# PHY221 Lab 3 - Projectile Motion and Video Analysis

Video analysis of flying and rolling objects.

February 3, 2016

Print Your Name

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Print Your Partners' Names

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You will return this handout to the instructor at the end of the lab period.

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## 0. Introduction

In the beginning, there were meter sticks and stop watches. Then there were motion detectors. Then came video analysis…

## 0.1 Discovering Motion, Motion Detectors and stop watches

One of the exercises you completed in the Discovering Motion lab was determining whether or not you should believe the data from Motion Detectors (MDs). You discovered that, although discrepancies on the absolute position existed, the changes in position were very accurate, agreed with your trusty meter stick, and could be sampled numerous times each second. This allows you to construct very accurate graphs of position, velocity and acceleration for moving objects, which is nearly impossible to do using rudimentary tools.

Throughout this semester, you learned how to collect data, learned to recognize when the MD did not correctly ‘see’ your object, and steps you could take to improve the quality of your data. We will need to go through that again as you are introduced to a new tool which we will use to investigate the natural world and uncover the physics that describes it.

**Your phone video camera and webcams**

Most cellphones have integrated cameras capable of capturing very high quality photographs and videos. We will exploit this feature to ‘capture’ experiments, and then collect data from these videos. You can collect MD data in Logger Pro at any data rate simply by changing that parameter in the *Data Collection* tab. We do not have that luxury when we take
Projectile motion and video analysis

Only a few options exist, but for most purposes, we will be taking normal video, which is automatically set to 30 frames/sec. This means that the camera takes 30 photographs/sec, and they are played back at 30 frames/sec. When photographs are played back at this speed, our brains do not detect the individual photographs and interpret this as a continuously moving image, i.e. a movie.

Some cameras have settings which allow you to shoot high speed video, which is useful for events occurring on very short time scales. For example, the iPhone 6 is capable of taking video at frame rates up to 240 frames/sec. When this video is played back at 30 frames/sec, the result is a slow motion video. Please browse to and read: [http://www.wired.com/2015/01/closer-look-slow-motion-video-iphone-6/](http://www.wired.com/2015/01/closer-look-slow-motion-video-iphone-6/)

Most Android devices have similar features.

More expensive instruments allow you to take thousands of frames/sec. If you are interested, just Google Phantom camera.

During today’s activities, you will be using a Logitech webcam, where framerates are set to 30 frames/sec.

**Comprehensive Equipment List**

- Web cam attached to computer with USB cable
- Computer with Logger Pro

1. **Activity #1: Video analysis of a rolling cart**

1.1 Open Logger Pro, then click Insert → Movie. Choose greatTAs.mp4 from the Computer→ Desktop → PHY221 → Movies. Your screen should look similar to this.

![Video Analysis Screen](image)

1.2 Click the ‘Play’ icon to watch the movie of the cart rolling along the track. The rewind and fast forward buttons do exactly as you might think.

1.3 Clicking this button opens up some data acquisition tools that you have at your disposal. Click this and we will explore these tools.

1.4 Clicking this button allows you to click a point in the movie, and creates an X-Y vs. t data point in the graph underneath. To analyze the motion of the cart, choose a particular point, for example, the front black bumper. Now click that point. A set of data points now appear on
the graph and the movie advances by a single frame, or 1/30 sec. Continue clicking the same point on the object while it is in constant motion, about 20 to 25 frames.

1.5 Since the cart is in uniform motion, we expect the x-t graph to be a straight line.

**Q 1** What is the velocity of the cart in the x-direction? Please be sure to include units.

**Q 2** Is the cart moving in the positive or negative direction? How do you know?

**Q 3** Does your answer to Q1 make sense? Why or why not?

1.6 Logger Pro has no way of ‘knowing’ the distances in this experiment. You need to tell LP exactly how long some object is, then it can appropriately scale all of the other distances. You should notice that there is a meter stick on the track that butts up against the stop on the right. Click the Set Scale radio button. This allows you to drag a line along an object of known length and tell LP how long that object is.

1.7 Click one end of the meter stick and drag along the entire length until you reach the other end. The ends may be difficult to see because of poor lighting. (You will not make that same mistake, right?) Make sure 1 m is entered in the dialog box and continue.

