# TITLE: The Physics of Motion

***Subtitle: How far can you hit the ball?***

**Authors:**

Ben Higgins, PhD Student, Dept of Ecology & Evolutionary Biology, UC Santa Cruz, CA

Caleb Bryce, PhD Candidate, Dept of Ecology & Evolutionary Biology, UC Santa Cruz, CA

Stephen Buchter, Physics & Engineering Instr., Watsonville High School, Watsonville, CA

**Field tested:** 10th & 11th grade Physics, Watsonville High School, Watsonville, CA

**Module Type:** Classroom & school-campus activity

**Duration:** ~one 2-hour class period

**Key materials:**

* High-speed camera (many modern smart phones (ex: iPhone6) are sufficient)
* Baseball/softball bat (or comparable) and baseball/softball tee
* Baseball/softball (or comparable)
* Transect tape (up to 100m ideal)
* Clipboard & pencil
* Physics of Motion worksheet & Excel file (for electronic submission)

**Concepts:** Motion, Newtonian physics, Acceleration, Velocity, Projectile, Mechanics

**Skills:** Critical thinking, Mathematics/computational thinking, Designing an experiment, Arguing from evidence

**NGSS DCI**:

HS-PS2: Motion and stability – Forces and interactions

**NGSS Practices:**

Analyzing and interpreting data, Planning and carrying out investigations

**NGSS CCC:**

Cause and effect. – HS-PS2.

# Overview:

This activity is an opportunity for students to:

* Use software (*Tracker*) to measure and analyze the physical properties of motion
* Hypothesize which factor(s) are responsible for how far a batter can hit a baseball
* See how far *they* can hit a baseball
* Test a hypotheses before interpreting and communicating the results

**Navigate:** [Background](#Background) [Materials &Time](#Materials) [Starting Point](#StartingPoint) [Procedures](#Details) [Standards](#Standards) [Supplemental](#Supplemental)

# Background for Teachers

**Why this matters:**

 Objects are in motion all around us, yet it is often difficult to measure even the basic properties of moving objects such as their velocity, acceleration, or turning angles. Fortunately, a freely available software, called *Tracker,* lets you measure the underlying mechanics of motion for any object you’re interested in. All you need is a computer and a video of the motion that you’d like to investigate. We provide video (and a subsequent class activity) of a baseball bat swing that provides a brief demonstration of the *Tracker* software. The software allows one to measure velocity, acceleration, angular rotation, and many additional physical properties of motion (i.e. mechanics).

**Assumed background:**

 Very little assumed background is needed for this module. Students should be familiar with the some conceptual physics ideas, like those presented in a mechanics/Newtonian physics unit (speed, velocity, acceleration, etc). This module will provide an engaging activity to “bring those terms to life” by showing students how to measure them with *Tracker.*

**Scaffolding supplements:** If you developed (or can point to) lectures, worksheets, videos, etc. to help with scaffolding this module, list and briefly describe here.

**Introductory video**:

* + <https://www.youtube.com/user/SCWIBLESvideos>
	+ Explains how to use Tracker to measure the mechanics of a baseball bat swing.

**Worksheet**

* + HigginsBryce\_Motion\_wksht.docx: “The Physics of Motion: Measuring How Objects Move”. This worksheet guides students through the data-collection process. Students will design their own exercise model, create their own data table and graph their own results.
* **Electronic Submission:**
	+ HigginsBryce\_Motion\_lab.xlsx. This MS Excel file provides an electronically-formatted submission vehicle for each group to list and describe, in the separate worksheets contained, their names and lab purpose, procedures, data table & figures, and conclusions.

# Module Description

## Materials:

* *Tracker* freeware downloaded onto student computers:
* https://www.cabrillo.edu/~dbrown/tracker/
* High-speed camera (many modern smart phones (ex: iPhone6) are sufficient)
* Baseball/softball bat (or comparable), Baseball/softball tee and Baseball/softball
* Transect tape (up to 50m ideal)
* Clipboard & pencil per group of 4
* One printed HigginsBryce\_Motion\_wksht.docx per group
* HigginsBryce\_Motion\_lab.xlsx per group

## Preparation:

* Students work in groups of 4

## Timeline:

1. Introduction ([Physics of Motion video](https://www.youtube.com/user/SCWIBLESvideos)) 4 min.
2. Brief in-class demonstration of *Tracker* 8 min.
3. Inquiry component & experimental design (incl. graphical hypotheses): what contributes most to ball distance (e.g. batter arm length, weight, age, swing speed)? 20 min.
4. Class experiment & data collection with batters (entire class) hitting baseball 50 min.
5. Analysis & conclusion 30 min.

