Algebra I Lab
Parabolic Action of a Free-Falling Object - Finding the Equation

There is nothing better for understanding than real world applications. In this lab, students use a motion detector to collect data, transfer the data to all group members, create scatter plots, and trace to find the vertex and three more points. In the group lab report, they answer questions about the meaning of the axes and the data points. Then each member of the group will use the vertex and one of the three other data points to find the equation of the parabola in vertex form, $y = a(x-h)^2 + k$. They will then compare answers, graph the equations over the data, choose the best model, and discuss discrepancies. If you have any questions, email me at fadisher@bellsouth.net .

- **MOTION DETECTOR**: I use a CBR (Calculator Based Ranger) from Vernier connected to a TI-84 graphing calculator. The CBR sends out an ultrasonic pulse in the shape of a cone and measures how long it takes that pulse to return after bouncing off the closest object. The students should not stand in the cone and should move their hands as soon as they throw the ball.
- **BALLS**: Smoother balls reflect the ultrasonic pulse better so a soccer ball or children's ball or even cheap blow-up punch balls from Dollar General work better than basketballs or tennis balls.
- **COMMON MISTAKES**:
  - Weak batteries in motion detector or in calculator.
  - Calculator memory full (too many games!!!)
  - Students hold the ball too close to the CBR or hold the ball under the ball instead of on the sides.
  - Students forget to move their hands which records false data.
  - Students toss the ball too soon. They should start the CBR <u>before</u> tossing ball. Yes, it will give them a flat section, but the directions tell how to select the parabolic portion of the graph.
  - Students choose the wrong tossing and catching points. The data they select is not be part of the completely free-falling activity of the ball so the curve at the beginning and end is not parabolic.
- **GROUP ASSIGNMENTS**: Assigning each person in group a task makes each person stay engaged and one person does not take over. This lab is written for groups of three. (You can have multiple materials managers if you need more than three roles.)
  - The **project manager** makes sure that the other members of the team do not skip steps and only one person is guiding the lab. Initialing steps tells you where they are in the lab as you walk around.
  - **Materials Manager** runs the calculator to collect the data and links data to other group members
  - **Recorder** writes the lab report but gets all answers from the other team members. You only want to spend one class period on this lab, so students collect data and start the lab report. If they do not finish, group members email any missing answers to the recorder to finish lab report.
- Sample answer key is attached, but answers will vary based on the collected data.

Labs are also available on my TpT site for Precalculus and Calculus with questions geared to these classes.
https://www.teacherspayteachers.com/Store/Fans-Math

Precalculus/Algebra II Lab: Collect data, use the Easy Data® app to select the parabolic portion of the graph, and use the calculator to find the regression equation. Answer questions dealing with interpolation, extrapolation and transformations.
https://www.teacherspayteachers.com/Product/Precalculus-Lab-Parabolic-Action-of-a-Free-Falling-Object-Applying-Equation-5322936

Calculus Lab: Collect data, use the Easy Data® app to select the parabolic portion of the graph, and use the calculator to find the regression equation. Answer questions dealing with velocity, acceleration and speed. https://www.teacherspayteachers.com/Product/Calculus-Lab-2-1-Parabolic-Action-of-a-Free-Falling-Object-4036427

Algebra I Lab

Parabolic Action of a Free-Falling Object - Finding the Equation

OBJECTIVE: The learner will be able to use data points collected by throwing a ball into the air to find the vertex form of the equation of the parabola.

MATERIALS: TI 84 Calculator and calculator-to-calculator cable, CBR Motion Detector with cord to attach to calculator, EasyData® APP, ball *(soccer ball or smooth children's ball)*

LAB RESPONSIBILITIES:

Project Manager – Read the lab as you go, initial each step as you go, keep group on task

Materials Manager – Handle equipment, collect data (must have EasyData® app), link data to group members' calculators

Recorder – record the answers in lab report.

LAB INSTRUCTIONS:

_____ 1. Turn the calculator [on] and connect it to the Motion Detector. Press [apps] and select the EasyData® application, if it is not already running.

_____ 2. Select [WINDOW] [Setup] and 1: Dist. Set units to feet by pressing [WINDOW] [Units] 2: (ft). Then press [graph] [OK].

_____ 3. **PRACTICE COLLECTING DATA**: Place the motion detector or CBR on the floor or desk pointing up. Hold your hand over the motion detector *(The motion detector does not read anything closer than one foot.)* When you are ready, press [graph] [OK] on the Data Deletion screen and move your hand up after you hear the clicks. When the motion detector stops, the CBR will transfer the data to your calculator. Practice one more time then continue with the ball.

