Chapter 2 - Motion in 2 Dimensions

KEY CONCEPTS

After completing this chapter you will be able to

- explain the difference between vectors and scalars
- solve vector problems involving distance, position, and displacement
- describe how to determine total displacement in two dimensions by scale diagram and by the component method
- solve problems related to the horizontal and vertical components of motion of a projectile using kinematics equations (determine the range, maximum height, and time of flight for a projectile's motion)
- assess the social and environmental impacts of a technology that applies kinematics concepts

Learning Goal: By the end of this section, I will be able to calculate the range, max height, time of flight, etc. for projectile motion

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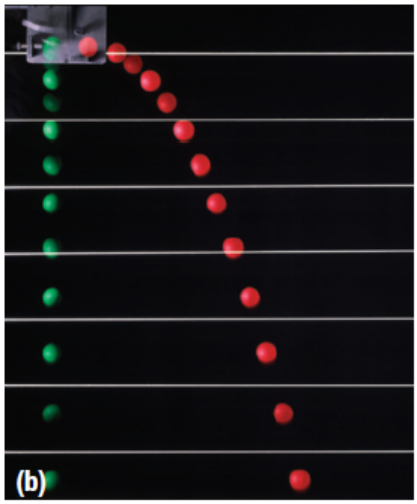
Projectile Motion

Any object that moves in response to **gravity** along a two-dimensional curved trajectory is called a projectile. The motion of a projectile under gravity is called projectile motion.

Time Lapse Image of a Rubber Ball being dropped and one being projected.



What similarities and differences can you see?

Demo - ball bearing and washer

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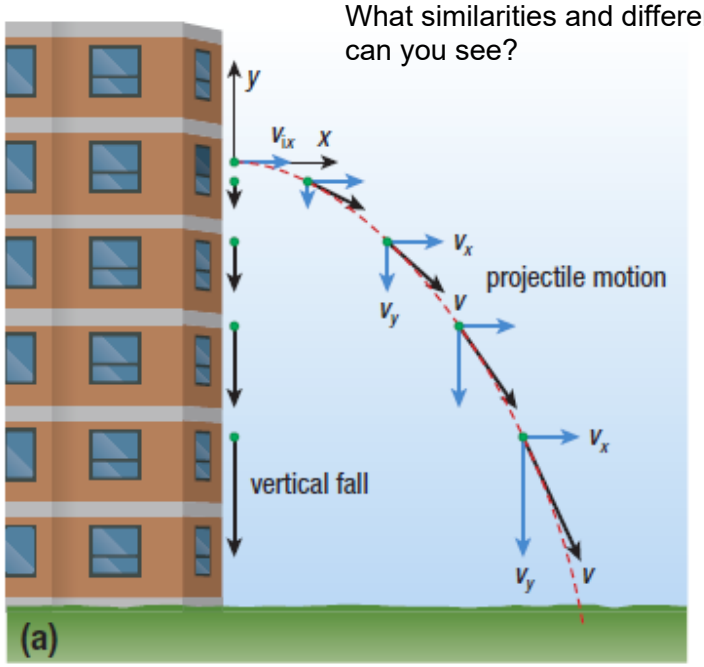
Vector Representation of Projectile Motion

What similarities and differences can you see?



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In projectile motion, once the object is "launched/projected" there is only on exterior acceleration taking place, and that is the acceleration due to gravity We ignore air resistance at this point in time.

This means that the horizontal velocity NEVER changes, while the vertical velocity experiences the effects of gravity, similar to the one dimensional problems discussed in Chapter One.

In two dimensional motion, we now have to indicate whether an object's velocity is Horizontal or Vertical, this can be done using subscripts.

Vertical Notations

V_{yi} V_{yf} V_{Vi} V_{Vf}

Horizontal Notations

V_{xi} V_{xf} V_{Hi} V_{Hf}

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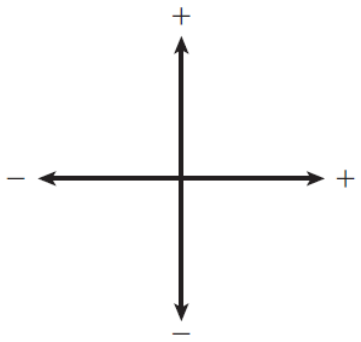

Figure 3 Sign conventions for projectile motion

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Sample Problem 1

A beanbag is thrown from a window 10.0 m above the ground with an initial horizontal velocity of 3.0 m/s.

(a) How long will it take the beanbag to reach the ground? That is, what is its time of flight?

(b) How far will the beanbag travel horizontally? That is, what is its range?

