1 is shown in Figure 2. The velocities are the average velocities for the 5-second time intervals connected by straight lines in Figure 1, and they are plotted at the midpoints of the intervals. For this example, the acceleration is zero for the first part of the trip, since the velocity is constant there. During the last part of the trip, the acceleration is negative, called a deceleration, and it is approximately -0.2 cm/s^2. Straight lines extending over the 5-second time intervals have been drawn through the data points.

Figure 2: Velocity-Time Graph for a Walking Toy



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