ACTIVITY FOUR
ACCELERATED MOTION IN TWO DIRECTIONS

PURPOSE

For this experiment, the Motion Visualizer (MV) is used to capture the motion of a ball rolling down an inclined plane. The overall goal of this activity is for students to gain an understanding of acceleration in two directions. This can be accomplished by analyzing the various graphs produced by the MV software.

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

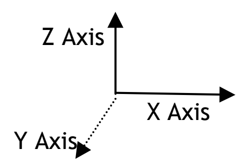
- √ Distinguish between *constant velocity* and *changing velocity*.
- √ Use words to describe what it means for an object to be accelerating.
- √ Predict how accelerated motion will be displayed on the various graphs.
- √ State the meaning of and determine the slope on a Velocity v. Time graph.
- √ Calculate the average acceleration of an object given velocity and time data.
- √ Apply the equation Acceleration = ΔVelocity / Δ Time to various situations.

ACTIVITY SET-UP GUIDELINES

Below, you will find a materials list and a description 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.

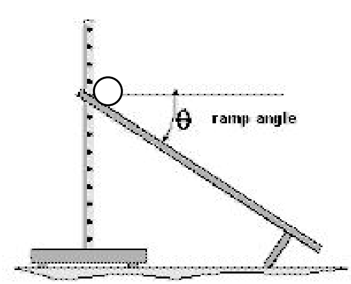
SOFTWARE SET-UP

This is a 2D, one-object experiment with horizontal motion. The distance from camera lens to plane of motion was set to 2 meters and the camera angle was set to + 5°. With this set-up, the software displays the horizontal motion on the X-axis and the vertical motion on the Z-axis.



MATERIALS

- Bright colored ball.
- Computer with MV software and hardware.
- Video camera with tripod.
- Angle measuring device.
- Tape measure or meter stick.
- Long ramp (about 2 meters.)
- Sturdy object(s) to elevate ramp.



PROCEDURE

1. Secure and elevate ramp to one side of table.
2. Place a bucket on floor at the end of ramp.
3. Adjust the view finder of video camera to capture entire range of motion.
4. Mark the start and end of the ramp with masking tape and marker.
5. Use angle finder to determine the angle of elevation of the ramp. Enter this value in computer.
6. Measure distance from camera lens to plane of motion. Enter this value in computer.
7. Place ball at start point.
8. Run experiment.

