The Physics of Angry Birds

Time
3 class periods.

Level
Physics; best-suited for students who have had pre-calculus and a basic understanding of Newton’s laws (usually sophomores and juniors).

Purpose
This activity introduces the use of computer simulations to model physical systems. Specifically, this lesson uses a well-known game, Angry Birds, as the simulation to investigate 2-D equations of motion for projectiles. The students observe the results of the simulations to calculate the value of the gravitational acceleration on the Angry Birds’ world.

Overview
The activity has two main parts: 1.) Gathering data and 2.) Analyzing data and forming models/equations. The students will use computational tools to capture the motion of an Angry Bird in its world, record the data, determine the mathematical functional form of the data, and ultimately derive the gravitational acceleration on the Angry Birds’ world.

Student Outcomes

Learner Objectives:
1. Students are able to apply the equations of motion in a new context.
2. Students are able to use a computer simulation to generate data
3. Students are able to use a spreadsheet program to fit a mathematical model to their data.
4. Students understand the impact of short versus long time steps in a computer simulation.
5. Applications of learning: The students apply their knowledge of Newton’s mechanics in solving a novel problem with a method that few, if any, will have used before.
6. Communicating: The students are instructed to generate a graph clearly showing their results.
7. Using technology: The students learn to use a program to fit their data to a model.
8. Working on teams: We encouraged working together in groups.
9. Making connections: We hope to promote the use of computer simulations in attacking physics problems rather than just as a tool for visualizing the data.

Computational Thinking in STEM Skills:
1a. Collecting Data
1b. Generating Data
1e. Analyzing Data
2g. Choosing Effective Computational Tools
3c. Assessing Computational Models

Next Generation Science Standards:
- MS.PS-FM Forces and Motion

Scale, Proportion, and Quantity
-Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. The observed function of natural and designed systems may change with scale
(a) Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (b),(d)

Analyzing and Interpreting Data
-Analyzing data in 9@C12 builds on K@C8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
-Use tools, technologies, and/or models (e.g., computational, mathematical) to generate and analyze data in order to make valid and reliable scientific claims. (b)

Using Mathematics and Computational Thinking
-Mathematical and computational thinking at the 9@C12 level builds on K@C8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
-Use mathematical expressions to represent phenomena or design solutions in order to solve algebraically for desired quantities. (c)

Systems and System Models
-When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (b),(e)
Illinois State Science Standards:
- Apply scientific inquiry and scientific habits of mind 11A/13A/13Bl.I
- How the scientists really work 13A/12A-F/13B.J
- Gravitational factors 12D/11B/13A.H

Prerequisites
- Students should be familiar with the equations of motion and how to apply them to projectiles.
- Familiarity with spreadsheets and organizing scientific data will come in handy when graphing and interpreting the results of the simulation.

Background
General content knowledge and skills students will need to succeed in this lesson. This should be written as if you are speaking to the students.

Teaching Notes
- A computer lab with at least one computer per student is recommended, but groups may be formed for classrooms with less computer resources.
- Either way, the students should work in small groups (even if each is working on their own computer).
- Keep in mind that a strong student may dominate the group work.
- The activity should be straightforward when following the instructions and serve mostly as an introduction into computer simulations.
- The instructor should give immediate help if the question has to do with a technical question about using the tools.

The activity has two main parts:
1. Gathering data
2. Analyzing data and forming models/equations

The instructor should write up a few steps on how to set up the activity based on their individual set up. An example is given in the handout.

Important: The instructor should lead the students through the downloading and installation process of the various programs.

The instructor should also demonstrate how to gather the data from the simulation.

The students will then record an example of projectile motion in the simulation, using the software provided in class. An example of how to capture a video using screen-cast-o-matic is given in the handout.
Once the students have a recording they should open Physics Tracker and track the motion of the projectile using the tools provided (explained in detail in the handout). The students will then scale the simulation using reasonable assumptions and derive the gravitational acceleration on the Angry Birds world.

