ACTIVITY THREE
CONSTANT VELOCITY IN TWO DIRECTIONS

Purpose

The overall goal of this activity is for students to analyze the motion of an object moving with changing velocity along an inclined plane. In this experiment, the Motion Visualizer (MV) captures the motion of an orange ball rolling down an inclined plane. The MV assists in the resolution of displacement and velocity in x and z components. The concept of acceleration is studied.

After this activity, students should be able to do the following:

√ Describe, in words, what is meant when an object is accelerating.

√ Define the following: constant velocity, changing velocity/acceleration.

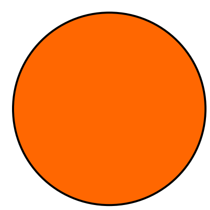
√ Predict how accelerated motion will be displayed on the following types of graphs: Distance v. Time, Position v. Time, Speed v. Time and Velocity v. Time, and Acceleration v. Time.

√ Compute the average acceleration of an object given velocity and time data.

√ Apply the equation Acceleration = ΔVelocity / Δ Time to various situations.

Materials

- A bright colored ball.
- Computer with Motion Visualizer software and activities kit.
- Video camera with tripod.
- Masking tape and marker.
- Angle measuring device.
- Tape measure or meter stick.
- A long ramp.
- Concrete blocks to elevate ramp.



Set-up Guidelines

1. Place concrete blocks on one side of a lab table.
2. Attach ramp to concrete blocks and table top.
3. Use angle finder to determine the angle of elevation of the ramp.
4. Adjust the view finder of video camera to see the entire ramp.
5. Mark the start and end of the ramp with masking tape and marker.
6. Place a bucket on the floor at the end of the ramp to catch ball.
7. One person should hold ball at start.
8. Another person should start the video camera.
9. Let ball roll.
10. Capture the motion of the ball with video camera MV software.

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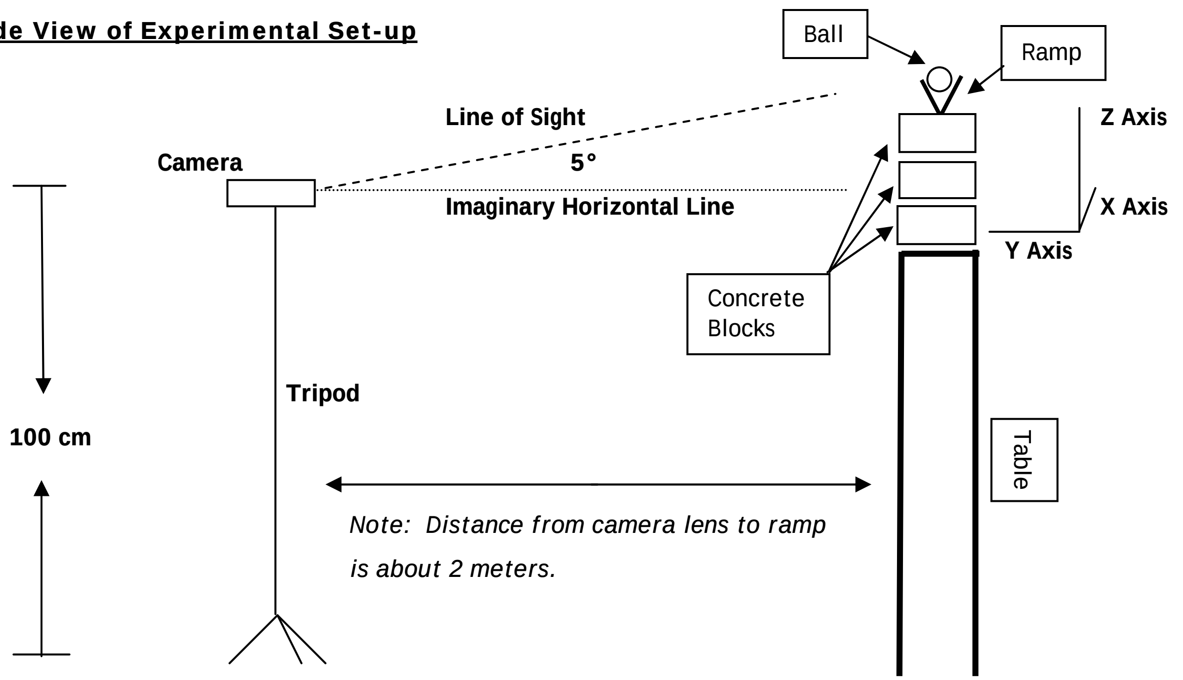
Diagram

