UNIT VI: 2-D Particle Models

Instructional Goals

1. **Free Fall**
   define free fall as motion when the only force acting on the object is gravity
   revisit 1-D accelerated motion (now in y-direction)

2. **Projectile Motion** (application of two particle models)
   extend 1-D math models of accelerated motion to 2-D projectile motion
      decompose projectile motion vectors into x and y components
      describe projectile motion as the simultaneous occurrence of two 1-D motions (horizontal and vertical)
   extend force diagrams and motion maps to motions in 2-D

3. **Other combinations of particle models**
   FP in different inertial reference systems (FP + FP)
   CFP in a non-inertial reference system (CFP + CFP)

Overview

In this unit students come to recognize that motion in 2 dimensions can be treated as combinations of the models they have learned thus far. They have already decomposed forces acting in directions other than vertical or horizontal. So, it should be a simple matter to see that constant velocity at an angle could be represented as the vector sum of constant velocities in both x and y directions. The object is exhibiting behavior of a free particle in both x and y directions.

In the case of projectile motion, students come to understand the parabolic path of the object is a consequence of the combination of constant velocity in the x-direction (free particle model) and constant acceleration in the y-direction (constant force particle model).

Instructional Notes

Instead of beginning with a paradigm lab, the first couple activities review basic skills in kinematics.

Worksheet 1

This worksheet deals with free fall from rest and with an initial downward velocity.

Wile E Coyote on Earth

This worksheet deals with an object that is shot upward, but with no horizontal component to its initial velocity. In the Resource folder are two variations of this worksheet that could be used as a quiz, if desired.

Video Analysis of Projectile Motion

Apparatus

Low-tech	**High Tech**
video camera	digital video camera
several VCR/monitor setups	iMac or PC with video card
overhead transparency sheets, markers	Videograph or VideoPoint software (PAS)

Pre-lab discussion

¥ Demonstrate projectile motion to your students. Ask them if either model - Free Particle (FP) or Constant Force Particle (CFP) appears to be adequate to describe the behavior of the object.
¥ Show students frame-by-frame view of projectile motion. Induce them to see that a 2-D motion map would allow them break down motion into x and y components.

Lab performance notes

¥ Be sure to have something to indicate scale in the background.
¥ Students should be encouraged to video projectile motion at home and bring tape to school.

Low-tech mode

¥ Affix transparency to monitor. Students mark position of object frame by frame. Be sure to mark some point as the origin.
¥ Place transparency on top of sheet of graph paper. Carefully determine x and y coordinates of points representing object.

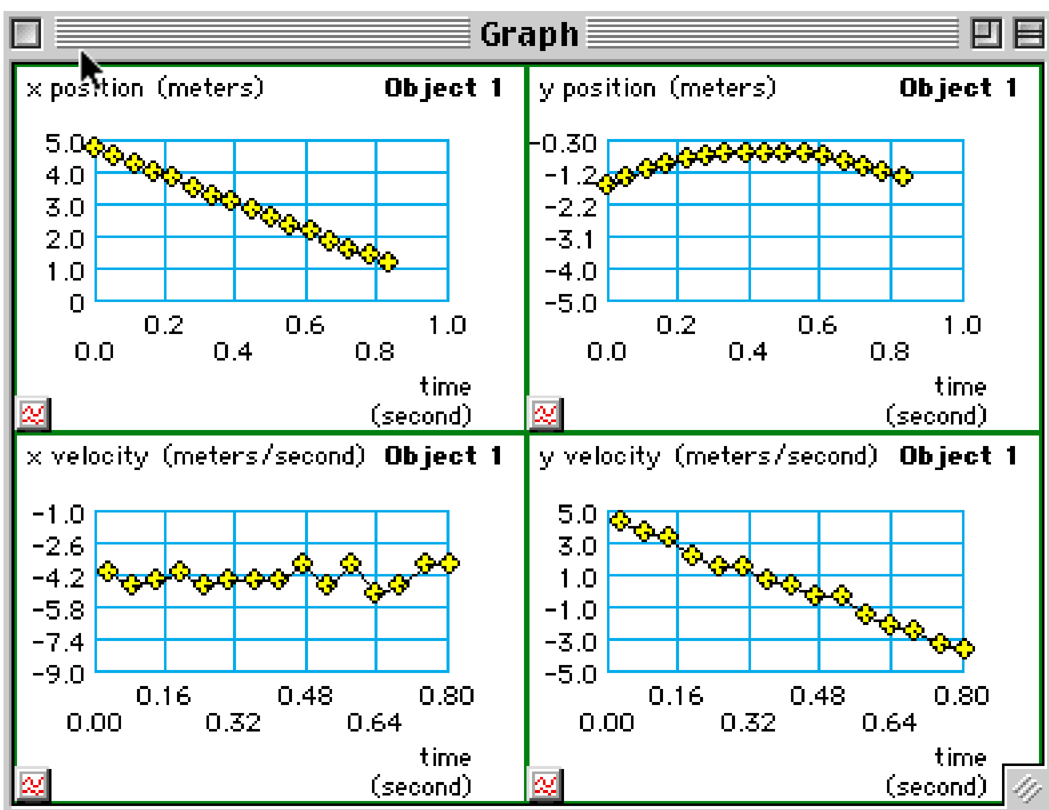
¥ Enter position/time data into spreadsheet.. Have students build formulas for determining x and y components of velocity.
¥ Use spreadsheet's graphing capability or export columns of data to Graphical Analysis for study.