## Starting Point for Inquiry:

 In an introductory Physics course, students learn about the field of mechanics (Newtonian physics) but may not have the opportunity to pose their own questions about velocity, acceleration, force, etc in an experimental context. This is partly because direct measurement of these variables has traditionally been difficult without sophisticated equipment. Now there is *Tracker*, free software, and high quality digital cameras (capable of high-speed filming), that allow students to readily measure a variety of mechanical properties associated with motion. Questions like “How does golf club swing speed relate to ball distance?” or “How does the angle of a ramp affect the rolling speed of a ball?” can now be easily and empirically tested with *Tracker* !This creates enormous potential for inquiry-driven investigation, both inside and outside of the physics classroom.

## Detailed Procedure:

1. Introduction 10 min.
	1. Begin with several “hook” questions: e.g. “Have you ever wondered how athlete speed affects long-jump distance?” Or “Do you think the impact location of a tennis ball on a racquet affects how far it will travel?”
	2. Highlight the importance yet difficulty of measuring an object’s mechanics without expensive/sophisticated equipment…until now with *Tracker*
	3. Play introductory video, found here: https://www.youtube.com/user/SCWIBLESvideos
2. In-class demonstration of *Tracker* 8 min.
	1. Instructor performs an in-class demonstration of the bat swing speed analysis from the introductory video, taking time to address student questions
3. Inquiry component & experimental design (incl. graphical hypotheses): 20 min.
	1. In groups of 4, students brainstorm (and record where prompted on their worksheet) what factors they think contribute most to ball distance (e.g. batter arm length, weight, age, swing speed)?
	2. Students generate *graphical hypotheses* to guide their investigations (e.g., What type of data, based on which variable, is independent and which is dependent? What do you predict and therefore what might you expect in the results?)
4. Class experiment & data collection with batters (entire class) hitting baseball 50 min.
	1. Each student will rotate through each of the following 4 roles:
		1. Batter: hits the baseball off the tee
		2. Filmer: films the hit from above with high-speed camera
		3. Distance measurer: watches where ball lands and yells back the distance to the data recorder
		4. Batter measurer & recorder: collects data on the batter name, ball distance, and the independent variable the group has chosen to measure for each batter/batting swing (e.g., batter height, length along bat where bat contacts ball)
	2. Each group completes batting activity in succession, with the none “up to plate” groups serving as ball catchers/measurers in the outfield; i.e. Group A has members 1, 2, 3, and 4 complete the roles successively before moving on to Group B
5. Analysis & conclusion 30 min.
	1. After collecting data in the field, each group returns to the classroom to analyze data using *Tracker*
	2. Groups must turn their completed worksheets and electronic data table/write-up for credit. Whatever cannot be finished in class is homework.

## Assessment Methods:

Projects are evaluated using the completed Physics of Motion worksheet. This includes 1) their group’s list of the factors they think will influence batted baseball distance, 2) a graphical hypothesis and written prediction, and 3) a completed data table. Their electronic submission, the .xlsx file, must also reflect a thorough analysis of their data and their conclusions (i.e., was their hypothesis rejected or supported by the data they collected).

## Possible pitfalls:

* Instructor must “sign off” on each group by checking their dependent/impendent variable, predictions, and graphical hypotheses before sending them outside to being the data collection in the field. Special care must be taken to ensure that each group member understands what the group is testing, how they will measure it, and what their expectation is
* Student confusion over collection of class data *vs* group data in the field, and how the groups use this information for their write-up.
* Information that goes on the printed worksheet *vs* the spreadsheet for electronic submission.
* Timing of activity may vary depending upon the variables students decide to measure.
* Each group testing the same relationship used as the example in the introductory video (bat swing speed and ball distance). Encourage creativity!

## Glossary:

Acceleration - In physics, is the rate of change of velocity of an object.

Mechanics – The behavior of physical bodies when subjected to forces.

Motion – Any movement or change in position over time

Projectile - Any object thrown into space by the exertion of a force.

Tracker – A piece of software that lets us analyze variables of motion.

Velocity - A physical vector quantity; both magnitude and direction are needed to define it.

## Optional:

Modules vary in their needs, and if you have a particular section that would be helpful here (pointing out particularly useful links with other modules, a list of useful references, hints about calculations, add those sections here, with appropriate headers).

# NGSS Standards Addressed:

Physical Science

**Disciplinary Core Ideas**

PS2A – Forces and motion

**Science & Engineering Practices**

Asking questions

Planning and carrying out investigations

Analyzing and interpreting data

Constructing explanations

Engaging in an argument from evidence

**Cross Cutting Concepts**

2. Cause and effect

6. Structure and function

# Guide to supplemental materials:

Provide an annotated list of supplemental materials that are appropriate to the module. For each, provide the name of the file and a brief description of the contents and how it is used. The actual supplemental materials may be appended in ready-to-use formats at the end of the document or be stand-alone-document.

**Labs (or Activities)**

* + HigginsBryce\_Motion\_lab.xlsx

**Worksheets**

* HigginsBryce\_Motion\_wksht.docx

**Videos**

* **Introductory video**: how to use Tracker to measure the mechanics of a baseball bat swing.

 https://www.youtube.com/user/SCWIBLESvideos