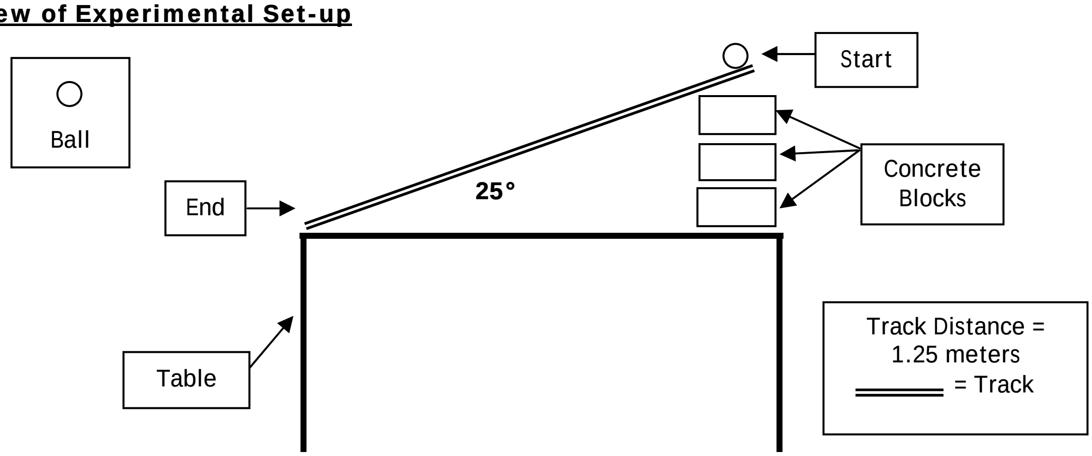
[Note: Refer to the MV Quick Start Guide for a complete description of equipment set-up. In the guide, you will find a comprehensive description of how the video camera should be set-up and the settings needed for each type of activity. You will also find instructions on how the MV software can be used to capture the motion of the object.

Below, you will find a diagram of how the equipment was used for this activity. This apparatus design works well but is just one of many possibilities. We encourage you to design your own set-up based on the materials available.]

Side View of Experimental Set-up



Camera View of Experimental Set-up



In this activity, the ball moved leftward and down the track. Since the motion of the ball occurs both in the horizontal and vertical directions, the video camera settings must be modified. This can be done by choosing *2D Camera Alignment* under the *Experiment* menu item [Figure 1.]

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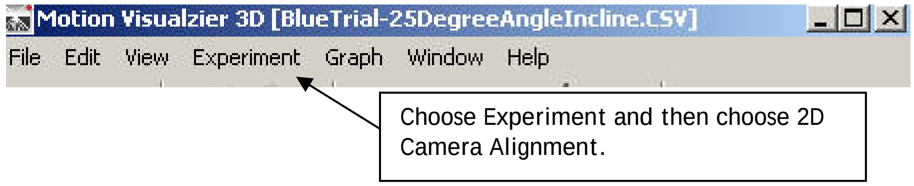
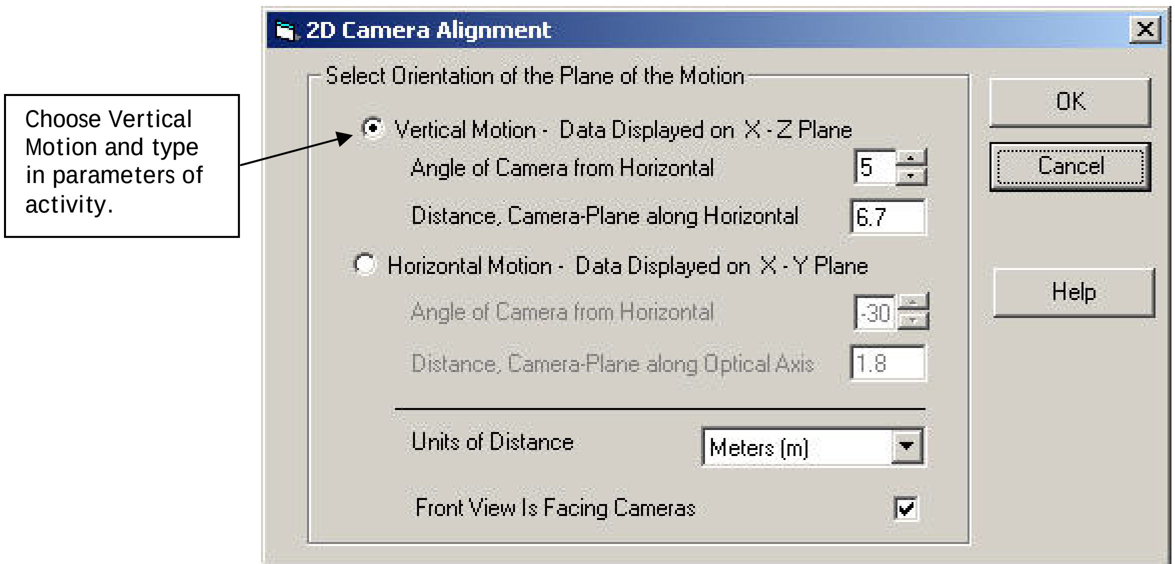
Figure 1