High-tech mode

- Use iMovie (for digital video) or MyVideo (for VHS) to produce a QuickTime movie of a video clip. You need only have one AV-capable computer to do this, so long as you have the ability to transfer the files readily to other computers. QuickTime movies of even brief clips will be too large to fit on a floppy disk.

¥ Use video analysis software (VideoGraph or VideoPoint) to locate position of the object frame by frame.

- VideoGraph allows students to view position-time and velocity-time graphs in both the x and y directions.



Videograph will even determine slope as well as the area under the curve for a v - t graph.

VideoPoint has a wide variety of movies on the CD for analysis by the software. This saves students the task of producing the movies and allows them to focus on the analysis of the movies. However, students generally find movies of their own making more interesting to analyze than pre-made movies.

Post-lab discussion

- Have students make motion maps decomposing velocity vectors into x and y components.
- Students should mathematically model the motion of the object in the x -direction. The straight-line position-time graph should indicate to students that the object is moving at constant velocity in the horizontal direction. The parabolic position-time graph in the y-direction should be a clue that the object is accelerating vertically. The implication is that the object is subject to a constant force. The slope of the y-velocity vs time graph gives the acceleration of the object; for most objects this value should be nearly - 10 m/s^2. Students should be able to draw the conclusion that the only force acting on the object is the force of gravity.
- Lead students to see by combining the free particle model and the constant force particle model, one can explain the trajectory of a projectile.

Worksheet 2

Worksheet 3

These worksheets provide opportunities to use the skills learned in the lab to solve projectile motion problems.

Quiz

Model Deployment Lab (Practicum) - Trajectory

Apparatus

metal rails
steel balls
ring stands and clamps (or equivalent to secure incline and hold rail)
photogates
meter sticks
target and carbon paper
Timing software

Pre-lab discussion

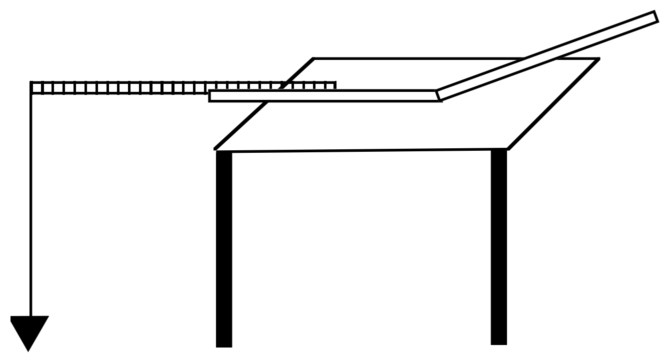
¥ Ask students to do the following:
draw a sketch of the ball’s path from the time of release to hitting the floor.
construct a motion map of the ball’s path.
draw force diagrams of the ball during each part of its motion.

¥ Ask students what quantities they must know in order to predict where the ball will hit the floor. They need to mention the instantaneous velocity when the ball leaves the rail and the time for it to hit the floor after leaving the rail. Discuss how to determine the instantaneous velocity.

- Ask students what mathematical tools they will need to determine where the ball will hit the floor.
- If the ball is launched at an angle, remind students that they need to determine the horizontal and vertical components of velocity.
- Students may roll the ball down the ramp as many times as they want to get data to calculate the distance to the impact point, but they must catch the ball at the end of the ramp. They can only let it hit after they predict the distance.

Lab performance notes

- Use a horizontal rail for regular classes; an inclined rail for honors classes.
- Don't let the metal ball hit the floor; have the students catch it before it hits. Only allow it to hit the floor after the students have made their prediction.
- Place the target on the floor, then use the following hint to help students line up the rail with the target.



Place a meter stick in the rail and hang a plumb line off the end of the meter stick. Place the target under the plumb bob, then place a sheet of carbon paper on top of the target. When the ball strikes the floor, it leaves a mark on the target.

Test