

# Lecture PowerPoints

## Chapter 3 *Physics: Principles with Applications, 7<sup>th</sup> edition* Giancoli

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# Chapter 3

## Kinematics in Two Dimensions; Vectors



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- Subtraction of Vectors, and Multiplication of a Vector by a Scalar
- Adding Vectors by Components
- Projectile Motion
- Solving Projectile Motion Problems
- Projectile Motion Is Parabolic
- Relative Velocity

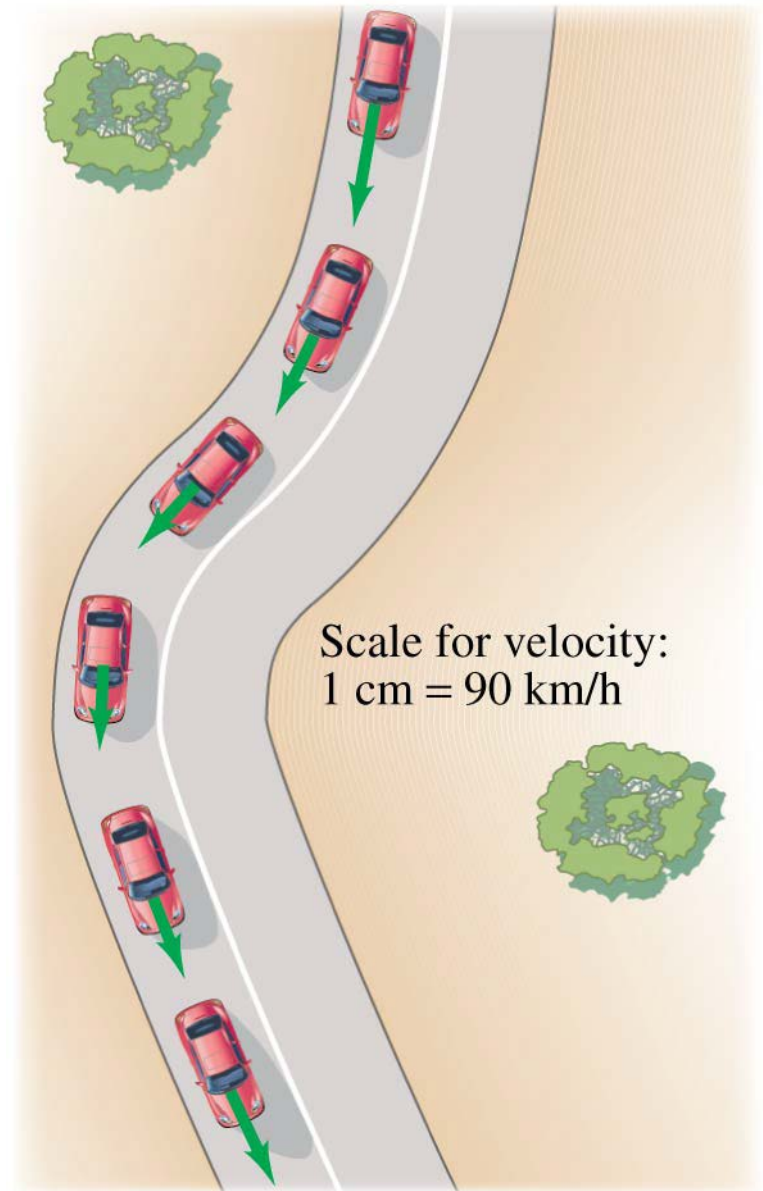
# 3-1 Vectors and Scalars

A vector has magnitude as well as direction.

Some vector quantities:  
displacement, velocity, force,  
momentum

A scalar has only a magnitude.

