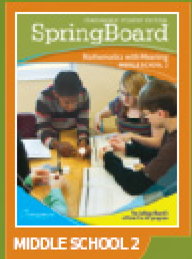
SpringBoard

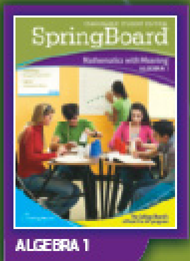
- Supports high expectations for ALL students
- Bridges the gap between middle school, high school and college expectations
- Prepares ALL students for success in Advanced Placement courses and college

MIDDLE SCHOOL 1

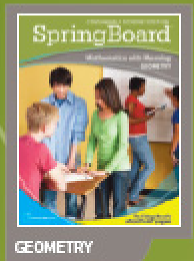


MIDDLE SCHOOL 2

MIDDLE SCHOOL 3



ALGEBRA 1



GEOMETRY

ALGEBRA 2

PRECALCULUS

The College Board's official Pre-AP program is SpringBoard, which consists of a full curriculum in mathematics and English language arts for middle school and high school, integrated with professional development and formative assessments.

www.collegeboard.com/springboard

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ALGEBRA 1
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CONSUMABLE STUDENT EDITION

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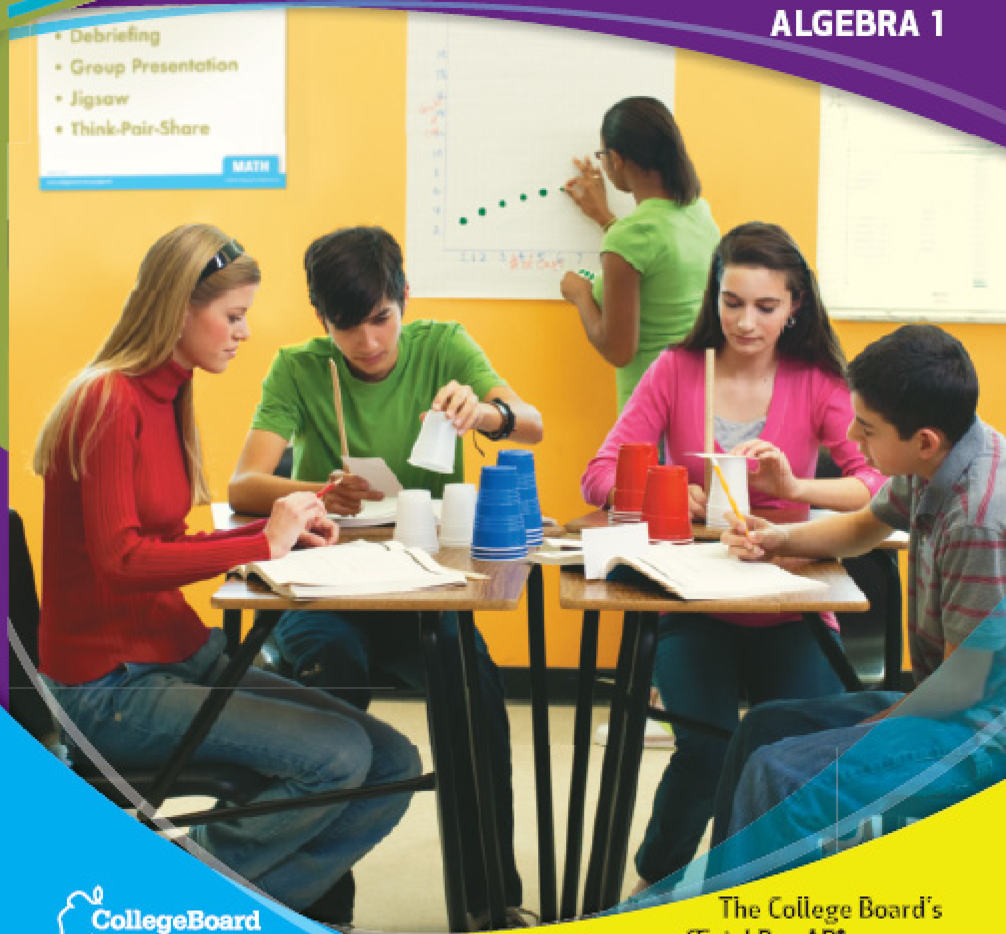
ALGEBRA 1