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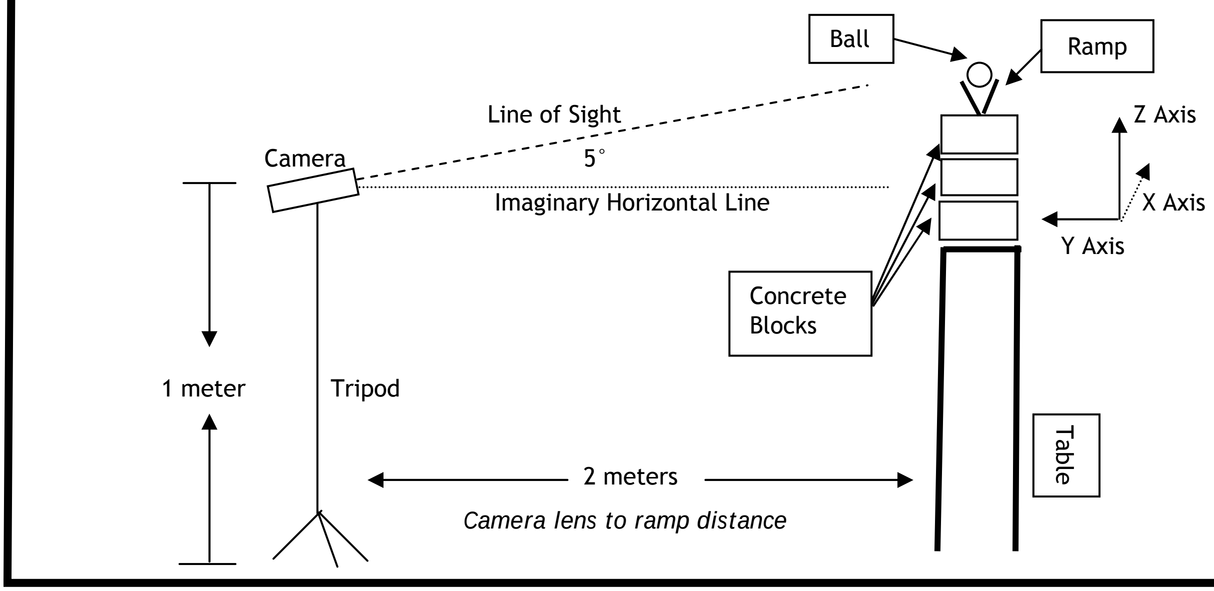
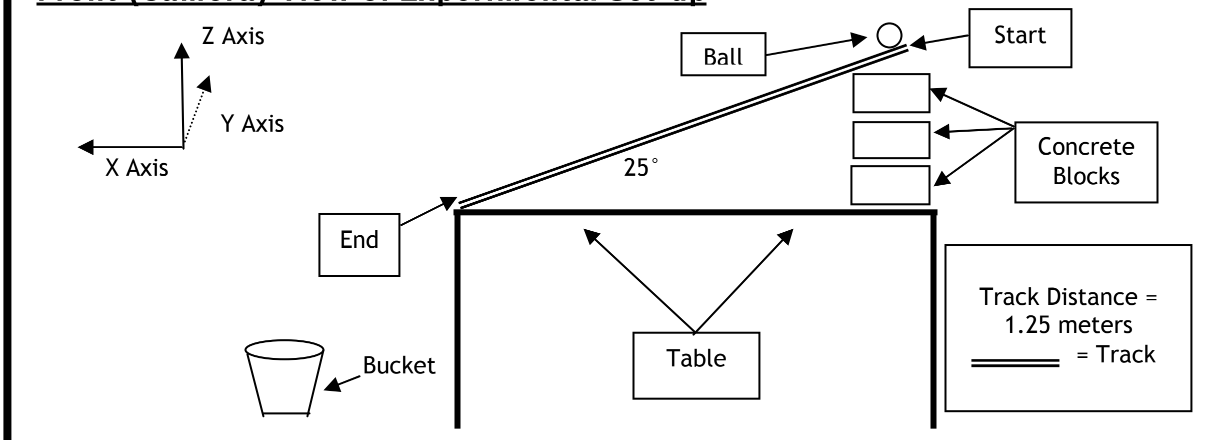
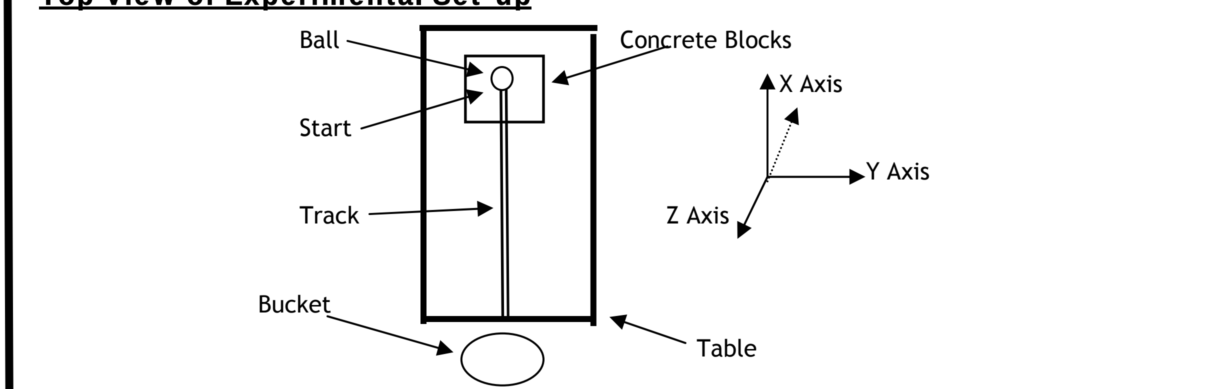
Side View of Experimental Set-up