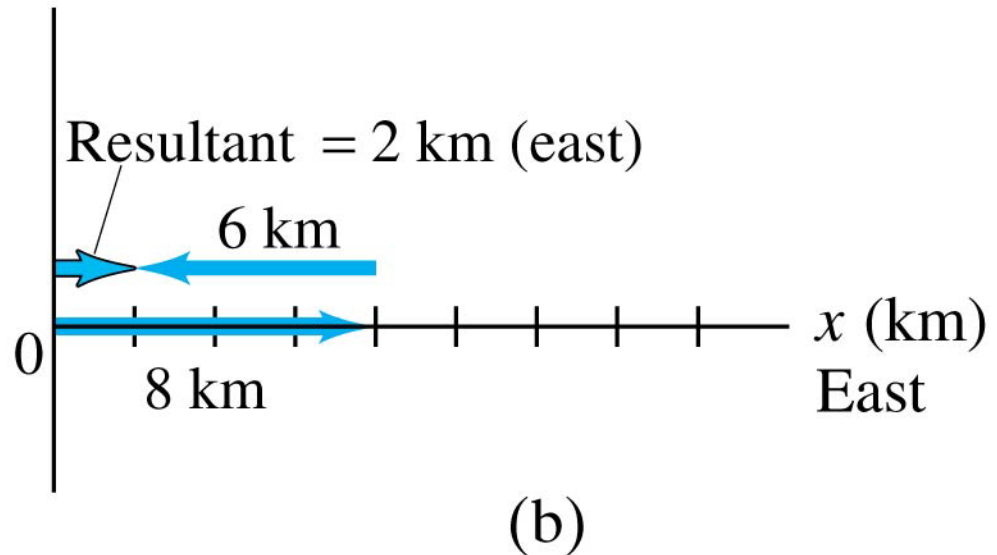
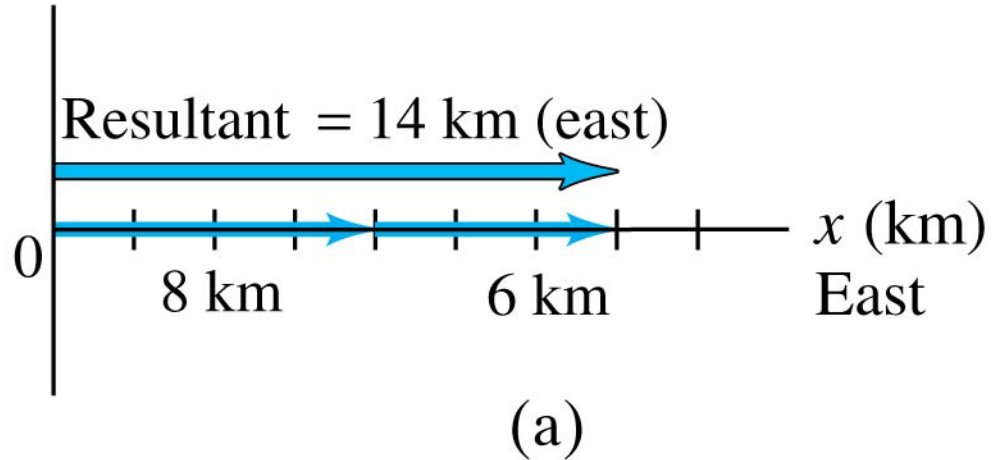
Some scalar quantities: mass,  
time, temperature



## 3-2 Addition of Vectors—Graphical Methods

For vectors in one dimension, simple addition and subtraction are all that is needed.

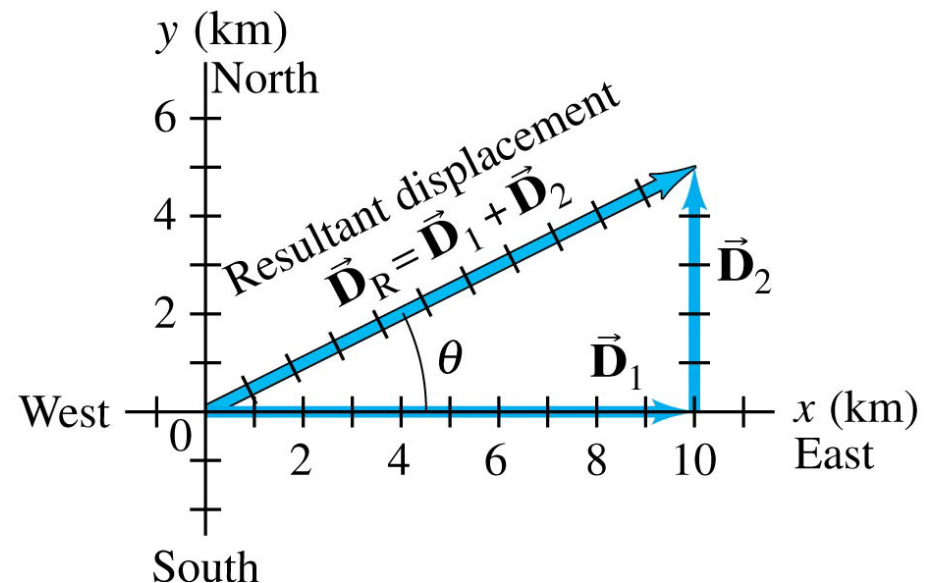
You do need to be careful about the signs, as the figure indicates.



