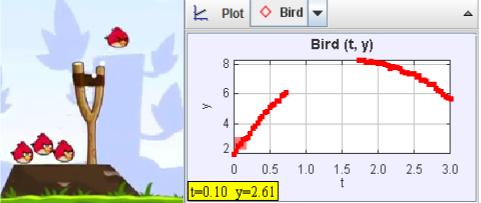
**Projectile Motion: Angry Birds[[1]](#footnote-1)**

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In the game *Angry Birds*, birds are shot from a slingshot. Does their motion follow the principles of projectile motion? We can use video analysis to answer this question.

When we do video analysis, we chose an item in the video to use as a reference to determine distances (how many pixels equals 1 meter, for example). In the case of *Angry Birds*, instead of scaling the video with a known object on the screen, we can scale the video by the acceleration due to gravity, assuming the *Angry Bird* world is the Earth.

Begin by downloading the following files:

* angry\_bird\_short.mov
* angry\_bird\_projectile.trk

The “trk” file is a partially marked Tracker file and if you double click it (and Tracker is installed), it should launch a tab in Tracker (it will likely ask you where the video file is and you will have to point to where you downloaded the mov file). Play the video and notice that the “camera” moves to follow the bird and that the window changes size.

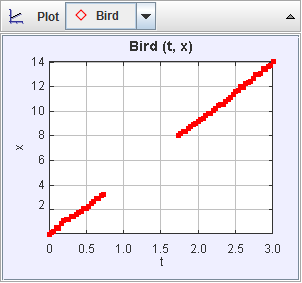
In order to track the bird, we will need a fixed origin (the slingshot) and since the origin goes off screen, we need an offset point (the distance from the slingshot to a blade of grass that shows up for most of the trajectory of the bird).

We also need a set length since the movie zooms in and out. It turns out that the height to the fork of the slingshot is the same as the height of the pedestal the pig sits on. We will establish this height as “1” in “trk” file. Now, even as the image zooms and pans, the length of the pig’s pedestal is always “1” and the location of the origin is set. DO NOT adjust the “Coordinate Offset” or the “Calibration Stick” or the data will no longer account for the movement of the camera or the zooming in and out on the screen.

The “trk” file already has the position of the angry bird marked. The track of the marked points is not a parabola on the video. Why not?

The video is constantly zooming in and out, along with moving the point of view around too, so the track of the bird, while it may actually be a parabola, does not appear so due to the distortions of the video interfering with the shape of the trajectory.

The plots of x vs. t and y vs. t match more closely with what you might expect for projectile motion. Sketch the plot of x vs. t below:



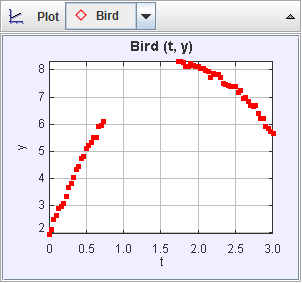
Explain why some points are missing:

In the video, the bird momentarily goes off screen. Since no data can be gathered from that time interval, the points are left out of the graph.

Explain why the plot is a straight line:

It is a straight line as the plot is displaying x position in terms of time, and the x velocity vector remains constant throughout the trajectory, so no parabolic shape can form since the bird travels at a constant rate to the right.

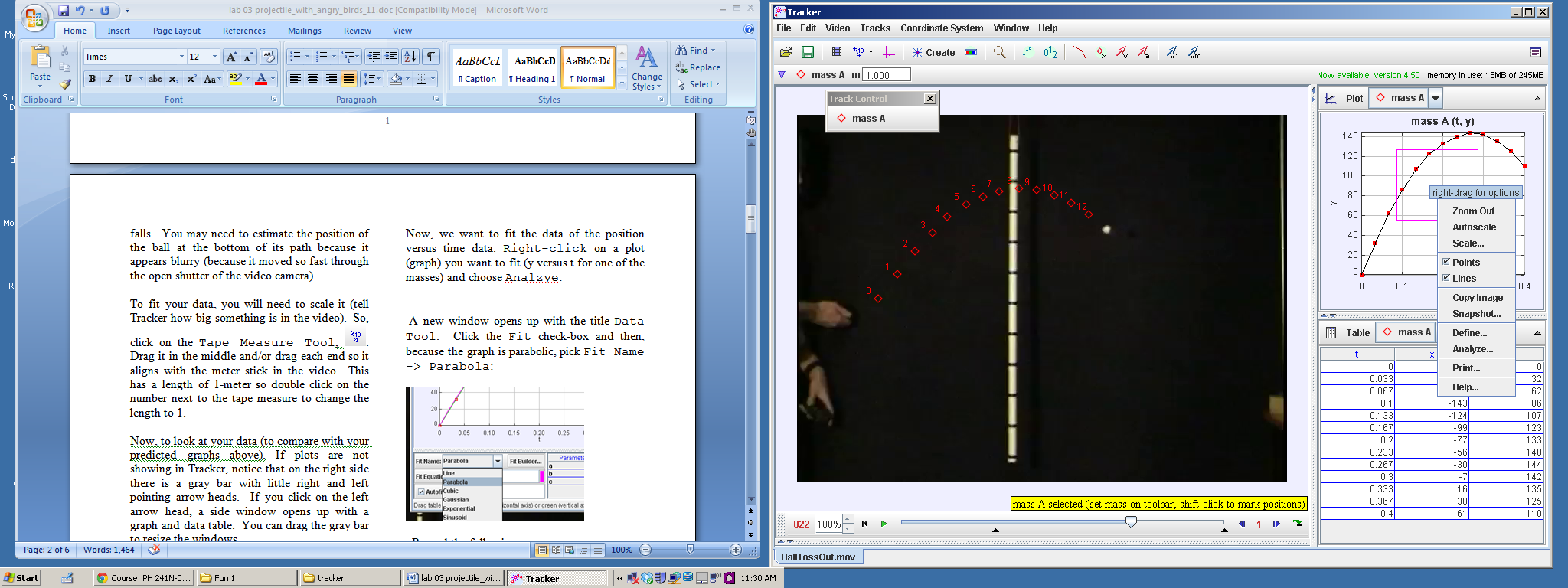
Now, sketch the y-position data as a function of time (click on the vertical axis label “x” and change it to “y”).