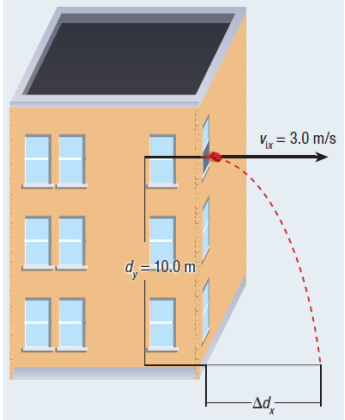

Figure 4 Projectile motion, launching horizontally

Given:

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Practice

1. A hockey puck is launched horizontally from the roof of a 32 m tall building at a velocity of 8.6 m/s. T/I
   (a) What is the hockey puck's time of flight?
   (b) What is the hockey puck's range?
2. Suppose the hockey puck in Question 1 has an initial velocity one-half the value given. How does this affect the puck's time of flight and range? K/U

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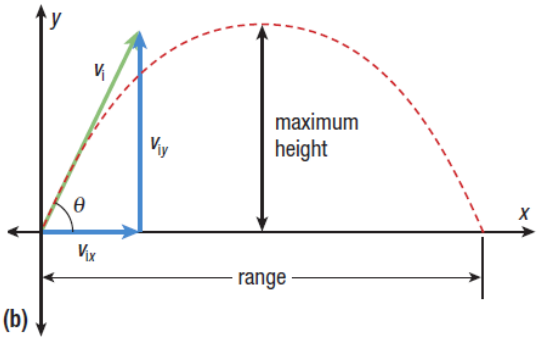
Projectiles can be launched at angles measured to the horizontal.

By changing the angle you can control the horizontal and vertical distance travelled by the projected object.

As we did with the displacement vectors, we can resolve or break up the given velocity into its horizontal and vertical components.

Many flash video games are a variation of this concept.

Flash Game - Arrow Demo



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Sample Problem 1

A soccer player running on a level playing field kicks a soccer ball with a velocity of 9.4 m/s at an angle of 40° above the horizontal. Determine the soccer ball's

(a) time of flight

(b) range

(c) maximum height

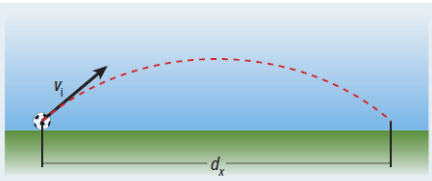

Figure 6 Motion of the soccer ball

Given Information:

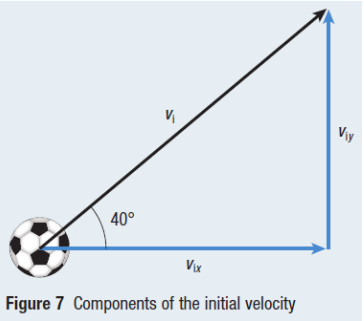

Figure 7 Components of the initial velocity

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Sample Problem 2

A golfer is trying to improve the range of her shot. To do so she drives a golf ball from the top of a steep cliff, 30.0 m above the ground where the ball will land. If the ball has an initial velocity of 25 m/s and is launched at an angle of 50° above the horizontal, determine the ball's time of flight, its range, and its final velocity just before it hits the ground. **Figure 8** shows the motion of the golf ball.

For this solution we will combine the horizontal and vertical given statements.

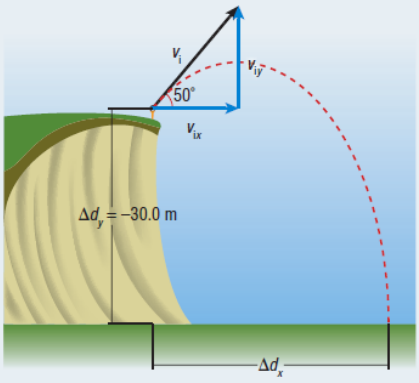

Figure 8 Motion of the golf ball

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Practice

1. A superhero launches himself from the top of a building with a velocity of 7.3 m/s at an angle of 25° above the horizontal. If the building is 17 m high, how far will he travel horizontally before reaching the ground? What is his final velocity?

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2.3 Questions

1. What do the horizontal and vertical motions of a projectile have in common? K/U
2. A tennis ball thrown horizontally from the top of a water tower lands 20.0 m from the base of the tower. If the tennis ball is initially thrown at a velocity of 10.0 m/s, how high is the water tower? How long does it take the tennis ball to reach the ground? T/I
3. At what angle should you launch a projectile from the ground so that it has the
   (a) greatest time of flight?
   (b) greatest range, assuming no air resistance? (Hint: Use your findings from Investigation 2.3.1) K/U
4. A field hockey ball is launched from the ground at an angle to the horizontal. What are the ball's horizontal and vertical accelerations
   (a) at its maximum height?
   (b) halfway up to its maximum height?
   (c) halfway down to the ground? K/U
5. An archer shoots at a target 60 m away. If she shoots at a velocity of 55 m/s [right] from a height of 1.5 m, does the arrow reach the target before striking the ground? What should the archer do to get her next shot on target? T/I C
6. An acrobat is launched from a cannon at an angle of 60° above the horizontal. The acrobat is caught by a safety net mounted horizontally at the height from which he was initially launched. Suppose the acrobat is launched at a speed of 26 m/s. T/I
   (a) How long does it take before he reaches his maximum height?
   (b) How long does it take in total for him to reach a point halfway back down to the ground?
7. A championship golfer uses a nine iron to chip a shot right into the cup. If the golf ball is launched at a velocity of 20 m/s at an angle of 45° above the horizontal, how far away was the golfer from the hole when he hit the ball? What maximum height did the ball reach? T/I
8. As part of a physics investigation, a student launches a beanbag out of an open window with a velocity of 4.5 m/s at an angle of 25° above the horizontal. If the window is 12 m above the ground, how far away from the building must the student's friend stand to catch the beanbag at ground level? T/I

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