A dialog box will appear where the parameters of the experiment can be set [Figure 2.]

Figure 2



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Data Collection, Presentation and Analysis Guidelines

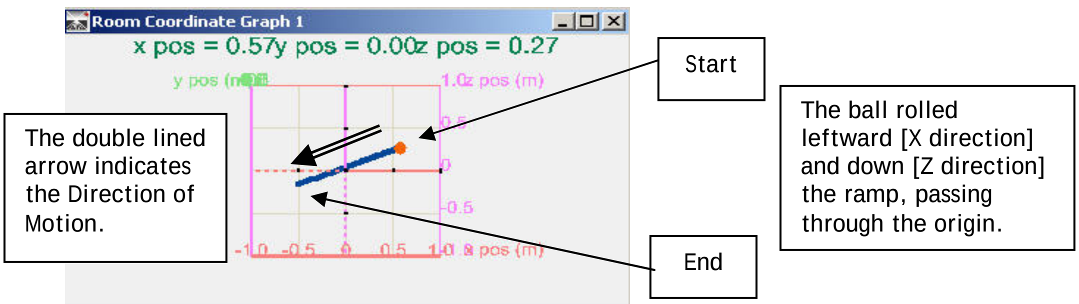
There are many ways to use the MV software to display the motion of an object; however, it is important to keep in mind the objective of the activity. This will help prevent the user of the software from displaying redundant or unnecessary information.

In this activity, the motion of an object moving with a changing velocity in the X and Z planes was studied. Knowing these guidelines, data that was irrelevant to the activity was not displayed [e.g., Y Position v. Time, Y Velocity v. Time, etc.] Only the graphs that best demonstrate accelerated motion in two dimensions were included. These graphs are here to provided with ideas about how the data can be used with students.

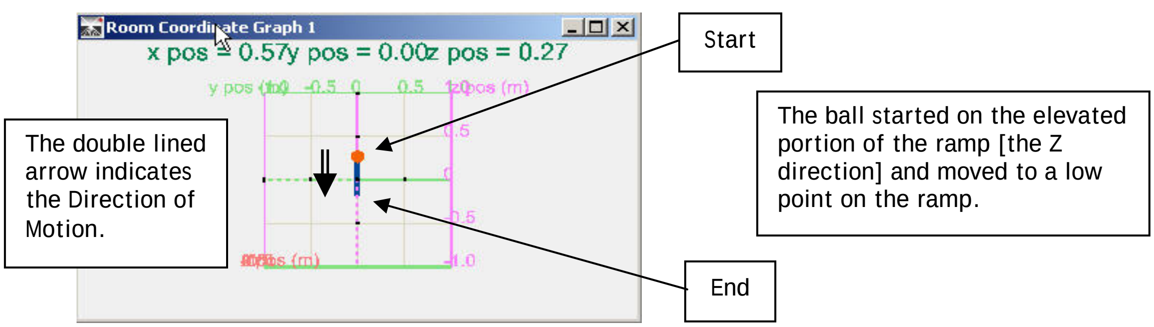
The following is a list of the graphs, with analyses, that can be used with this activity.