## 3-2 Addition of Vectors—Graphical Methods

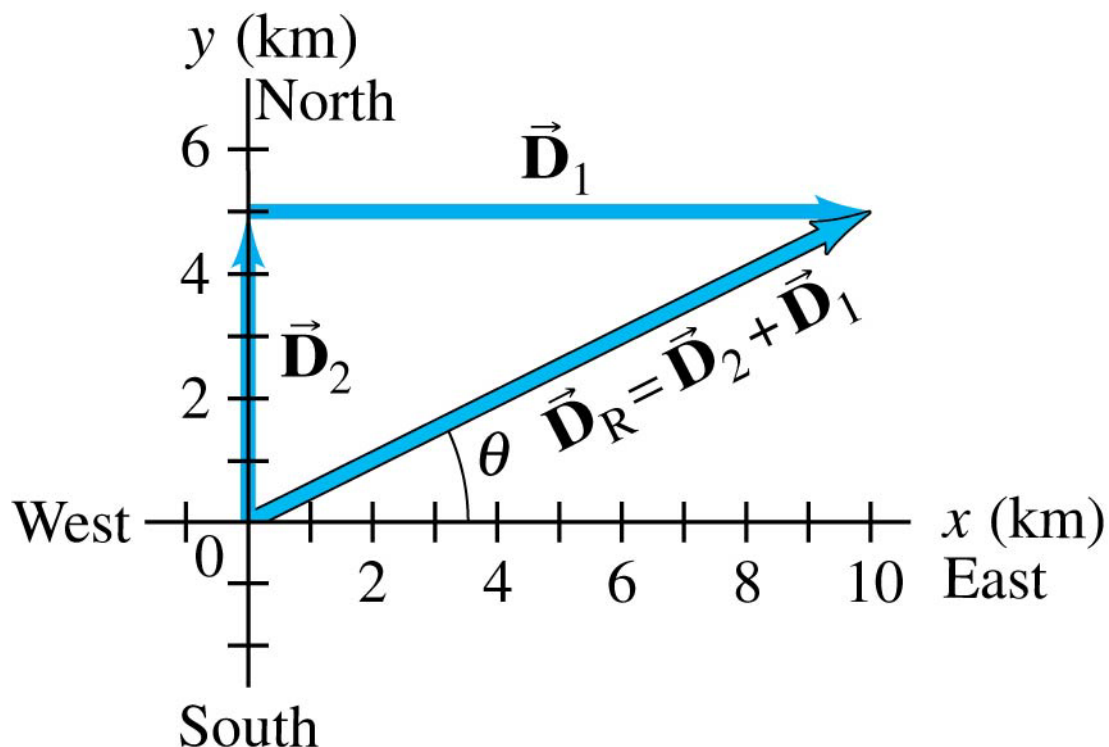
If the motion is in two dimensions, the situation is somewhat more complicated.

Here, the actual travel paths are at right angles to one another; we can find the displacement by using the Pythagorean Theorem.



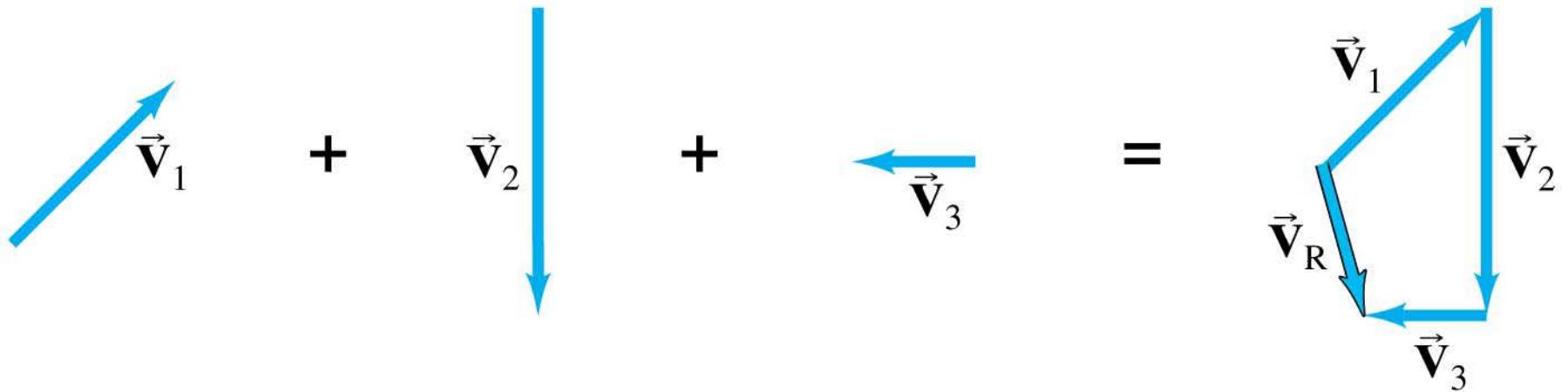
## 3-2 Addition of Vectors—Graphical Methods

