

Name _____

Partner(s): _____

Experiment 2 – Free Fall and Projectile Motion

Objectives Learn how to solve projectile motion problems. Understand that the acceleration due to gravity is constant (9.8 m/s^2) and downward toward the center of the Earth. Understand that the horizontal motion and the vertical motion are decoupled.

Preparation You will be pressed for time during the lab. Since successful completion of all lab activities counts towards your final lab grade it will be important to be well prepared by doing Pre-Lab assignments and reading the entire lab **before** attending the lab.

Pre-Lab Read the Pre-Lab introduction and answer the accompanying questions and problems **before** this Lab.

Points earned today

Pre-Lab _____

Lab _____

Challenge _____

Total _____

Instructor Initials _____

Date _____

Pre-Lab for LAB#2

Intro Free Fall and the Acceleration Due To Gravity

What happens when you toss a ball up in the air? Or when an object is dropped? These are both examples of freely falling objects – a special case of uniformly accelerated motion in one dimension. The acceleration of a freely falling object is called the acceleration due to gravity, and its magnitude is denoted by the symbol g . In our laboratory near the surface of the Earth g has a value of 9.8 m/s^2 . This acceleration is always directed down toward the center of the Earth.

Projectile motion is a special case of uniformly accelerated motion in 2 dimensions. The only acceleration is the acceleration due to gravity with a magnitude of 9.80 m/s^2 directed down toward the center of the Earth. In projectile motion there is no acceleration in the horizontal direction.

Equations in “ x ” direction (usually the horizontal direction) also apply to “ y ” direction (usually the vertical direction) since in projectile motion we can treat the x and y motions independently. The location of a coordinate system is important to define the “direction” (+ or - sign) of accelerations, velocities, and displacements.

You – the observer – choose the direction and location of the coordinate system. Always show your coordinate system as part of the solution.

Equations For general uniformly accelerated motion in 2 dimensions:

$$v_x = \frac{\Delta x}{\Delta t} \quad a_x = \frac{\Delta v_x}{\Delta t}$$

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$$

$$\Delta x = \bar{v}_x t = \frac{(v_x + v_{x0})}{2} t$$

$$v_x = v_{x0} + a_x t$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

$$v_y = \frac{\Delta y}{\Delta t} \quad a_y = \frac{\Delta v_y}{\Delta t}$$

$$y = y_0 + v_{y0}t + \frac{1}{2}a_y t^2$$

$$\Delta y = \bar{v}_y t = \frac{(v_y + v_{y0})}{2} t$$

$$v_y = v_{y0} + a_y t$$

$$v_y^2 = v_{y0}^2 + 2a_y(y - y_0)$$

For projectile motion this simplifies:

$$a_x = 0 \quad (\text{assuming we use } x \text{ for the horizontal direction})$$

$$v_x = \text{constant} \quad (\text{no acceleration})$$

$$a_y = +/- 9.80 \text{ m/s}^2 \quad (\text{the sign depends on the direction of the } y\text{-axis in your coordinate system. If the positive } y\text{-axis points up, use } a_y = -9.80 \text{ m/s}^2)$$

Pre-Lab for LAB#2

Problem 1 The Basketball

Let's assume a basketball is dropped from a height of 1.5 m. How long will it take the basketball to reach the ground and what velocity will it reach?

Show Your Problem Solving Steps:

Show these below:

- 1) (Simple) Sketch
- 2) Choose origin and coordinate direction.
- 3) Inventory – What is known? [Note: Any variables are now taken with respect to your coordinate system – consider this when you write down values and signs.]
- 4) Write the appropriate kinematics equation(s) and solve.

Problem 2 More Basketballs

Use these values of initial position and initial velocity in the following questions.

Initial position: 1.0 m above ground
Initial velocity: 6.3 m/s, up

Question What is the magnitude and direction of the acceleration as the ball goes up?

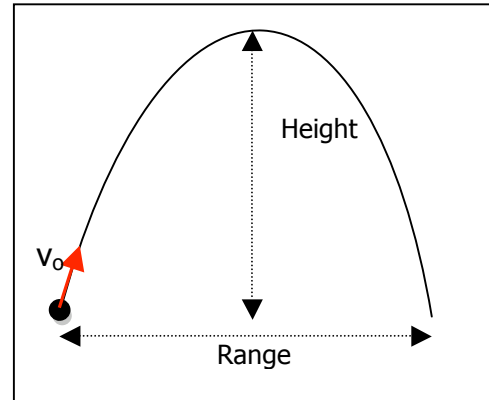
What is the magnitude and direction of the acceleration as the ball goes down?