Pre-class Preparation
- Student computers with chrome installed.
- To save class time, you may consider working with your IT to download and set up the various programs beforehand, though this is part of the learning process for using computational tools.
- The instructor should be familiar with the activity, preferably running it before to better understand the possible pitfalls and more difficult areas of the activity.

Materials and Tools
- A computer lab with chrome with angry birds, physics tracker, and optionally, Microsoft Excel.
- Also, a whiteboard or blackboard is useful for demonstrating the activity as well as a projector so the teacher can model certain parts of the activity.

Assessment
- If the same assumptions are made (reference sizes for objects in the simulation), the students should come to a similar result for the gravitational constant in the Angry Birds world. Have the students consider what would change if the assumptions given were different.
- The activity is meant to be an introduction to computational thinking and computer simulations. Assessment of this aspect is through asking the students conceptual questions as they work through the handouts. In particular, check in with them throughout about the logic of the procedure they are following and whether it is optimal.

Handouts begin on following page.
Angry Birds Projectile Project (parts 1 & 2)

Purpose: To determine the two-dimensional equations of motion for projectiles in the game “Angry Birds”. What is the acceleration of gravity in the Angry Birds world?

Introduction/Background: Some of you may have heard of the game, “Angry Birds”. In this game, birds are used as projectiles. Using your knowledge of 1-D motion, you will analyze the track of a flying bird and calculate the equations of motion in the x- and y-directions.

Procedure: This project will be divided into a few parts:
1. Gathering data
2. Analyzing data and forming models (equations)
3. Using these equations/models to write a computer program, which simulates the game!

Part 1. Gathering Data

A. Setup your computer to take data
1. Make sure you are logged onto your computer. Most computers are not going to be on the ETHS network. You can log in using “wildkit/student” if the computer isn’t already logged on.
2. Open up Google Chrome. You will likely be in offline mode, which is fine.
3. Go to “chrome.angrybirds.com”. The offline version of the game will load up. Make sure that you click on SD (standard def). The reason we have to do this is that HD has too much data for our recording program to handle.
4. If you look in the computer tray (lower right corner of the screen), you will see an icon for “Screen-cast-o-matic” (I’m not making it up, this is the name!). Left-click on this icon once and the program should open.
5. Click on the button that says “record”. You will see a dotted frame pop up. At the bottom of the frame you will see the record button as well as a big X to close the frame.
6. Now go back to the Angry Birds window. The frame will still be there. Click on the border of the frame and you can drag it to cover the Angry Birds game. You can also stretch the corner so that it full covers the game screen.
7. Begin playing. I mean experimenting with physics. You can take a few minutes to play, I mean explore, the Angry Bird World. But eventually you need to take data!

B. Recording Data
8. When you are ready, you can record data using the Screen Cast interface. Make sure that you scroll out a bit (scroll button on mouse), so that you can see the entire Angry Birds Screen. One thing we want to avoid is PANNING and ZOOMING!!! (= BAD!!!!!!). Before you go any further, discuss with your group WHY this is bad and write this down in your lab book.
9. Click on the Record button, and when you are done click on “Done”. You will get a screen that shows you choices as to what you can do with the video. NOTE: Your computer may be very slow while recording. Try to take this into account when playing.
10. Click in the box below the text that says “The recording is saved on your computer with name:” and enter a name, like “Angry Birds Trial 1”.
11. Click on “Save to Video file”, then at the bottom click “Save Video”. Find the folder named “Tracker” on the C drive, then save to Tracker\videos. Ask if you need help doing this.

Part 2. Analyzing the Data

Using Physics Tracker
1. Go to the Start Menu and open up the Program “Tracker”.
2. We first open the video up for analysis; click ‘File’ → ‘Open’
   Then find where you saved your video and double click the video file.
3. Now we want to cut out the interesting part of the video. First find the place where the bird is
   first launched by going through the video using the horizontal scroll bar. Note that we want the
   bird as soon as it has been launched by the slingshot. Note the red number on the bottom left.
   This is your frame.