1.8 You should see the graph automatically update to the correct units. In fact, the previous graph was in correct units, just not a unit you are accustomed to in lab. The original units were screen pixels. We will not get into that here, but you do see these units in descriptions for HD TVs, computer monitors, etc. Your fit for x-t should automatically update to meters.
Q 4 What is your new $v_x$? Does this answer make sense?

Q 5 Watching your video, perform a rough calculation to determine whether or not your $v_x$ is close. Show your work below.

2. Activity #2: Video analysis of a flying object

2.1 Measure the width of this paper. You should get 8.5” or 21.6 cm. Now repeat the measurement from a very different geometry. Have one lab partner hold the meter stick horizontally, another lab partner hold this paper about 20 cm in front of the meter stick, and the last lab partner stand about 50 cm away from the paper.

2.2 Without moving your head, measure the width of the paper.

Q 6 What is the measured width of the paper in this geometry?

2.3 Repeat this measurement, but move the meter stick just above the paper, i.e. in the same plane as the paper.

Q 7 What is the measured width of the paper in this geometry?

2.4 You should notice a very large difference in the width of your paper, and of course, you believe the measurement which occurred in the same plane of the paper. These kinds of measurement errors are due to parallax. Your videos are no different. When you take your videos, make sure that the meter stick is in the same plane of motion as your moving object or
you will introduce parallax errors. The gray bar in the Figure 1 is obviously 4 dashes long. The person shown measuring the bar thinks it is about 8 dashes long. This is parallax error.

![Figure 1](image)

*Figure 1 The person measuring the length of the gray box measures about 8 dashes. This error is caused because the measuring tool is not in the same plane as the object being measured.*

2.5 Determine who is going to throw, who will catch, and who will record the video.

2.6 Practice tossing a ball in as large a parabolic arc as possible without the ball leaving the frame of view. Make sure you are doing this in the same plane as your meter stick and that this stick is in the field of view.

2.7 When you are satisfied, record a video. Do not follow the ball with the camera. Hold the camera still. Copy the video to the Movies folder. Name it your name, i.e. SamS.

**Q 8 Why is it important to hold the camera motionless?**

2.8 Follow the instructions from Activity 1. Create graphs of x vs. y and x and y vs. t.

**Q 9 What is the name of the shape of the y vs. x graph? Can you prove this? How?**
Q 10 What is the acceleration of the object in the x-direction? How do you know?

Q 11 From this value, what can you say about the velocity of the object in the x-direction?

Q 12 What is the acceleration of the object in the y-direction?

Q 13 What was the highest point the ball reached relative to the point at which it was released?

3. Your turn to design an experiment

3.1 Roll a ball off the table. How far away does it land? Does your answer make sense? How would you model this, i.e. calculate how far away the ball should land.

Q 14 Please state your experiment, what data you will collect (using video), and what question(s) you want to answer. How will you use your data to answer your questions?
**Q 15** Determine the horizontal velocity of the ball just before it leaves the table. Please state how you will determine this.

**Q 16** In the space below, using measurements of table height (use a meter stick) and your x-velocity, how far away from the table should the ball touch the floor. Please show all work.

**Q 17** How does your calculated value compare to the experimentally determined value?

4. **When you are finished**…
4.1 Please turn in this handout with all questions answered and printouts of your graphs, including the data analysis.
This page intentionally left blank.
Read the Introduction to this handout, and answer the following questions before you come to General Physics Lab. Write your answers directly on this page. When you enter the lab, tear off this page and hand it in.

1. A ball is tossed with an initial velocity \( v_0 \). For each of the following initial velocities \( v_0 \), sketch the initial x and y components of the velocity (\( v_{0x} \) and \( v_{0y} \)) as well as \( v_0 \). Calculate \( v_{0x} \) and \( v_{0y} \) for cases a, c, e, g, and h.

a) \( v = 5 \text{ m/s, } \theta = 0^\circ \)
b) \( v = 10 \text{ m/s, } \theta = 30^\circ \)
c) \( v = 7 \text{ m/s, } \theta = 110^\circ \)
d) \( v = 12 \text{ m/s, } \theta = 180^\circ \)
e) \( v = 5 \text{ m/s, } \theta = 225^\circ \)
f) \( v = 7 \text{ m/s, } \theta = 270^\circ \)
g) \( v = 5 \text{ m/s, } \theta = 335^\circ \)
h) \( v = 7 \text{ m/s, } \theta = -25^\circ \)