Front (Camera) View of Experimental Set-up



Top View of Experimental Set-up



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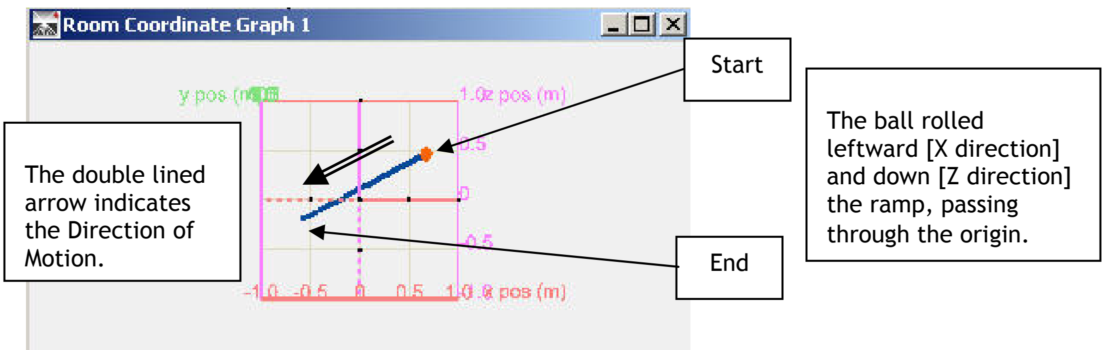
DATA COLLECTION, PRESENTATION AND ANALYSIS GUIDELINES

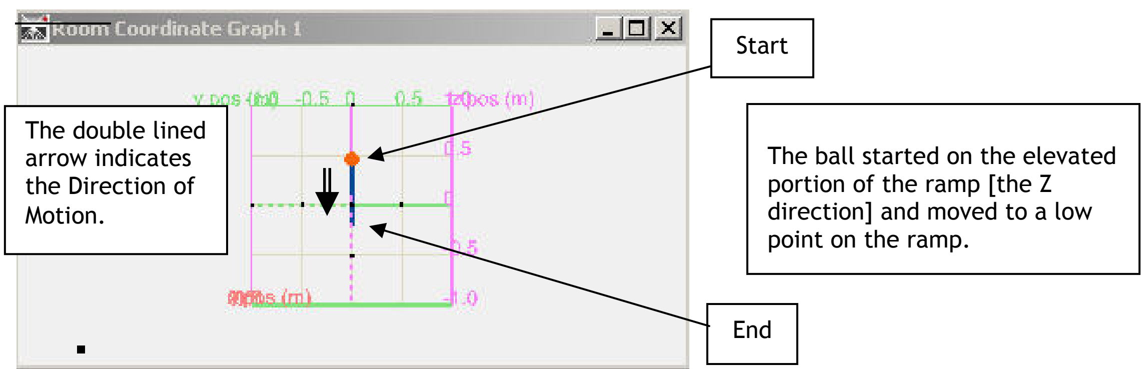
In this activity, an object was accelerating while moving in the X and Z directions. The following graphs are here to provide ideas about how the data can be used with students.

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

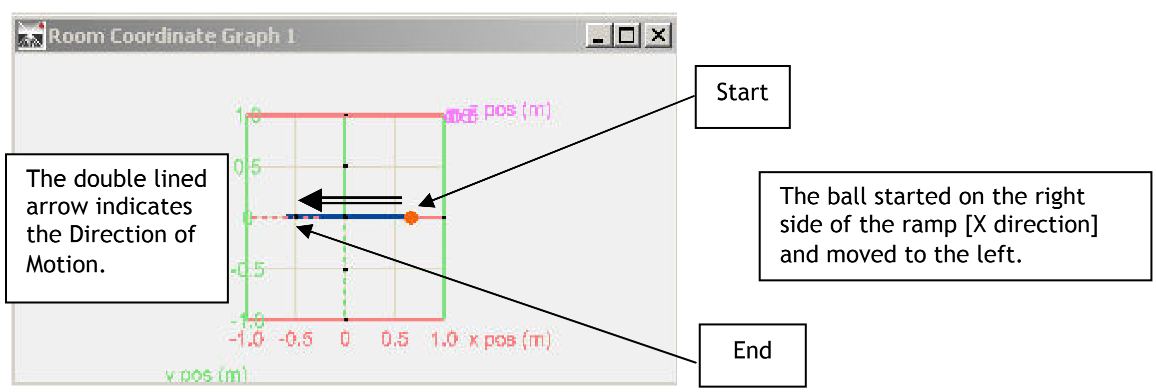
   - **Front (Camera) view** – This view shows the motion of the object from the camera's perspective.