4. Click the third to left button on the toolbar near the top of the screen that looks like a clip of
   film. In the text box next to ‘Start frame’, enter the number you had and click enter. The video
   should lock onto that frame.

5. Now find exactly where the bird is just about to hit an object using the horizontal scroll bar.
   Note that frame and enter it in the text box next to ‘End frame’. Click OK. We have now chosen
   our clip.
6. To track the bird's motion click ‘Tracks’ → ‘new’ → ‘point mass’.

7. Hold shift and click the bird. Notice how the frame increases by one automatically. Hold shift and click the bird again. Repeat 5 times.

8. In order to avoid clicking hundreds of times we will have this program autotrack the bird. In the box ‘Track Control’ click ‘mass A’ → ‘autotrack’. Now click the bird without holding shift. Hit
next three times. The program should put you at the ‘4. Search’ tab. Click ‘search’. It should automatically ID several other data points. When done, click “close”

**Scaling the data**

Because physics tracker does not know the scaling within the videos used we want to use a tool to tell tracker exactly what 1 meter is. We have decided to have a small pig have a face that is one meter long. To do so look at the icons toolbar and select the calibration stick, which is next to the filmstrip icon. After clicking this move the blue calibration stick so that the crosses encompass the face of one of the small pigs. Then in the lower toolbar change the ‘length’ textbox to 1.000.

In the plot to the top right of your screen change the y axis to ‘y’ and note how the shape looks. It should look like a parabola. Play around with other settings for the x and y axes to derive
various properties of the angry birds program. Q: What are your initial observations concerning these graphs?

**QUESTIONS**

1. Use Tracker to sketch 4 graphs in your notebook: x vs. t, y vs. t, Vx vs. t, and Vy vs. t. You can do this by looking at the right side of the screen where a plot is shown. If you click on the vertical variable (it starts originally with “x”), you can select many variables to plot, all vs. time on the x-axis. Make sure to label important parts of the graph (intercepts, maxes, mins, etc) with their values (include units).

2. Write equations for your 4 graphs. In other words, write equations for x(t), y(t), Vx(t), and Vy(t). You can do this a couple of different ways. One good way to do this is by measuring the slope and intercept directly off the computer graph. You could also right click on the graph and click on “analyze” and see if you can come up with an equation that way. Remember how to write a “good” equation! Include units!

3. a) What is the acceleration due to gravity, “g”, in the Angry Birds world? To do this, you should have already set a scale for your video. If not, look back at the procedure and set a proper scale.
   
   b) The acceleration is probably not 9.8 m/s/s. Why might the game’s programmers choose the value you found in question 3a?

4. Use your equations to determine the following. Note that your units should be in [m] and [s]!
   a) Vxi, the initial x velocity of the bird
   b) Vyi, the initial y velocity of the bird
   c) Vi, the total initial velocity
   d) [?] the angle of launch

**Extensions**
1. Try this activity by recording in HD mode. The challenge is that you may get frames where no motion happens. In other words, Screen-cast-o-matic is recording, but the game may not have calculated a new frame.
   a) How do you adjust your analysis to account for this?
   b) What is the framerate (frames per second) of the actual game?

2. If instead you assume that the gravity in this world has a value of 9.8, what are the real-life sizes of the birds and pigs? (You will have to work backwards)

3. Brainstorm a list of 3-4 other games you would like to try video analysis on. Some ideas - Mario jumping, cars accelerating in GT, etc.
Angry Birds Take Two

Mr. DuBrow & Mr. J

1. The Problem

As an astrobiologist you are one of the few chosen to investigate the newly discovered world with a multitude of interesting bio-organisms. In particular, you are assigned to study the mechanisms used by the 'blue-bird', 'yellow-bird' and the 'white-bird'.