1. Room Coordinate Graphs– These images show the actual path of the object in the X and Z directions.

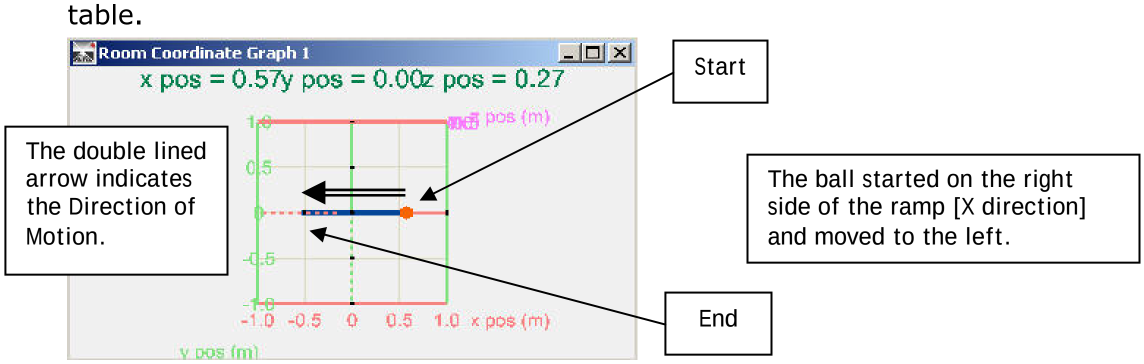
   - Camera view – This view shows the motion of the object from the camera's perspective.



   - Side view – This view shows the motion of the object looking from the side toward the elevated part of the ramp.



   - Top view – This view shows the motion of the object looking down on the table.



Since the motion happened in only the X and Z directions, it is recommended that these graphs be used for discussion purposes.

1. X Position v. Time Graph
   This is a graphical interpretation of the object's displacement in the X direction.

   Total X Displacement = X_f – X_s
   (-0.5 m – 0.5 m) = -1.0 m

- Students can describe, with words, the motion of the object as depicted by this graph.
- The curved nature of the graph should be highlighted showing that the distance the object covered increased for every equal time interval.

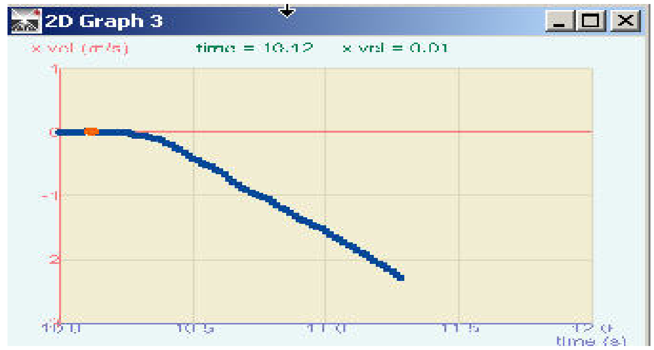
2. Z Position v. Time Graph
   This is a graphical interpretation of the object's displacement in the Z direction.

   Total Z Displacement = Z_f – Z_s
   (-0.2 m – 0.2 m) = -0.4 m

- Students can describe, with words, the motion of the object as depicted by this graph.
- The curved nature of the graph should be highlighted showing that the distance the object covered increased for every equal time interval.

3. X Velocity v. Time Graph
This is a graphical interpretation of the object's velocity in the X direction.

X Acceleration = $(VX_f - VX_s)$ / Δ Time
(-2.25 m/sec – 0.0 m/sec) / (11.25 sec – 10.25 sec) = -2.25 m/sec^2



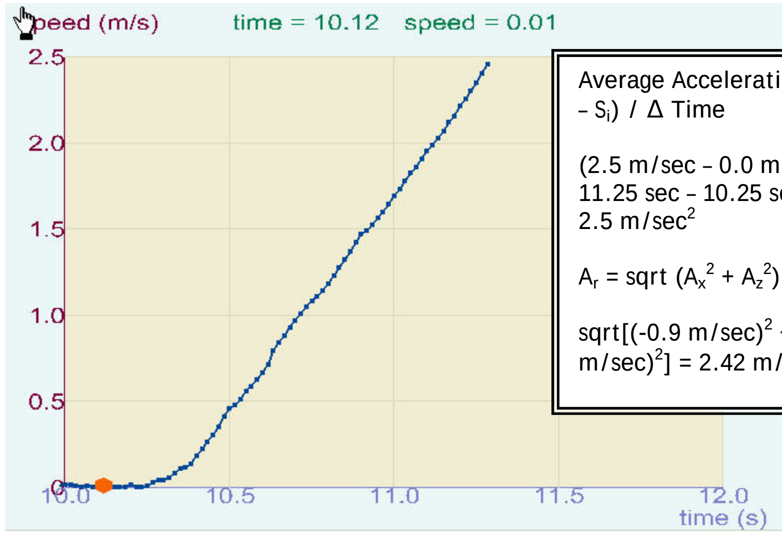
- Students can describe, with words, the motion of the object as depicted by this graph.
- Students can draw a best-fit line and calculate its slope.
- The meaning of the slope of a line on this type of graph can be discussed.
- A discussion of what this graph's slope means for the motion can be addressed.
- The calculated slope value can be compared to the X Acceleration v. Time graph.
- The idea that this is one component of the object's velocity can be discussed.