_____ 4. **COLLECTING DATA**: You are going to throw the ball up so that it comes back down over the motion detector. *(Move your hands after you throw to get out of the range of the detector, but please catch the ball so that it won't hit my motion detector.)* Hold the ball *(hands on the sides)* at least 1 foot above the motion detector. *(Practice tossing the ball up about 2 feet.)* Press [zoom] [Start]. When you are ready to throw, press [graph] [OK] on the *Data Deletion* screen and throw the ball after you hear the clicks *(and catch it before it hits the CBR.)* When the motion detector stops, the CBR will transfer the data to your calculator.

_____ 5. When data collection is complete, a graph of Distance (ft) versus Time (sec) will be displayed. The graph should contain a parabolic section of smoothly changing distance. *(If there is no parabolic curve, press* [trace] [MAIN] > [zoom] [Start] *to overwrite the original data and repeat step #4.) (Show your graph to the teacher to approve before you proceed.)*

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_____ 6. **TRANSFERRING DATA TO OTHER CALCULATORS**: Material Manager: unplug CBR. In EasyData®, select [trace] [MAIN] > [graph] [Quit] > [graph] [OK] . Press [graph] to make sure your plot is still there, then [2nd] [mode] [quit] to get back to the Home Screen. Use a calculator-to-calculator cable to link your calculator to **all** your group members' calculators and transfer lists L1 and L6.

RECEIVER: [2nd] > [X,T,θ,n] [link] > Receive > [enter] > Your screen should say "Waiting"
SENDER: [2nd] > [X,T,θ,n] [link] > Send > List (press [enter] to select L1 and L6 > Transmit
RECEIVER: 2: Overwrite
BOTH: [2nd] [mode] [quit]

_____ 7. **CREATING SCATTER PLOT:** All group members create a scatter plot using Lists 1 and 6.
[2nd] > [y=] [stat plot] > 1: Plot 1 [enter] > On [enter] > Type: [enter] > Xlist: [2nd] [1] [L1] > Ylist: [2nd] [6] [L6] > Mark: • [enter] > [graph] > [zoom] > 9: ZoomStat)

_____ 8. **RECORDING DATA:** All group members press [▸] and [◂] keys to move the cursor to the time you think you tossed the ball up, the time you caught the ball, and the highest data point. Find one additional data point near the vertex. RECORDER: Sketch graph and the four ordered pairs on Recorder's Lab Report.

_____ 9. **ANALYZING DATA:** All group members collaborate to answer questions #1a, b, c and #2 on Recorder's Lab Report. Each group member write the vertex and your ordered pair on your Individual Lab Report.

At this point, if class time is short, students can finish Individual Lab Reports for homework then combine the results and collaborate by email or at the beginning of class tomorrow.

_____ 10. **INDIVIDUAL LAB REPORTS**: Use the vertex and your data point to solve for "a" in the vertex form of the equation of a parabola showing your work. Complete the Mathematical and Technical Growth discussions on the Individual Lab Report.

_____ 11. **COLLABORATION**: Back in class or by email, give your equation to the Recorder who will record all three equations in question #3. All group members graph all 3 equations in your calculator and answer question #4 on the Recorder's Lab Report. Attach the Individual Lab Reports to the Recorder's Lab Report to hand in.

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Algebra I Lab **Recorder:** _____ **Grade:** ___/25

Recorder's Lab Report **Project Manager:**_____ **Grade:** ___/25

Parabolic Action of a Free-Falling Object **Materials Manager/s:**_____ **Grade:** ___/25

Finding the Equation

Only one lab report should be handed in with the attached work from each group member.
All answers should be 3 places decimals. *(5 pts./question)*

(1) Sketch the initial graph with ordered pairs of the times you think you tossed and caught the ball, the highest data point and an additional data point near the vertex. Label the ordered pairs T *(tossed)*, C (caught), V *(vertex)*, and P *(additional point)*. Label axis with units relative to situation. (*sec after…, distance in ft. from…)*

(a) At what time do you think you tossed the ball? (*time should be discussed as, "… seconds after…"*

_____

(b) At what time do you think you caught the ball? (*time should be discussed as, "… seconds after…"*

_____

(c) Highest data point: (_____, _____) What real-world meaning does your vertex have? (*Your answer should specify "After …., the ball is … from the … " using your data numbers and correct units.)*

_____

_____

(2) Write the equation of the parabolic section of the graph in the form $y = a(x-h)^2 + k$ inserting the vertex.

$$y = a(x - _____)^2 + _____$$

(3) Each member of the group use a different point from #1 to find three different equations solving for "a". Attach your work to the lab report and record your equation here.

Recorder: T: (_____, _____) y = _____

Project Manager: C: (_____, _____) y = _____

Materials Manager: P: (_____, _____) y = _____

(4) Looking at the graph of all three equations and the data, which is the best model? Explain why.

_____

_____

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Algebra I Lab: Individual Lab Report Name: _____

Parabolic Action of a Free Falling Object

Finding the Equation

Each member of the group should complete this page and attach to the Recorder's Lab Report.