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The College Board's
official Pre-AP® program

Applying Quadratic Equations
Rockets in Flight

ACTIVITY 5.5

SUGGESTED LEARNING STRATEGIES: Shared Reading, Marking the Text, Questioning the Text, Look for a Pattern, Quickwrite

My Notes

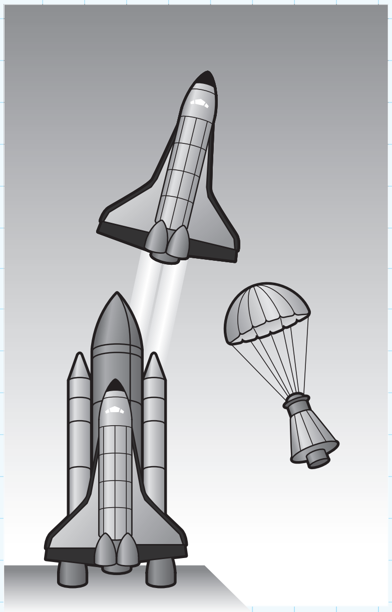
Homer H. Hickam Jr. is a coal miner's son, who lived in West Virginia during the 1950s. After the Russians launched the *Sputnik* satellite, Homer was inspired to learn about model rocketry. After many tries, Homer and his friends discovered how to launch and control the flight path of their model rockets. Homer went on to college and then worked for NASA.

Cooper is a model rocket fan. Cooper's model rockets have single engines and, when launched, can rise as high as 1000 ft depending upon the engine size. After the engine is ignited, it will burn for 3–5 seconds and the rocket will accelerate upward. Once the engine burns out, the rocket will be in *free fall*, because the only acceleration is due to gravity. The rocket has a parachute that will open as the rocket begins to fall back to Earth.

Cooper wanted to track one of his rockets, the *Eagle*, so that he could investigate its time and height while in flight. He installed a device into the nose of the *Eagle* to measure the time and height of the rocket as it fell back to Earth. The device started measuring when the parachute opened. The data for one flight of the *Eagle* is shown in the table below.

CONNECT TO SCIENCE

NASA is the National Aeronautics and Space Administration and is responsible for all space exploration.



The *Eagle*

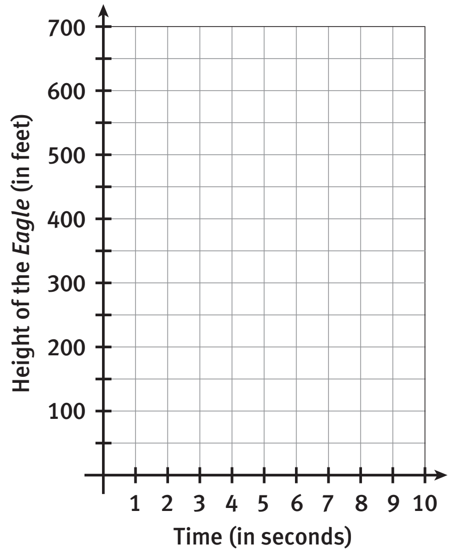
Time Since Parachute Opened (seconds)	0	1	2	3	4	5	6	7	8	9
Height (feet)	625	618	597	562	513	450	373	282	177	58

1. Use the data in the table above. Determine whether the height of the *Eagle* can be modeled by a linear function of time. Explain your reasoning.

SUGGESTED LEARNING STRATEGIES: Create Representations, Close Reading, Activating Prior Knowledge

My Notes

2. Graph the data from the table above Item 1 on the grid below.



3. The height of the *Eagle* can be modeled by the quadratic function $h(t) = kt^2 + h_0$, where k is a constant and h_0 is the initial height of the rocket. You can use the table data to find the values of k and h_0 in the *Eagle's* height function.

a. Solve for the value of h_0 using the point (0, 625). Include the appropriate units for h_0 in your solution.

b. Use a different ordered pair from the table above Item 1 to find the value of k. Write a function for the height of the rocket as a function of time.

READING MATH

A variable with a zero subscript such as h_0 is read "*h* naught," or "*h* sub zero." This means that it is the initial value.