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



   - **Top view (Bird's Eye) view** – This view shows the motion of the object looking down on the table.



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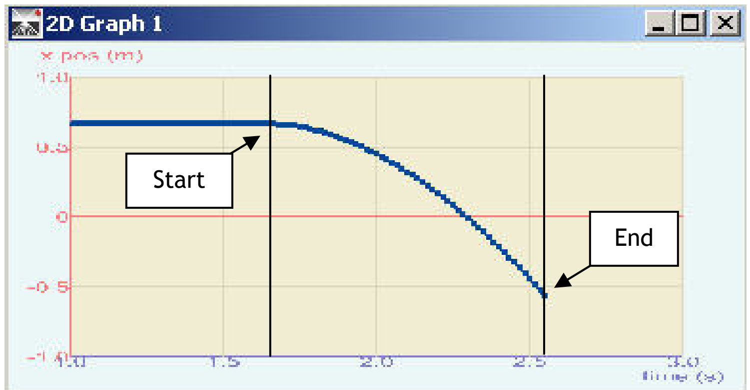
2. **X and Z Position v. Time Graphs** These are graphical interpretations of the object's displacement in the X and Z directions.

X Position v. Time Graph



Total X Displacement =

$X_f - X_s$

(-0.6 m - 0.6 m) = -1.2 m

Z Position v. Time Graph

Total Z Displacement =

$Z_f - Z_s$

(-0.2 m - 0.5 m) = -0.7 m

- Words can be used to describe the motion of the object as shown on these graphs.
- The curved nature of the graphs should be highlighted to show that the distance the object covered increases for every equal time interval, indicating a faster velocity.
- Tangent lines could be drawn at various points along the curves to show that the slope changes, indicating a changing velocity.
- The idea that these graphs only show one component of the object's displacement can be discussed.
- The total displacement of the object can be calculated.

Total displacement =

Sqrt $(DX^2 + DZ^2)$

Sqrt$(1.2^2 + 0.7^2)$ =

1.3 meters

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3. **X and Z Velocity v. Time Graphs** These are graphical interpretations of the object's velocity in the X and Z directions.

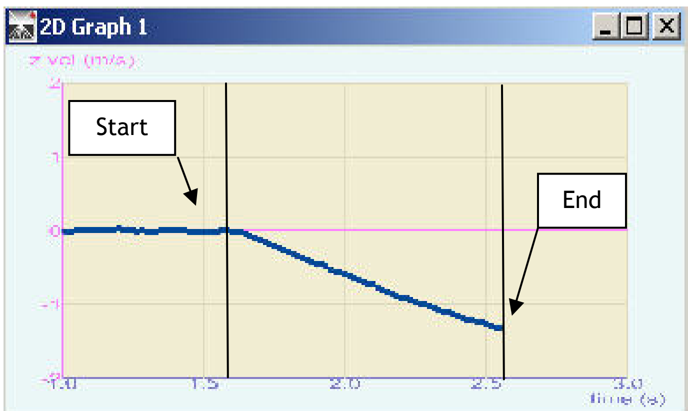
X Velocity v. Time Graph

X Acceleration =
$(VX_f - VX_s) / \Delta$ Time

(-2.6 m/sec - 0.0 m/sec) /
(2.6 sec - 1.6 sec) =

-2.6 m/sec^2

Z Velocity v. Time Graph



Z Acceleration =

$(VZ_f - VZ_s) / \Delta$ Time

(-1.3 m/sec - 0.0 m/sec) /
(2.6 sec - 1.6 sec) =

-1.3 m/sec^2

- Words can be used to describe the motion depicted on these graphs.
- Best-fit lines can be drawn.
- Slope values can be calculated.
- The meaning of slope on this type of graph can be discussed.
- The object's motion can be described by the slope.
- Each slope value can be compared to the X and Z Acceleration v. Time graphs.
- Each graph shows one component of the object's acceleration.
- The total acceleration can be determined from each component's acceleration.

