Math Objectives

- Students will understand how changing the initial velocity and the initial angle change the path of a projectile.
- Students will be able to write the parametric equations for the path of a projectile.

Vocabulary

- parametric
- projectile
- velocity
- angle
- vector

About the Lesson

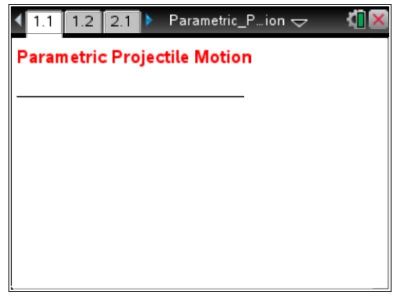
- This lesson involves observing how changing the initial values affects the path of a projectile.
- As a result, students will:
  - Discover the parametric equations for the path of a projectile.
  - Test an initial velocity and an initial angle and determine if they have chosen the right values to make a basket.
  - Identify the conditions that must be met to make a basket.

TI-Nspire™ Navigator™

- Use Document Collection/Quick Poll/Class Capture to enable teachers to assess student understanding during the lesson.
- Use Class Capture to examine patterns that emerge.
- Use Quick Poll to assess understanding.
- Use Live Presenter to increase student understanding.

Activity Materials

- Compatible TI Technologies: TI-Nspire™ CX Handhelds, TI-Nspire™ Apps for iPad®, TI-Nspire™ Software



Tech Tips:

- This activity includes screen captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:
Student Activity

- Parametric_Projectile_Motion_Student.PDF
- Parametric_Projectile_Motion_Student.DOC

TI-Nspire document

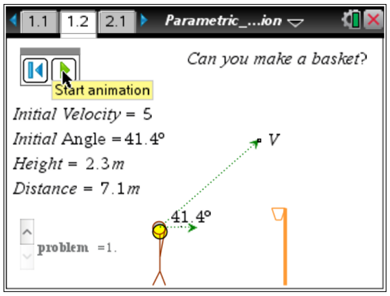
- Parametric_Projectile_Motion.tns

Discussion Points and Possible Answers

Tech Tip: Students can self-check their answers to the included assessment questions by selecting **MENU > Self Check** and then pressing enter.

Tech Tip: Students can self-check their answers to the included assessment questions by selecting **> Self Check**

Move to page 1.2.



Press the "Start animation" button and observe the trajectory of the ball. Point *V* changes the initial velocity vector that gives the initial speed and the initial angle.

Tech Tip: The "Start animation" and 'reset' button are in the upper right of the window 

Reset the animation and move point *V* to change the initial speed and/or the initial angle. Observe the effect of the changes, and continue to adjust the vector to score a basket.

Use ▲ to change to a new problem. The height of the player and the distance from the basket will both change.

1. What do you notice about the path of the ball when the velocity is large and the angle is small?

   Sample answer: The ball will go almost parallel to horizontal but will continue to drop as it moves.

TI-Nspire Navigator Opportunity: *Live Presenter/Class Capture*
See Note 1 below.

2. What do you notice about the path of the ball when the velocity is large and the initial angle is large?

   Sample answer: The ball will go nearly straight up and then immediately come down close to where the player shot it.

Teacher Tip: Students might choose an angle that is larger than 80^o, but to see the path of the ball, they should not choose an angle that is not acute.

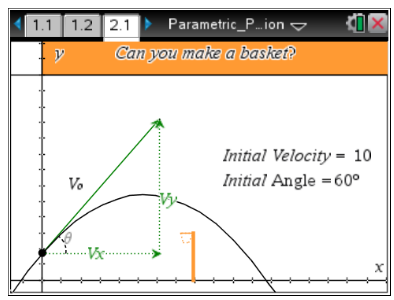
3. How can you change your initial conditions to make the ball go very high?

   Sample answer: I can change the initial conditions so that the angle is close to a right angle and the initial velocity is as large as possible.

4. How can you change your initial conditions to make the ball go very far?

   Answer: I can change the initial conditions so that the initial velocity is large and the initial angle is 45^o.

Move to page 2.1.

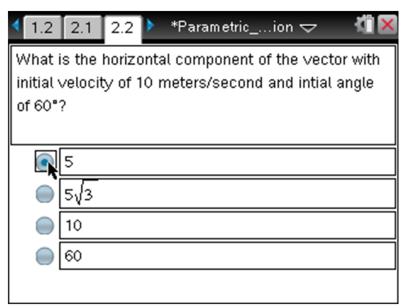


5. Find the x-component (horizontal component) of the vector V_0 and the y-component (vertical component) of the vector V_0. Note: V_0 is the initial velocity, V_x is the x-component of the vector, and V_y is the y-component of the vector.

   Answer: x-component: $\cos(\theta) = \frac{V_x}{V_0}$, so $V_x = V_0 \cos(\theta)$

   y-component: $\sin(\theta) = \frac{V_y}{V_0}$, so $V_y = V_0 \sin(\theta)$

Move to page 2.2.



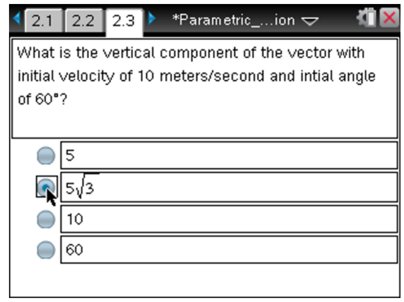
6. What is the vertical component of the vector with initial velocity of 10 meters/second and initial angle of 60^o?