Adding the vectors in the opposite order gives the same result:



## 3-2 Addition of Vectors—Graphical Methods

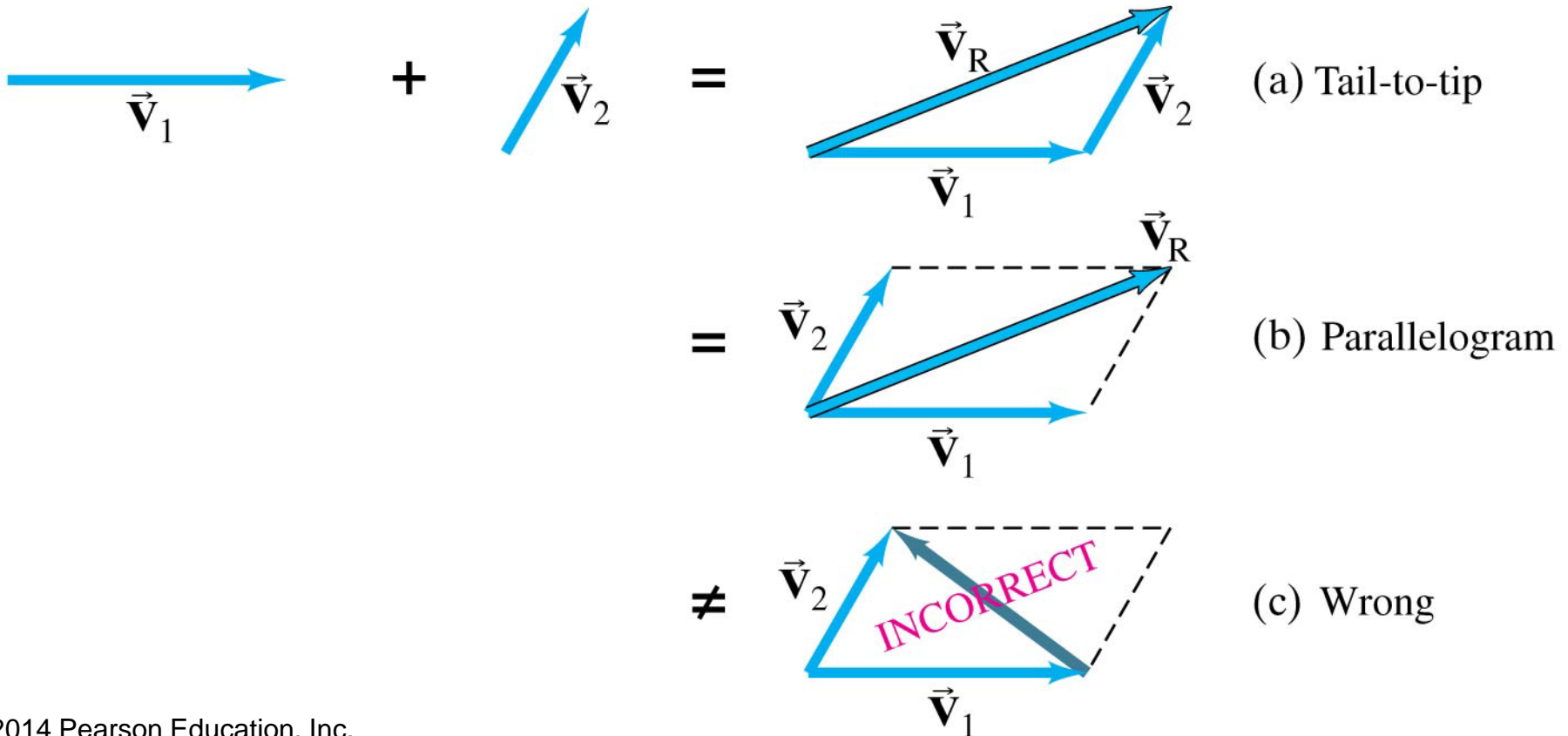
Even if the vectors are not at right angles, they can be added graphically by using the “tail-to-tip” method.