SUGGESTED LEARNING STRATEGIES: Activating Prior Knowledge, Visualization, Questioning the Text, Create Representations, Think/Pair/Share, Group Presentation

My Notes

4. Use the function from Item 3 to answer these questions.

a. At what time was the rocket's height 450 ft above Earth? Verify that your result agrees with the data in the table.

b. After the parachute opened, how long did it take for the rocket to hit Earth?

Cooper wanted to investigate the flight of a rocket from the time the engine burns out until the rocket lands. He set a device in a second rocket, named *Spirit*, to begin collecting data the moment the engine shut off. Unfortunately, the parachute failed to open. When the rocket began to descend it was in free fall.

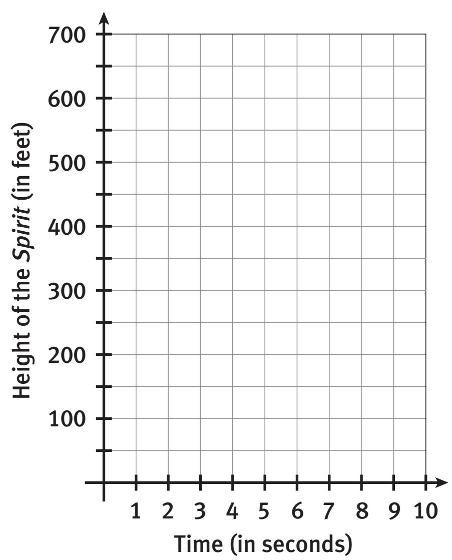
CONNECT TO SCIENCE

A *free falling* object is an object which is falling under the sole influence of gravity.

5. Graph the data for the height of the *Spirit* versus time on the grid.

The *Spirit*

Time Since the Engine Burned Out (s)	Height (ft)
0	512
1	560
2	576
3	560
4	512
5	432
6	320



SUGGESTED LEARNING STRATEGIES: Think/Pair/Share, Close Reading, Create Representations

My Notes

6. Use the table and graph in Item 5.

a. How high was the *Spirit* when the engine burned out?

b. How long did it take the rocket to reach its maximum height after the engine cut out?

c. Estimate the time the rocket was in free fall before it reached the earth.

7. Use the table and graph in Item 5.

a. Use a graphing calculator to determine a quadratic $h(t)$ function for the data.

b. Sketch the graph of the function on the grid in Item 5.

TECHNOLOGY TIP

For Item 7(a), enter the data from the table in Item 5 into a graphing calculator. Use the calculator's quadratic regression feature to find a representative function.

8. Use the function found in Item 7 to verify the height of the *Spirit* when the engine burned out.

SUGGESTED LEARNING STRATEGIES: Create Representations, Predict and Confirm, Activating Prior Knowledge, Quickwrite

My Notes

9. Graph the function found in Item 7 on your graphing calculator. Use the graph to approximate the time interval in which the *Spirit* was in free fall. Explain how you determined your answer.

10. The total time that the *Spirit* was in the air after the engine burned out is determined by finding the values of t that makes $h(t) = 0$.

a. Set the equation found in Item 7(a) equal to 0.

b. Completely factor the equation.

c. Identify and use the appropriate property to find the time that the *Spirit* took to strike Earth after the engine burned out.

SUGGESTED LEARNING STRATEGIES: Activating Prior Knowledge, Create Representations, Think/Pair/Share

My Notes

11. The quadratic formula can also be used to solve the equation from Item 10(a).

a. State the quadratic formula.

b. Use the quadratic formula to determine the total time that the *Spirit* was in the air after the engine burned out. Show your work.

12. Draw a horizontal line on the graph in Item 5 to indicate a height of 544 ft above Earth. Estimate the approximate time(s) that the *Spirit* was 544 ft above Earth.

13. The time(s) that the *Spirit* was 544 ft above Earth can be determined exactly by finding the values of t that make $h(t) = 544$.

a. Set the equation from Item 7(a) equal to 544.

SUGGESTED LEARNING STRATEGIES: Activating Prior Knowledge, Quickwrite, Create Representations, Think/Pair/Share

My Notes

b. Is the method of factoring effective in solving this equation? Explain your reasoning.

c. Is the quadratic formula effective in solving this problem? Explain your reasoning.

d. Determine the time(s) that the rocket was 544 ft above Earth. Round your answer to the nearest hundredth of a second. Verify that this solution is reasonable compared to the estimated times from the graph, Item 12.