We are especially interested in the various bird abilities for several very wealthy companies. NASA is interested in the blue birds' ability to split for rocket technology. NASCAR wants information on the yellow birds' ability to spontaneously speed up. Lastly, I want to know if the white birds' ability to 'rocket jump' can help the development of jet-packs. In preparation for the observational experiment, we are going to use physics to generate a set of equations.

2. Investigation

\[ E_i = E_f \] (2.1)

\[ PE_i + KE_i = PE_f + KE_f \] (2.2)

\[ \vec{p}_{i,tot} = \vec{p}_{f,tot} \] (2.3)

\[ \vec{p} = m\vec{v} \] (2.4)

Equations 2.1 and 2.2 describe the conservation of energy, stating that energy is conserved at each point. Equation 2.3 illustrates the conservation of momentum.

Equation 2.3 may be split into x and y components:

\[ p_{xi,tot} = p_{xf,tot} \] (2.5)

\[ p_{yi,tot} = p_{yf,tot} \] (2.6)
Equations 2.5 and 2.6 can be further broken down by writing the total momentum as the sum of each particle’s momentum:

\[ p_{xi,1} + p_{xi,2} + \ldots = p_{xf,1} + p_{xf,2} + \ldots \]  
\[ p_{yi,1} + p_{yi,2} + \ldots = p_{yf,1} + p_{yf,2} + \ldots \]  

(2.7)  
(2.8)

Translate the above 2 equations into a sentence or two describing what they mean.

Given the initial momentum vector and angle, break down the momentum vector into \( p_{xi} \) and \( p_{yi} \) components. Do the same for the initial velocity vector. Keep in mind that the momentum and velocity vectors are related by the equation \( \vec{p} = m\vec{v} \).

\[ 2.1. \text{ Blue Bird} \]

The blue bird (pre-split) may be approximated as a sphere of mass \( M \). After the split, assume that the three small birds each have a mass of \( M/3 \). Draw two free body diagrams, one immediately before the split and the other immediately after the split. Include the velocity \( \vec{v}_i \) of the bird before the split and the three velocities of the small birds \( \vec{v}_{f,1} \), \( \vec{v}_{f,2} \), and \( \vec{v}_{f,3} \) after the split.
Like we did previously, split $\vec{v}_i$ into $v_{xi}$ and $v_{yi}$. Do the same for $\vec{v}_{f,1}$, $\vec{v}_{f,2}$ and $\vec{v}_{f,3}$.

\[
\begin{align*}
v_{xi} &= & v_{yi} &= \\
v_{xf,1} &= & v_{yf,1} &= \\
v_{xf,2} &= & v_{yf,2} &= \\
v_{xf,3} &= & v_{yf,3} &= 
\end{align*}
\]

Using your answers from the previous question, write down the equation for conservation of momentum in the x-direction:

\[2.2. \text{Yellow Bird}\]

Draw a free body diagram linking the pre-boost picture to the post-boost picture. Before the boost, approximate the yellow bird as a sphere of mass $M$. Assume that the bird poots a clear gas of mass $m$ that has zero velocity relative to the ground after emission (treat the post-boost system as two particles, the bird and the gas), meaning the mass of the bird after the boost is $M - m$. Make sure to include the velocities in your diagrams.

Use conservation of momentum in the x direction to calculate the mass of the gas as a fraction of the bird’s initial mass, $m/M$. 
2.3. White Bird

The white bird may be approximated as a sphere of mass $M$. Similar to the yellow bird and the gas, after the egg-drop, assume that the egg has a mass $m$ and the bird now has a mass $M - m$. Draw a free body diagram linking the pre-split mass to the post-split mass.

Use conservation of momentum in the y direction to calculate the mass of the egg as a fraction of the bird’s initial mass, $m/M$.

2.4. Conservation of Energy

Investigate whether or not energy is conserved on this planet. Think of and write down your procedure. (Hint: there are different ways of doing this)