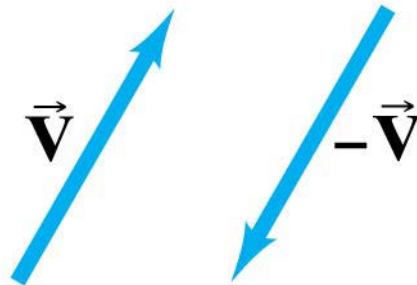
# 3-2 Addition of Vectors—Graphical Methods

The parallelogram method may also be used; here again the vectors must be “tail-to-tip.”



# 3-3 Subtraction of Vectors, and Multiplication of a Vector by a Scalar

In order to subtract vectors, we define the negative of a vector, which has the same magnitude but points in the opposite direction.

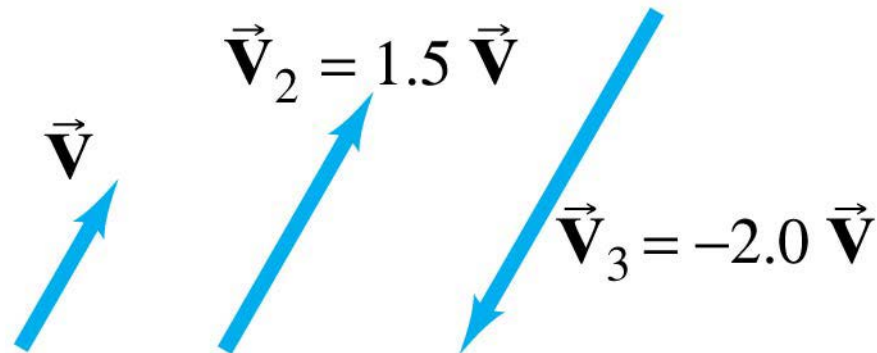


Then we add the negative vector:



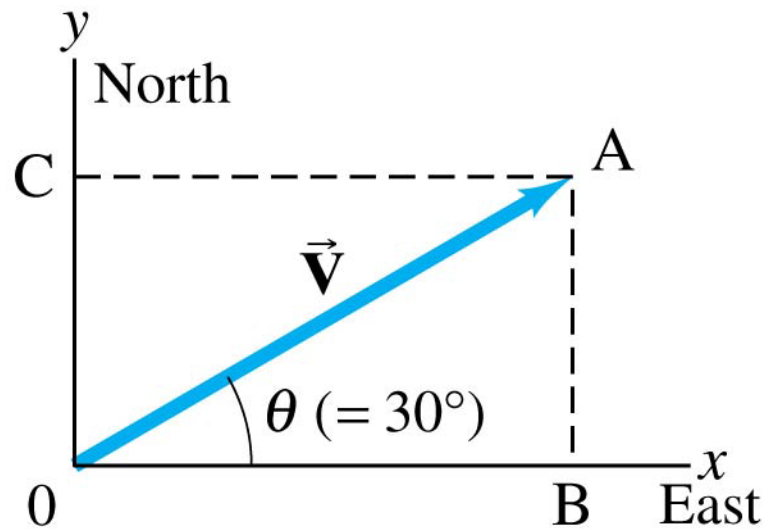
## 3-3 Subtraction of Vectors, and Multiplication of a Vector by a Scalar

A vector  $V$  can be multiplied by a scalar  $c$ ; the result is a vector  $cV$  that has the same direction but a magnitude  $cV$ . If  $c$  is negative, the resultant vector points in the opposite direction.