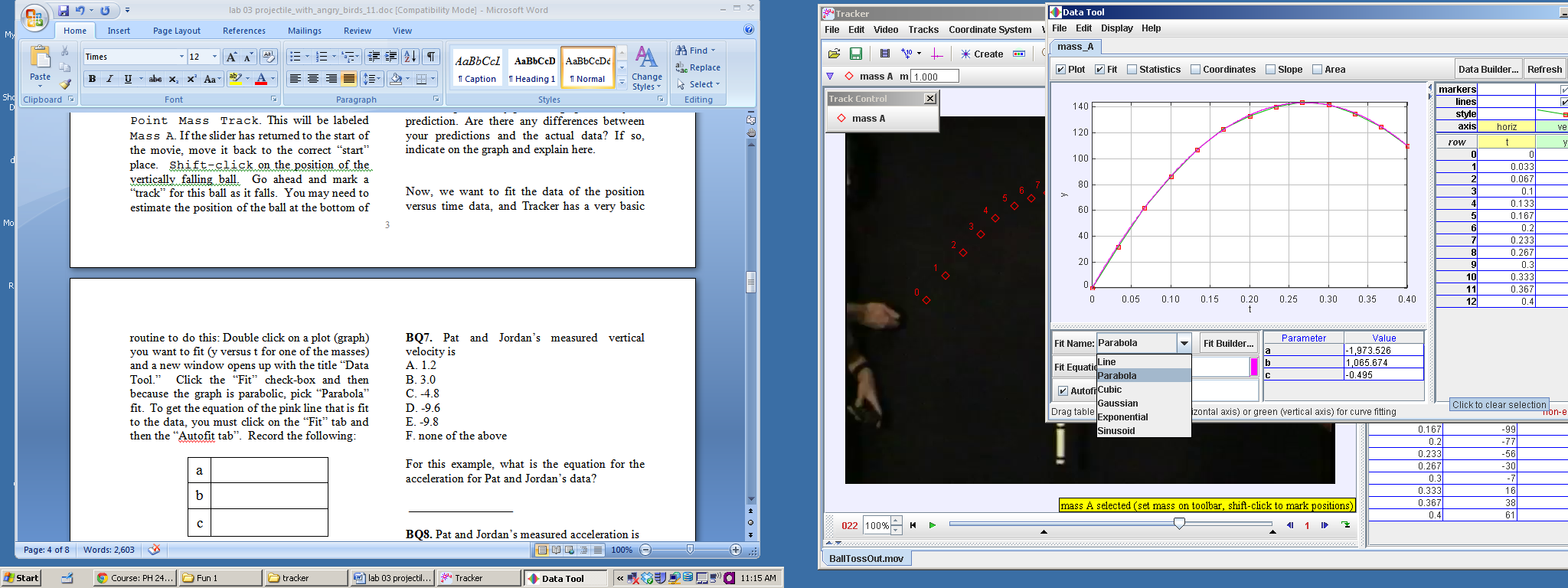
Why is it parabolic (or would be if there weren’t missing data)?

Since this plot is displaying y position in terms of time, and since there is constant acceleration g, the plot of the bird’s y rate of change is constantly decrementing, producing this parabola shape.