Total average acceleration =

Sqrt $(AX^2 + AZ^2)$

Sqrt$(-1.3^2 + -2.6^2)$ =

2.9 meters/sec^2

4. **X and Z Acceleration v. Time Graphs -** These are graphical interpretations of the object's acceleration in the X and Z directions.

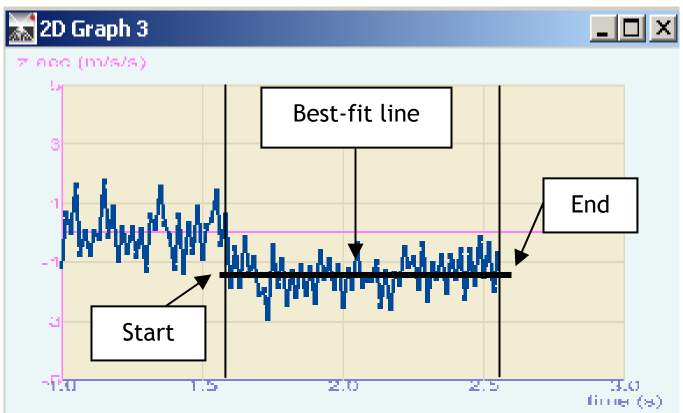
X Acceleration v. Time

▬▬▬ = Best Fit line

Slope = 0 meaning constant acceleration

X Acceleration = -2.6 m/sec^2

Z Acceleration v. Time



▬▬▬ = Best Fit Line

Slope = 0 meaning constant acceleration

Z Acceleration = -1.2 m/sec^2

- Words can be used to describe the motion of the object as shown on these graphs.
- Students can draw best-fit lines and calculate their slope.
- The meaning of slope 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 compare the acceleration shown on these graphs to the accelerations determined from the slope on the velocity v. time graphs.
- The total average acceleration can be calculated and compared to the total average acceleration found from the X and Z velocity graphs.
- Students can apply the equation Distance = 0.5 (Acceleration) X (Time)^2 to verify the distance traveled.

Total average acceleration =

Sqrt (AX^2 + AZ^2)

Sqrt(-2.6^2 + -2.6^2) =

2.9 meters/sec^2

X Distance = 0.5 (XA) X (Time)^2 = (0.5)(2.6)(1)^2 = 1.3 meters

Z Distance = 0.5 (ZA) X (Time)^2 = (0.5)(1.2)(1)^2 = 0.6 meters

Total Distance = 0.5(A) X (Time)^2 = (0.5)(2.9)(1)^2 = 1.45 meters

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

Magnitude of the Object's Average Acceleration =

$(SZ_f - SZ_s)$ / Δ Time

(2.9 m/sec - 0.0 m/sec) / (2.6 sec - 1.6 sec) =

2.9 m/sec^2

- Words can be used to describe the motion of the object as shown on 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.
- Students can determine the magnitude of the average acceleration of the object.
- The idea that this value represents the numerical portion of the resultant acceleration can be discussed.
- This value can be compared to the total average acceleration found from the X and Z velocity graphs.
- Students can apply the equation Distance = 0.5 (Acceleration) X (Time)^2 to verify the distance traveled.

Questions for Discussion

1. Use words to describe what an object might be doing if the following lines were printed on a Position v. Time graph:
    - Positive slope followed by no slope followed by negative slope

2. Sketch a Position v. Time graph 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 two equations that can be used to determine acceleration.

8. Use the equations 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?
    - How far did an object travel in 5 seconds when if it was accelerating at a constant 1.5 m/sec^2?

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.

Extensions

1. Predict graphs for different angles and directions of motion.
2. Collect data for different angle orientations.
3. Collect data for the ball rolling down the ramp in the opposite direction.

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