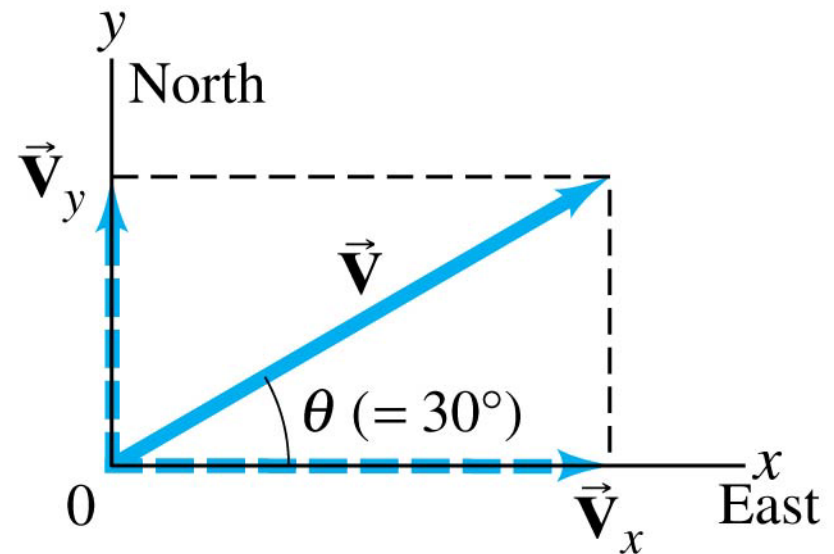


## 3-4 Adding Vectors by Components

Any vector can be expressed as the sum of two other vectors, which are called its components. Usually the other vectors are chosen so they are perpendicular to each other.



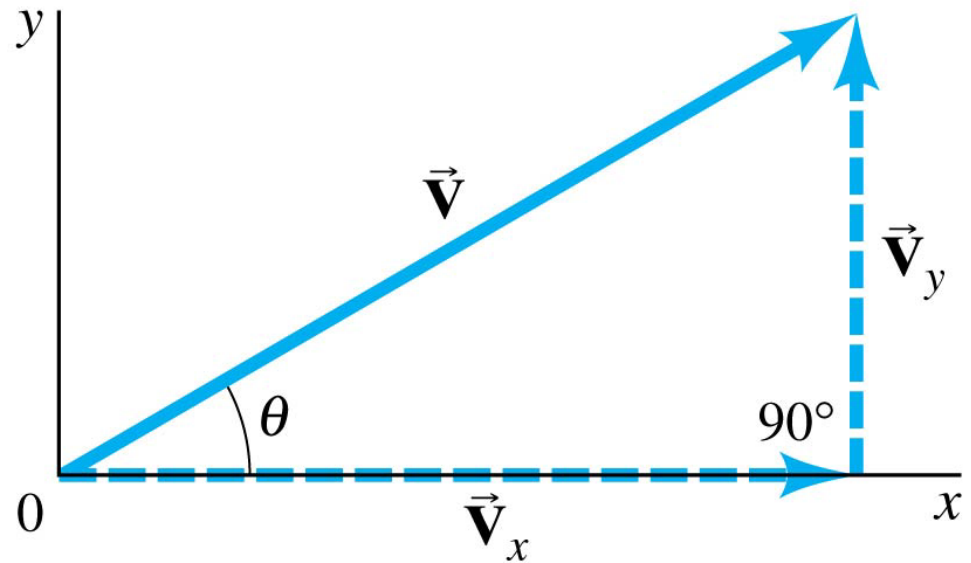
(a)



(b)

## 3-4 Adding Vectors by Components

If the components are perpendicular, they can be found using trigonometric functions.



