INVESTIGATION 1.4.1 *continued*

5. Repeat step 4 for the motion with an initial horizontal velocity (see **Figure 3**, Motion B). Ignore sparker dots created when the pushing force was in contact with the puck or created after the puck came near the edge of the table.

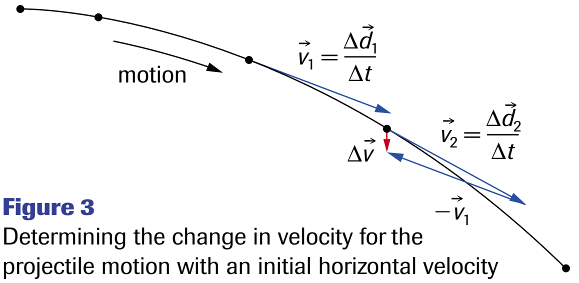

Figure 3
Determining the change in velocity for the projectile motion with an initial horizontal velocity

6. Repeat step 5 for the motion in which the puck was launched upward from the initial position (see **Figure 4**, Motion C).

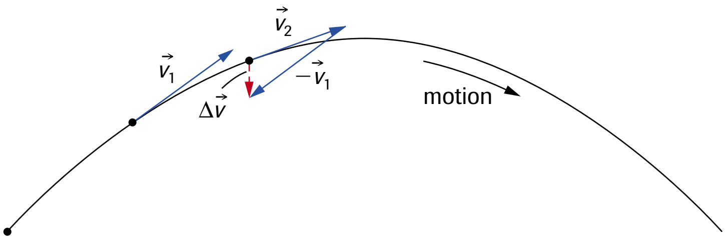

Figure 4
Determining the change in velocity for the projectile motion with an initial velocity at an angle to the horizontal

Analysis

(b) Compare the magnitudes and directions of the accelerations for the three motions tested in this investigation.

(c) Use the angle of the table, θ, to determine the magnitude of the acceleration down the inclined plane. (*Hint:* Use the equation $a = g \sin \theta$, where $g = 9.8$ m/s^2.)

(d) Find the percent difference between your answer in (c) and each of the other average accelerations.

(e) Answer questions (i) and (ii).

Evaluation

(f) Comment on the accuracy of your hypothesis.

(g) Describe random and systematic sources of error in this investigation. How could you minimize these sources of error?

Synthesis

(h) In analyzing the vectors of the motions in this investigation, is it better to use smaller or larger values of Δt? Give your reasons.

(i) Explain why you were asked to calculate the percent difference rather than the percent error in (d).

(j) Prove that the equation $a = g \sin \theta$ is valid for the magnitude of the acceleration down a frictionless plane inclined at an angle θ to the horizontal.

LAB EXERCISE 1.4.1

Hang Time in Football

Inquiry Skills

- ○ Questioning
- ○ Hypothesizing
- ● Predicting
- ○ Planning
- ○ Conducting
- ○ Recording
- ● Analyzing
- ● Evaluating
- ● Communicating

To give the punting team (**Figure 1**) time to get downfield to tackle the receiver, the hang time of the football must be as great as possible. But at the same time, the horizontal range of the ball must be large so that the team can gain field advantage. Factors such as the launch angle, the initial speed, and wind speed and direction affect the ball's motion, which makes experimentation complex. This lab exercise uses a small sampling of data from video recordings of football games. As you analyze the data, consider how you would extract a kinematics data set from a video of your favourite sport.

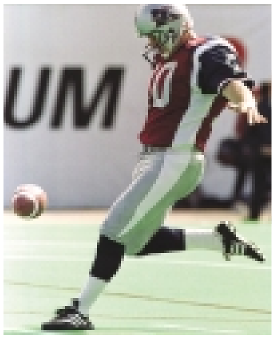

Figure 1
Think of all the factors that affect the hang time and horizontal range of a football during a football game.

LAB EXERCISE 1.4.1 *continued*

Question

How does maximizing the hang time and horizontal range of a football punt compare with maximizing the time of flight and horizontal range for an "ideal" projectile that has the same landing level as its starting level?

Hypothesis/Prediction

An ideal projectile (one with negligible air resistance acting on it) has a maximum horizontal range when it is launched at an angle of 45°. Its time of flight increases at angles greater than 45° above the horizontal and decreases at angles less than 45°.

(a) Predict what range of launch angles for a football will result in a combination of good hang time and good horizontal range.

Materials

For the data already analyzed:
video recordings of some football games
a VCR machine with stop-action control at known time intervals (such as 1.0 s)
transparent grid to determine angles and distances on the video screen
protractor
ruler

For student analysis:
graph paper

Evidence

Several punts were analyzed to determine the angle of launch θ, horizontal range x, hang time Δt, and an estimate of the initial velocity of the ball. For this exercise, only those punts with an initial velocity of magnitude 3.0×10^1 m/s, and with launch angles from 35° to 65° at 5° intervals were chosen. **Table 1** gives the resulting data.

Table 1 Data for Lab Exercise 1.4.1

x (m)	58	60	60	58	54	49	44
Δt (s)	3.1	3.5	3.8	4.2	4.4	4.6	4.7
θ (°)	35	40	45	50	55	60	65

Analysis

(b) Plot a graph of the horizontal range x as a function of hang time Δt. Choose the vertical axis to go from 40 m to 60 m, and the horizontal axis to go from 3.0 s to 5.0 s. Label the launch angle that corresponds to each data point on the graph.

(c) Looking at the graph and the data in the table, state what you think would be a range of launch angles that would achieve a good hang time and a good horizontal range. Explain your choice.

(d) Answer the question.

Evaluation

(e) Do the evidence and the analysis support or refute your hypothesis? Explain your answer.

(f) What assumptions would have to be made to gather the data presented in the data table?

(g) List sources of random and systematic error that are likely in this type of measurement and analysis.

(h) If you were trying to analyze the motion of a projectile in a sports activity, what would you do to obtain the most accurate data possible?

Synthesis

(i) If you had your choice of analyzing football punts in an open stadium or a closed one, which would you choose to obtain the most accurate results? Why?

(j) How could what you learned in this lab exercise be applied to enhance the performance of athletes?