4. Z Velocity v. Time Graph
This is a graphical interpretation of the object's motion in the Z direction.

Z Acceleration = $(VZ_f - VZ_s)$ / Δ Time
(-0.9 m/sec – 0.0 m/sec) / (11.25 sec – 10.25 sec) = -0.9 m/sec^2

- Students can describe, with words, the motion of the object as depicted by this graph.
- Students can draw a best-fit line and calculate its slope.
- The meaning of the slope of a line on this type of graph can be discussed.
- A discussion of what this graph's slope means for the motion can be addressed.
- The idea that this is one component of the object's velocity can be discussed.
- Students can combine the two velocity vectors and arrive at a resultant velocity vector. The numerical value of this result can be compared to the average speed of the vehicle as shown on the Speed v. Time graph.

5. Speed v. Time Graph – This is a graphical interpretation of the object's combined Z and Z speeds.



Average Acceleration = (S_f – S_i) / Δ Time

(2.5 m/sec – 0.0 m/sec) / 11.25 sec – 10.25 sec) = 2.5 m/sec^2

A_r = sqrt ($A_x^2 + A_z^2$)

sqrt[(-0.9 m/sec)^2 + (-2.25 m/sec)^2] = 2.42 m/sec^2

- Students can describe, with words, what this graph tells them.
- Students can draw a best-fit line and calculate its slope.
- The meaning of the slope of a line on this type of graph can be discussed.
- A discussion of what this graph's slope means for the motion can be addressed.
- Students can determine the average acceleration of the object. The idea that this value represents the numerical portion of the resultant acceleration can be discussed.

6. X Acceleration v. Time Graph This is a graphical interpretation of the object's acceleration in the X direction.

= Best Fit line

Slope = 0 meaning constant acceleration

X Acceleration = -2.25 m/sec^2

- Students can describe, with words, what this graph tells them.
- Students can draw a best-fit line and calculate its slope.
- The meaning of the slope of a line on this type of graph can be discussed.
- A discussion of what this graph's slope means for the motion can be addressed.

7. Z Acceleration v. Time Graph
This is a graphical interpretation of the object's acceleration in the Z direction.

= Best Fit line

Slope = 0 meaning constant acceleration

Z Acceleration = -0.9 m/sec^2

- Students can describe, with words, what this graph tells them.
- Students can draw a best-fit line and calculate its slope.
- The meaning of the slope of a line on this type of graph can be discussed.
- A discussion of what this graph's slope means for the motion can be addressed.

Questions for Discussion

1. Describe what the following lines on a Position v. Time graph tells you about the motion of an object:
    - Positive slope
    - Negative slope
    - No slope

2. Sketch a Position v. Time graph for the following situations:
    - A car moving in the leftward direction at a steady speed
    - A car moving in the rightward direction at a steady speed
    - A stationary car

3. Compare and contrast the phrases *constant velocity* and *changing velocity*.

4. Sketch Position v. Time graphs for the following situations:
    - An object that is increasing in speed.
    - An object that is decreasing in speed.

5. Sketch Velocity v. Time graphs for the following situations:
    - An object moving in the leftward direction at a steady speed
    - An object moving in the rightward direction at a steady speed
    - An object that is moving faster and faster in the rightward direction.
    - An object that is moving slower and slower in the leftward direction.
    - An object that is moving faster and faster in the leftward direction.
    - An object that is moving slower and slower in the rightward direction and then turns to travel faster and faster in the leftward direction.

6. What would be the sign (+ or -) for the slope of a line on a Velocity v. Time graph for the following situations:
    - An object moving to the right that is speeding up
    - An object that is moving to the left and is speeding up
    - An object that is moving to the right and slowing down
    - An object that is moving to the left and is speeding up

7. Write the equation that is used to calculate acceleration.

8. Use the equation written in Question 7 to answer the following questions:
    - What is the acceleration of a car that goes from 10 m/sec to 25 m/sec in 6 sec?
    - How long will it take for a car that is accelerating at 4 m/sec^2 to go from 10 m/sec to 50 m/sec?
    - What is the change in velocity for a car that accelerates at 6 m/sec^2 for 12 sec?

9. How do the total vertical and horizontal times compare for a football that is kicked at a 45° to the ground?

10. If you throw a ball from your outstretched arm straight up in the air while you are running, where will it land? Explain.

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