Week 6: Horizontal and Vertical Motion

General Physics I, Marlboro College, Fall '08

This week we'll begin our study of motion in two and three dimensions by looking at the motion of projectiles – objects moving simultaneously horizontally and vertically. The specific question at issue will be to what extent the horizontal motion affects the vertical (and vice-versa). The answer to this question will help us understand the role of vectors in physical laws.

I. INTRODUCTION

Believe it or not, we have already encountered *most* of the concepts that will be covered in General Physics I. We've clarified the concepts of velocity and acceleration, studied the motion of objects in free-fall, and thought about Newton's laws and forces as the cause of acceleration. However, up to this point we have talked about all of these concepts only in the context of one-dimensional motion, i.e., motion along a straight line.

This week we will begin the long process of systematically generalizing everything we've done so far to the cases of 2- and 3-dimensional motion, i.e., motion in which the trajectory of the object in question is not just along a straight line. The simplest and most familiar such motion is *projectile motion*, so we'll start there this week.   Actually, we'll still be talking about projectile motion next week. The point of the lab this week will be to illustrate a fundamental principle that will help explain and motivate the need to develop (before really studying motion in 2- and 3-D) the mathematical concept of *vectors*.

We have introduced the concept of vectors already in this class, but so far they have not been of much help in solving one-dimensional problems. This lab should help you to understand why it's convenient to use vectors in formulating Newtonian physics for general, three-dimensional motion.

II. MONDAY IN CLASS

We've seen in previous weeks that an object in vertical free-fall moves with *constant downward acceleration.* We've also talked about how a horizontally moving object in the absence of a net force moves with *constant velocity.*

Your basic assignment during Monday's class is to explore how the horizontal and vertical motions (of an object which is simultaneously moving horizontally and vertically) affect each other.

I'm not going to tell you exactly how to do this, as there are several different possible ways (that I know of, and maybe more that I don't).   And I like to let you think

creatively about how best to discover or demonstrate things. But you will probably end up doing something like this: launch a projectile sideways and see if the time it takes to fall vertically a certain distance is the same as – or different from -- the time it would have taken if it were *not* moving sideways. Or: see if the vertical motion depends in any systematic way on how *fast* the projectile is launched sideways.   Or: see if the fact that the projectile is accelerating downward affects its sideways motion (e.g., by making it speed up or slow down instead of moving with uniform horizontal velocity).

If you understand all those suggestions as so many different ways of examining the interdependence of the horizontal and vertical motions, you've got the idea. That's what I want you to examine: are the horizontal and vertical motions inter-dependent, or does each just do its thing independent of what's happening with the other?

We have some cool toys that you might find useful here, including some metal ball launchers, photogates that can trigger the computer's timing mechanism when something passes through the gate, and also some time-of-flight targets that can trigger the timing mechanism when they're hit. Together, these will allow you to shoot a ball toward the target and measure (using the computer) exactly how much time it was in the air. And there are some other toys that you might also find useful, too. Again, I'm leaving this deliberately open-ended so you'll need to think carefully and creatively to find a good way to examine what you need to examine.

III. HOMEWORK

As part of your usual weekly homework, I'll ask you to write up your results of this lab in typical lab report fashion. So make sure you keep track of the data that you gather on Monday.

I'll also ask you to summarize your observations about projectiles by writing down equations for

- $x(t)$, the horizontal position as a function of time
- $v\_x(t)$, the horizontal velocity as a function of time.

- $a\_x(t)$, the horizontal acceleration as a function of time.
- $y(t)$, the vertical coordinate (or height) as a function of time.
- $v\_y(t)$, the vertical velocity as a function of time.
- $a\_y(t)$, the vertical acceleration as a function of time.

You should be able to cite specific experimental evidence for each of these six equations (though that doesn't necessarily mean you need to have done six distinct experiments!). So be thinking about this as you decide exactly what to do on Monday.