Pre-Lab for LAB#2

Problem 3 A small ball is launched at an angle of 30.0 degrees above the horizontal. It reaches a maximum height of 2.5 m with respect to the launch position. Find (a) the initial velocity of the ball when it's launched and (b) its range, defined as the horizontal distance traveled until it returns to his original height. As always you can ignore air resistance.

(a) Initial velocity

[Hints: How is v_0 related to v_{x0} and v_{y0} . How can you use the information given to calculate either or both of the components of the initial velocity?]



(b) Range

[Hints: This problem is very similar to today's Lab Challenge except that for the challenge the ball will land at a different height.]

Laboratory

List of Today's Activities

Check Pre-Lab

Introduction Introduction to the equipment. What is expected of students.

Group Activity Group Work Problem (Motion in 2 dimensions)
You and your partner(s) solve a problem related to today's activities on your own.

Lab Challenge **Target Practice**
Projectile motion. Predict where a ball will land.

Activity 1 Group Work Problem (Motion in 2 dimensions)

Projectile Motion

You might think it is easy to throw a ball straight up into the air. Actually, it's quite difficult to do this, more likely the ball moves a bit horizontally as well. To describe this we need to talk about motion in 2 dimensions. Here is a simple example: Imagine that a ball is tossed across the room along an arc. Neglecting air resistance, where along the arc is the *speed* of the ball

a minimum? _____

a maximum? _____

Lab rooms usually have a level surface. Is that relevant for your answer? What – if anything – would change if the room slopes downward at the far end?

Where along the path of the ball does the acceleration change? What is the acceleration of the ball 0.78 seconds before it hits the ground?

Activity 2 Lab Challenge: Target Practice

Ball

Launcher

In this activity, we investigate the consequence of vertical and horizontal motions being independent. Remember the experiment, shown in lecture, of two steel balls falling to the ground – one with and the other without a horizontal velocity?

This activity is about projectile motion. Projectile motion is a special case of uniformly accelerated motion in two dimensions with (constant) acceleration only in the vertical direction. Since there is no acceleration in the horizontal direction the horizontal velocity stays constant.

The goal is to predict where a steel ball will land after it is launched at a certain angle from a launcher.

Apparatus Projectile Launcher

This lab will employ a spring driven projectile launcher. Your lab instructor will demonstrate how to use the projectile launcher.

Hints

Here are some important hints that will help you solve this challenge:

- You can neglect air resistance.
- You can assume that the magnitude of the launch velocity is independent of the launch angle.
- *Pay attention:* The initial position of the ball is not its position when the spring is compressed. The initial position is that when the drive shaft is fully extended (where the ball is released).
- The initial position of the ball is **not** level with the tabletop. You will need to measure this, but the apparatus has been designed well so that this value won't change when you change the launch angle.

Caution

Do not load the launcher while your head or body is in the line of fire. Do not allow anyone to get hit by the ball.

You will perform two kinds of launches: straight up and at an angle. Do not perform any launch unless every member in your group is aware and ready. Do not load the launcher for the angled launch unless your instructor is present.

Exercise 1 Determine the launch speed.

Use the minimum setting of the launcher; otherwise, the speed of the ball will be too great.

Orient your launcher so that it launches straight up. Launch the ball once or twice just to observe its motion. Then launch the ball and measure its peak height three times. Using the average height, calculate the launch speed of the ball.

Use the vertical meter stick to measure the peak height. You will have to “eyeball” this and catch the correct moment. You should be able to do this to within a centimeter. Make sure the person that does the measurement has his or her head near the peak height and does not view at an angle. No one should have their head near the line of fire.

Launch Speed: _____ m/s

Input Your instructor will tell you the launch angle (between 0° and 45°) for your group. Enter this value below.

Launch angle for range experiment: _____

Exercise 2 Determine the initial vertical position.

Carefully adjust your launcher to this angle. Use the meter stick to measure the height of the ball above the tabletop. Remember that the spring in the launcher compresses and then expands. What is the correct position to measure the initial position?

Initial Vertical Position: _____ m

- Kinematics equation(s) – Treat the horizontal and vertical motion separately.

Predicted Range: _____

No practice runs - Do not load your launcher until you have permission from your instructor.

Exercise 4 Test your prediction

Your instructor will place a small target at your predicted position. Once he gives you permission you can launch the ball.

- Our prediction was correct and the ball hit the target.
- The ball missed the target.

Please clean up your worktable for the next class.

End of Lab 2