$$\sin \theta = \frac{V_y}{V}$$

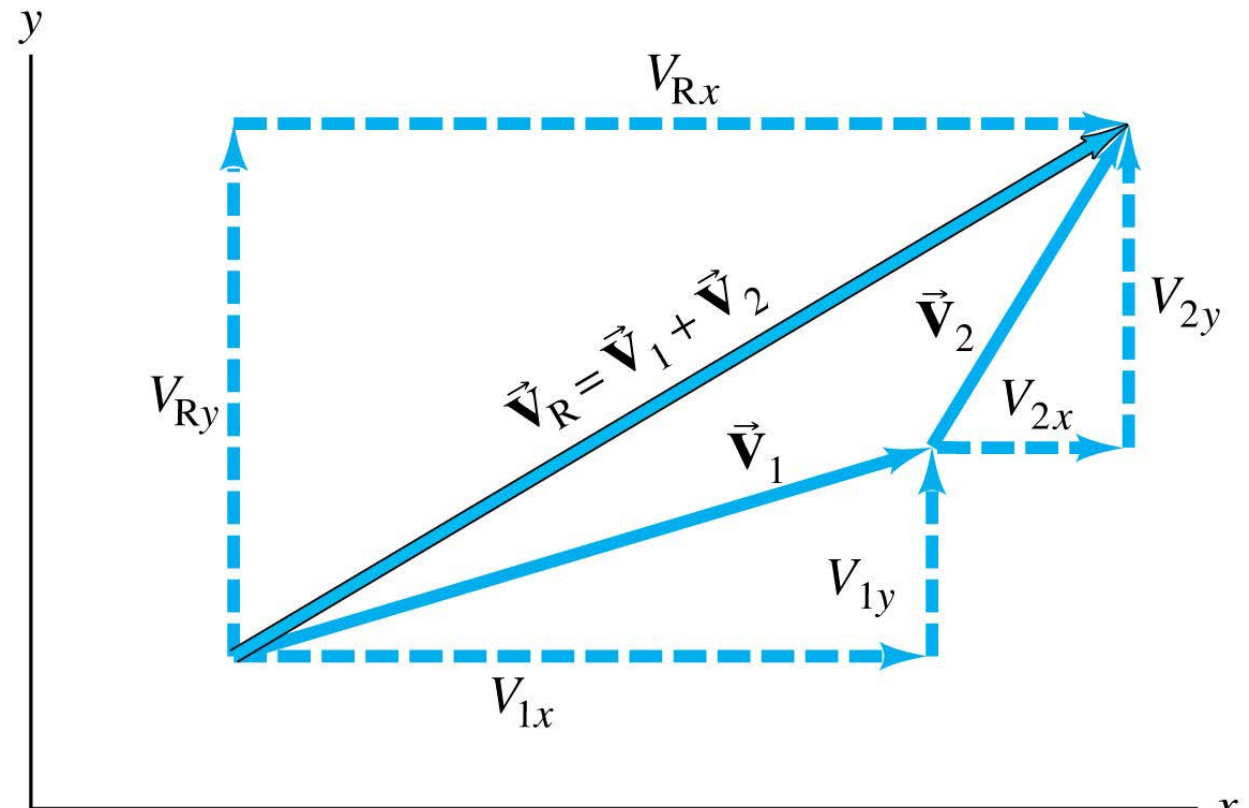
$$\cos \theta = \frac{V_x}{V}$$

$$\tan \theta = \frac{V_y}{V_x}$$

$$V^2 = V_x^2 + V_y^2$$

## 3-4 Adding Vectors by Components

The components are effectively one-dimensional, so they can be added arithmetically:



## 3-4 Adding Vectors by Components

Adding vectors:

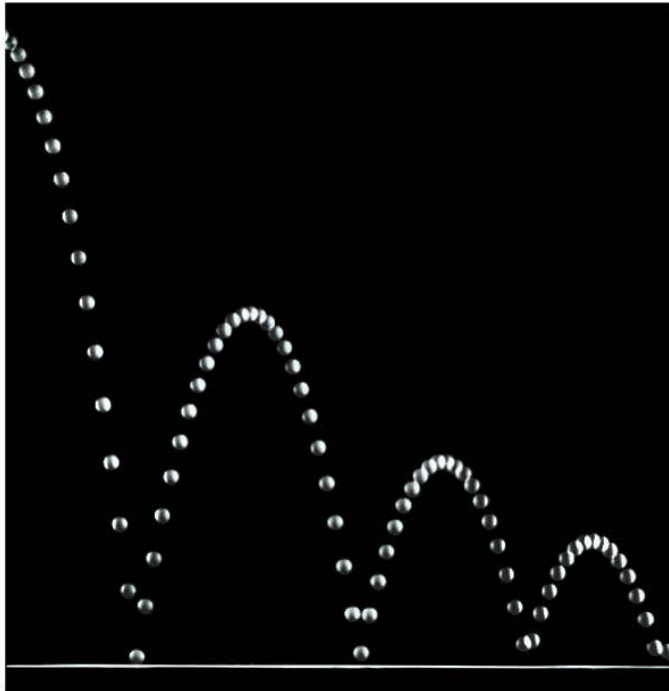
1. Draw a diagram; add the vectors graphically.
2. Choose  $x$  and  $y$  axes.
3. Resolve each vector into  $x$  and  $y$  components.
4. Calculate each component using sines and cosines.
5. Add the components in each direction.
6. To find the length and direction of the vector, use:

$$V = \sqrt{V_x^2 + V_y^2} \quad (3-4a)$$

$$\tan \theta = \frac{V_y}{V_x} \quad (3-4b)$$

# 3-5 Projectile Motion

A projectile is an object moving in two dimensions under the influence of Earth's gravity; its path is a parabola.