(All numbers 3 places behind decimal.)

Vertex: (_____, _____)

Your point from #1 on Recorder's Lab Report: T, C, or P? ___ : (_____, _____)

Your initial equation from #2 on Recorder's Lab Report: $y = a(x - _____)^2 + _____$

Solve for "a" showing your work.

Your final equation: y = _____

Write your final equation on Recorder's Lab Report in #3

(5) Describe the mathematical and technological growth experienced doing the lab. Be specific about what technology skills you learned or improved as well as the math you reinforced.

Mathematical Growth: _____

_____

_____

_____

Technological Growth: _____

_____

_____

_____

What would you do to improve the lab experience? _____

_____

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Algebra I Lab | **Recorder:** Sample Answers | **Grade:** ___/25

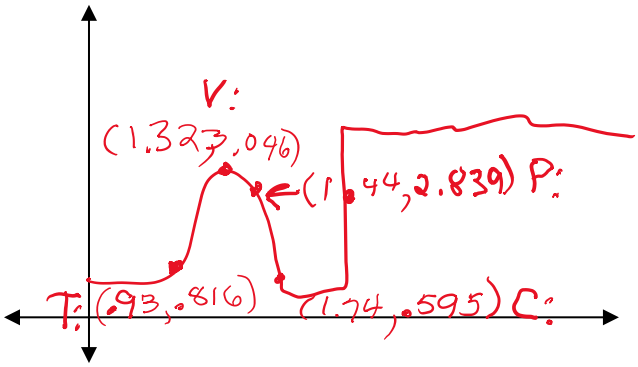
Recorder's Lab Report | **Project Manager:**_____ | **Grade:** ___/25

Parabolic Action of a Free Falling Object | **Materials Manager/s:**_____ | **Grade:** ___/25

Finding the Equation

Only one lab report, the Recorder's, should be handed in, with the attached work from each group member. All answers should be 3 places decimals. (10 pts./question)

(1) Sketch the initial graph with ordered pairs of the times you think you tossed and caught the ball, the highest data point and an additional data point near the vertex. Label the ordered pairs T *(tossed)*, C (caught), V *(vertex)*, and P *(additional point)*. Label axis with units relative to situation. *(sec after…, distance in ft. from…)*



(a) At what time do you think you tossed the ball? *(time should be discussed as, "… seconds after…"*

We tossed the ball .930 seconds after the CBR started clicking.

(b) At what time do you think you caught the ball? *(time should be discussed as, "… seconds after…"*

We caught the ball 1.74 seconds after the CBR started clicking.

(c) Highest data point: (1.320, 3.046) What real-world meaning does your vertex have? *(Your answer should specify "… after …., the ball is … from the … " using your data numbers and correct units.)*

1.320 seconds after the CBR started clicking, the ball was 3.046 feet above the CBR.

(2) Write the equation of the parabolic section of the graph in the form $y = a(x-h)^2 + k$ inserting the vertex.

$$y = a(x - 1.32)^2 + 3.046$$

(3) Each member of the group use a different point from #1 to find three different equations solving for "a". Attach your work to the lab report and record your equation here.

Recorder: T: (0.93, 0.816) $y = -14.661(x - 1.32)^2 + 3.046$

Project Manager: C: (1.74, .595) $y = -13.895(x - 1.32)^2 + 3.046$

Materials Manager: P: (1.44, 2.839) $y = -14.375(x - 1.32)^2 + 3.046$

(4) Looking at the graph of all three equations and the data, which is the best model? Explain why.

They all are the same shape but the tossed point equation seems to follow it better. Maybe the point we picked for catching the ball was a point after we caught it.

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Algebra I Lab: Individual Lab Report **Name:** Sample Answers

Parabolic Action of a Free Falling Object
Finding the Equation

Each member of the group should complete this page and attach to the Recorder's Lab Report.
(All numbers 3 places behind decimal.)

Vertex: (1.320, 3.046)

Your point from #1 on Recorder's Lab Report: T, C, or P? P : (1.440, 2.839)

Your initial equation from #2 on Recorder's Lab Report: y = a(x - 1.320____)^2 + 3.046

Solve for "a" showing your work.

$y = a(x-1.32)^2 + 3.046$

$2.839 = a(1.44-1.32)^2 + 3.046$

$2.839 = a(.12)^2 + 3.046)$

$-0.207 = a(.0144)$

$-14.375 = a$

Your final equation: y = $-14.375(x-1.32)^2 + 3.046$

Write your final equation on Recorder's Lab Report in #3

(5) Describe the mathematical and technological growth experienced doing the lab. Be specific about what technology skills you learned or improved as well as the math you reinforced.

Mathematical Growth: _____

_____

_____

Technological Growth: _____

_____

_____

What would you do to improve the lab experience? _____

_____

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