Now, we are going to fit the data of the position versus time graph. Right-click on a plot (graph) you want to fit (y versus t for one of the masses) and choose Analzye:



A new window opens up with the title Data Tool. Click the Fit check-box and then, because the graph is parabolic, pick Fit Name -> Parabola:



Record the following:

|  |  |
| --- | --- |
| a | -1.882 |
| b | 6.883 |
| c | 1.993 |

These coefficients correspond to the equation of the form:

*y* = a*t*2 + b*t* + c

Now, when two other students, Pat and Jordan, previously fit their data, they got the following (this is **not** the data you will get, it is simply an example):

|  |  |
| --- | --- |
| a | -4.8 |
| b | 3.0 |
| c | 1.2 |

Taking the above information and transforming it to the book’s notation, their equation of motion would be the following:

*y* = 1.2 + 3.0*t* – 4.8*t*2

**For the previous example with Pat and Jordan’s data**, (assuming that the ball has just left the hand at t = 0) what is the equation of the velocity in the y-direction (differentiate the equation of displacement):

y` = 3 - 9.6t

What is the vertical velocity right after the ball left the hand of the person throwing in this example?

3 u/s

**Q1.** Pat and Jordan’s measured initial vertical velocity is

A. 1.2

B. 3.0

C. -4.8

D. -9.6

E. -9.8

F. none of the above

For this example, what is the equation for the acceleration for Pat and Jordan’s data (second derivative of position function)?

y`` = -9.6

**Q2.** Pat and Jordan’s measured acceleration is

A. 1.2

B. 3.0

C. -4.8

D. -9.6

E. -9.8

F. none of the above

**Now, back to your data.**

What is **your** equation of motion?

y = -1.882t^2 + 6.883t + 1.993

Differentiating this, what is **your** equation for the velocity as a function of time?

vy = -3.764t + 6.883

What is the “initial” velocity in the y-direction (velocity leaving the sling shot)?

v0y = 6.883 u/s

What is the acceleration (from **your** data)?

ay = -3.764 u/s^2

You should not get a value of -9.8 or anything close to that because your acceleration is in units of pig pedestal/second2. Why is that your unit instead of m/s2??

Since there is no reference to a meter length in the video, nor are there any official scales on what the sizes of certain objects are in the video, a constant length had to be devised from an object from the video to serve as the metric for collecting the data. It just ever so happened to be the pig pedestals.

If we assume the acceleration due to gravity is -9.8 m/s2, what is the conversion for pig pedestal units to meters? For example, if Pat and Jordan found (with different data from above):

ay = \_\_-3.5 pig pedestals/s2\_\_\_\_\_\_\_\_\_\_

Then they know that

3.5 pig pedestals= 9.8 m or

1 pig pedestal = 2.8 m

What is your conversion between pig pedestals and meters?

1 pig pedestal = 2.606 meters

Your “measuring tape” is calibrated to pig pedestal units. Click on your measuring tape (Tape A) to measure the following (click on an end to adjust the length):

How many pig pedestal units tall is the sling shot?

1.886 pedestals

How many meters is that?

1.886 \* 2.606 m/p = 4.915 m

How many pig pedestal units is the angry bird?

.4081 units

How many meters tall is the angry bird?

.4081 \* 2.606 m/p = 1.064 m

Is that a big or small bird? Explain.

It is a large bird; most birds are 10-20 cm high. This bird is more like an emperor penguin sized bird.

From your tracker data, what is the initial   
y-velocity of the angry bird in m/s (instead of pig pedestal units/s):

voy = 17.937 m/s

Now, go back to the graph of x versus time and fit the x-position data to a line (instead of a parabola):

|  |  |
| --- | --- |
| A | 4.637 |
| B | -.066 |

(from x = a\*t + b)

x-position equation:

x = 4.637t - .066

What is the initial velocity in the x-direction?

v0x = 4.637 pig pedestals/s

and in meters/s:

v0x = 12.084 m/s

What then is the initial speed of the launch from the slingshot (magnitude of the initial velocity vector)?

17.937^2 + 12.084^2 = (467.759)^.5 = 21.628 m/s

Based on this analysis, what can you conclude about the motion of the birds in Angry Birds?

The motion of angry birds is indeed projectile motion, since the x velocity component is constant, as shown by the analysis, which would match with projectile motion in the x direction in this context (a trajectory that ignores air resistance and that is under negative y acceleration [gravity] only). The y position component also corroborates this sentiment, as its equation y = -1.882t^2 + 6.883t + 1.993 fits with the same y position equation of projectile motion (yf(y) = a/2(-1.882)t^2 + viy(6.883)t + yi(1.993) [which is close to the height of the slingshot the birds are launched from]).

1. Inspired by Rhett Allain’s DotPhysics blog for Wired Magazine: “The Physics of Angry Birds,” Oct 8, 2010. <http://www.wired.com/wiredscience/2010/10/physics-of-angry-birds/> and by Frank Nochese’s Action-Reaction blog, “Angry Birds in the Classroom,” <http://fnoschese.wordpress.com/2011/06/16/angry-birds-in-the-physics-classroom/> (accessed Nov 21, 2011). [↑](#footnote-ref-1)