14. Cooper could not see the *Spirit* when it was higher than 528 ft above Earth.

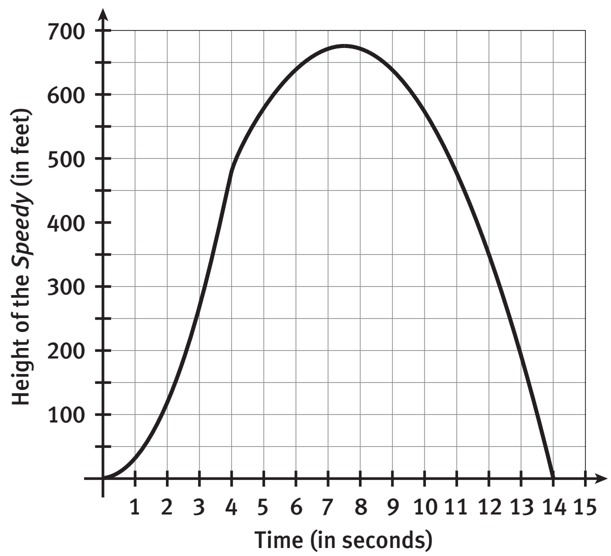
a. Find the values of t for which $h(t) = 528$.

b. Write an inequality for the values of t that are between the two times that the rocket was not within Cooper's sight.

SUGGESTED LEARNING STRATEGIES: Close Reading, Marking the Text, Quickwrite, Visualization, Group Presentation

My Notes

Cooper has a third rocket named *Speedy*. He decided to fire the rocket without a parachute to investigate a rocket's motion in free fall. Cooper represented the launch time as $t = 0$. The graph of the height of the *Speedy* is a piecewise function, shown below.



15. Use the graph above to estimate the answer to each question.

a. At what time did the *Speedy's* engine burn out?

b. What was the maximum height of the rocket and at what time did the rocket reach that height?

c. At what time did the rocket hit Earth?

SUGGESTED LEARNING STRATEGIES: Marking the Text, Simplify the Problem, Create Representations, Think/Pair/Share

My Notes

Cooper is entering the *Speedy* into a contest. The winner is the owner of the rocket that stays above 400 ft for the longest period of time.

16. Draw a horizontal line on the graph above Item 15 to indicate a height of 400 ft above Earth. Estimate when the rocket will be more than 400 ft above Earth.

While *Speedy's* engine is burning for the first 4 seconds, the height is given by the function $h_1(t) = 30t^2$. After the engine burns out, the height is given by $h_2(t) = -224 + 240t - 16t^2$.

17. Write a piecewise function $h(t)$ that expresses the height of the *Speedy* above Earth as a function of time.

18. For the contest, Cooper needs to determine the length of time that the *Speedy* will be 400 ft above Earth. Use the piecewise function for the height of the rocket from Item 17 to determine the exact time(s) that the rocket will be exactly 400 ft above Earth.

a. Explain why two different equations must be solved to determine the time(s) that the rocket will be 400 ft above Earth.

SUGGESTED LEARNING STRATEGIES: Simplify the Problem, Think/Pair/Share, Debriefing

My Notes

b. Write and solve an equation to determine the time that the rocket will be 400 ft above Earth during the time interval for which $0 \leq t \leq 4$.

c. Write and solve an equation to determine the time that the rocket will be 400 ft above Earth during the time interval for which $t > 4$.

d. Determine the length of time that the rocket will be 400 ft above Earth.

CHECK YOUR UNDERSTANDING

Write your answers on notebook paper or grid paper. Show your work.

The equation $h(t) = -16t^2 + 128t + 320$ represents the flight of a model rocket after the rocket's engine burns out.

1. Determine when the rocket hits Earth.
2. Graph the equation. Determine the time at which the rocket reaches its maximum height.
3. Determine the times when the rocket is higher than 423 ft. Explain how you arrived at your solution.

A model rocket burns for 3.5 s. The rocket will be 286 ft in the air when the engine burns out. After the rocket's engine burns out, the rocket's height is given by the function $h(t) = 286 + 190t - 16t^2$.

4. Determine the total time after the rocket is launched that it will be in the air.
5. Determine the times after the rocket is launched that it will be 450 ft in the air.
6. **MATHEMATICAL REFLECTION** Why are quadratic functions used to model free-fall motion instead of linear functions?