   Answer: $V_x = 10\cos(60^\circ) = 10\left(\frac{1}{2}\right) = 5$

TI-Nspire Navigator Opportunity: ***Quick Poll***
See Note 2 below.

Move to page 2.3.

7. What is the horizontal component of the vector with initial velocity of 10 meters/second and initial angle of 60°?



Answer: $V_x = 10\sin(60^\circ) = 10\left(\frac{\sqrt{3}}{2}\right) = 5\sqrt{3}$

TI-Nspire Navigator Opportunity: *Quick Poll*
See Note 2 below.

Teacher Tip: This is a good time to revisit Questions 6 and 7. Students could discuss how to find the horizontal or vertical component for *any* initial velocity and initial angle.

8. The distance the ball travels in the horizontal direction (neglecting air resistance) is given by the *x*-component (rate in the *x*-direction) multiplied by time (t). Find the distance the ball travels in the horizontal direction as a function of time.

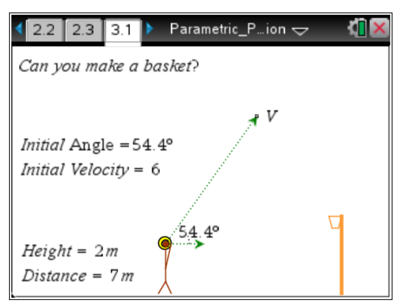
Answer: $x = V_0\cos(\theta) \cdot t$

9. The distance the ball travels in the vertical direction is given by the *y*-component multiplied by time (t) plus the initial height (h) minus the gravitational pull due to gravity given by $4.9t^2$. Find the height of the ball as a function of time.

Answer: $y = h + V_0\sin(\theta) \cdot t - 4.9t^2$

Move to page 3.1.

10. Find the parametric equation for the path of the ball that makes a basket if the player's height is 2 meters and the player is 7 meters from the basket. Graph the parametric equation of the path of the ball that will go through the basket.



Sample answer: $x(t) = 8.62 \cdot \cos(52.2) \cdot t$

$y(t) = 2 + 8.62 \cdot \sin(52.2) \cdot t - 4.9 \cdot t^2$

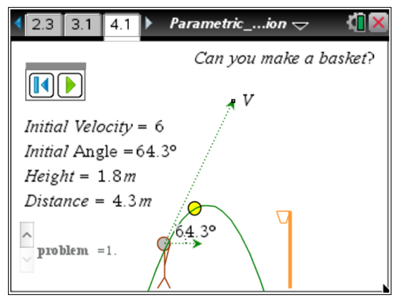
Tech Tip: Students can switch the graph type by selecting **MENU > Graph Entry/Edit > Parametric**.

Tech Tip: Select **> Graph Entry/Edit > Parametric** to switch the graph type.

TI-Nspire Navigator Opportunity: *Class Capture*
See Note 3 below.

Move to page 4.1.

11. Practice making a basket by graphing parametric equations for at least two more problems that are randomly created when you select another problem. Change the initial conditions.



Sample Answers: Student responses will vary.

Teacher Tip: Students will practice what they learn in Problem 4. Challenge them to see if they can make three baskets in a row.

TI-Nspire Navigator Opportunity: *Live Presenter*
See Note 4 below.

Wrap Up

Upon completion of the discussion, the teacher should ensure that students are able to understand:

- How the initial velocity and initial angle change the path of a projectile.
- The parametric equations associate with the path of a projectile.

Assessment

Embedded questions on pages 2.2 and 2.3.

TI-Nspire Navigator

Note 1

Question 1–4: Live Presenter/Class Capture

Choose a student to become the Live Presenter. Have the student demonstrate how to start and reset an animation. Discuss each of Questions 1–4 with the students. Use Class Capture to identify students to utilize as the Live Presenter.

Turn off Live Presenter. Turn on the Auto-Refresh feature (30-second intervals might be reasonable).

TI-Nspire Navigator can be used to monitor student progress. You might want to leave Class Capture projected (without student names). This will enable both you and the students to monitor their progress. Alternatively, you might want to turn off the projector so the student screens are visible only to you.

As you circulate around the classroom, frequently check Class Capture to identify students who need help. Use this information to decide whether to provide individual assistance or bring the class together to address what seems to be a common misunderstanding.

Note 2

Questions 6 and 7: Quick Poll (*Multiple Choice*)

Instead of having students self-check, change the teacher settings for this question to Exam and send Page 2.2 or 2.3 as a Quick Poll. You can save the results and show a Class Analysis to discuss possible misunderstandings students may have.

If students had difficulty, you can review the concepts covered in Questions 6 and 7. It might be useful to pair students up, assigning students of different abilities to the same group.

Note 3

Question 10: Class Capture

Use the Class Capture tool to make sure students are entering their equations correctly into a parametric graph type.

Note 4

Question 11: Live Presenter

Make someone in the classroom the Live Presenter, and have the other students help him or her find the parametric equation for the path of the ball to score a basket. Struggling students are a good choice for Live Presenter so that another student can help them find the correct initial velocity and initial angle to score a basket.