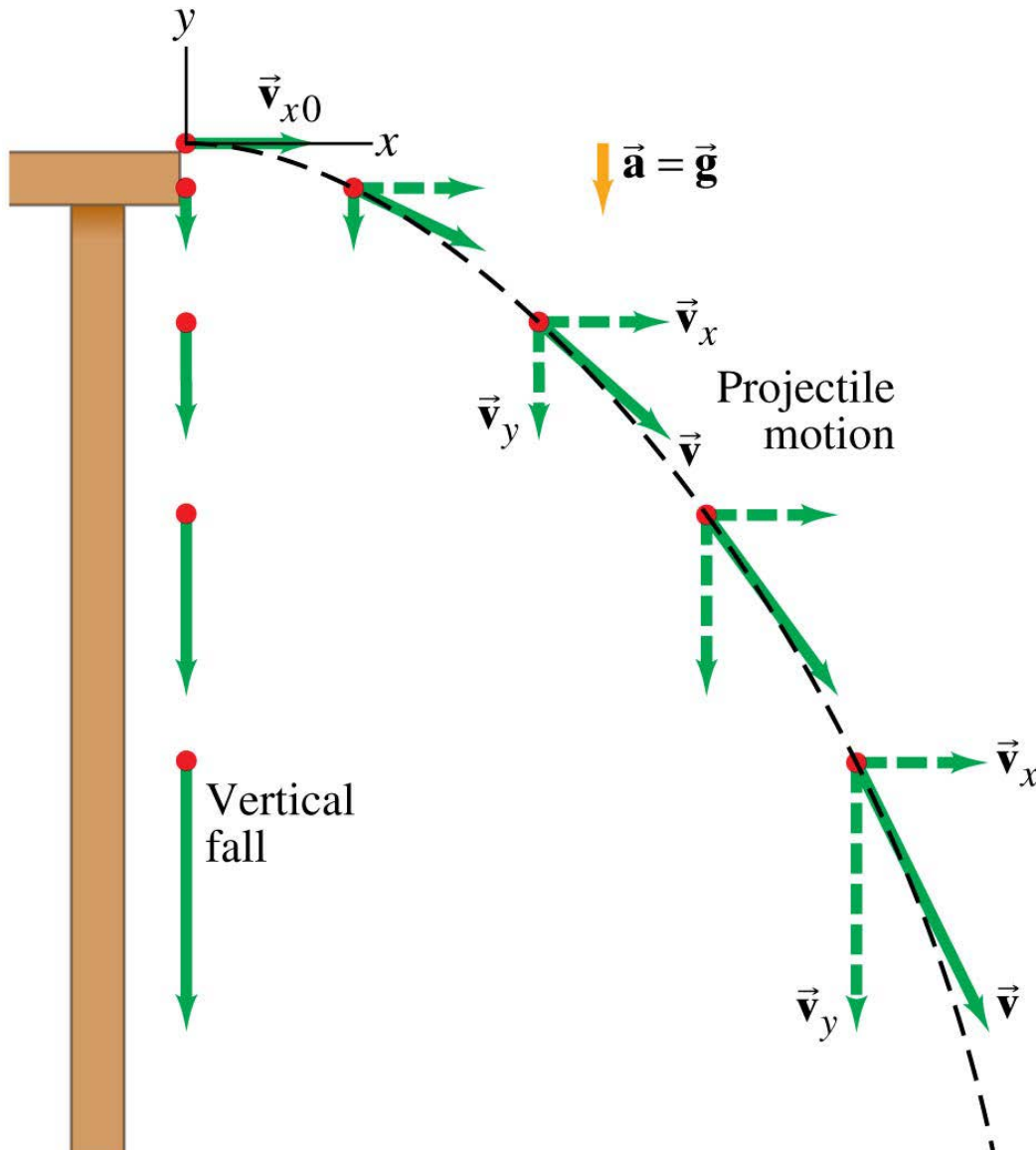
(a)



(b)



# 3-5 Projectile Motion

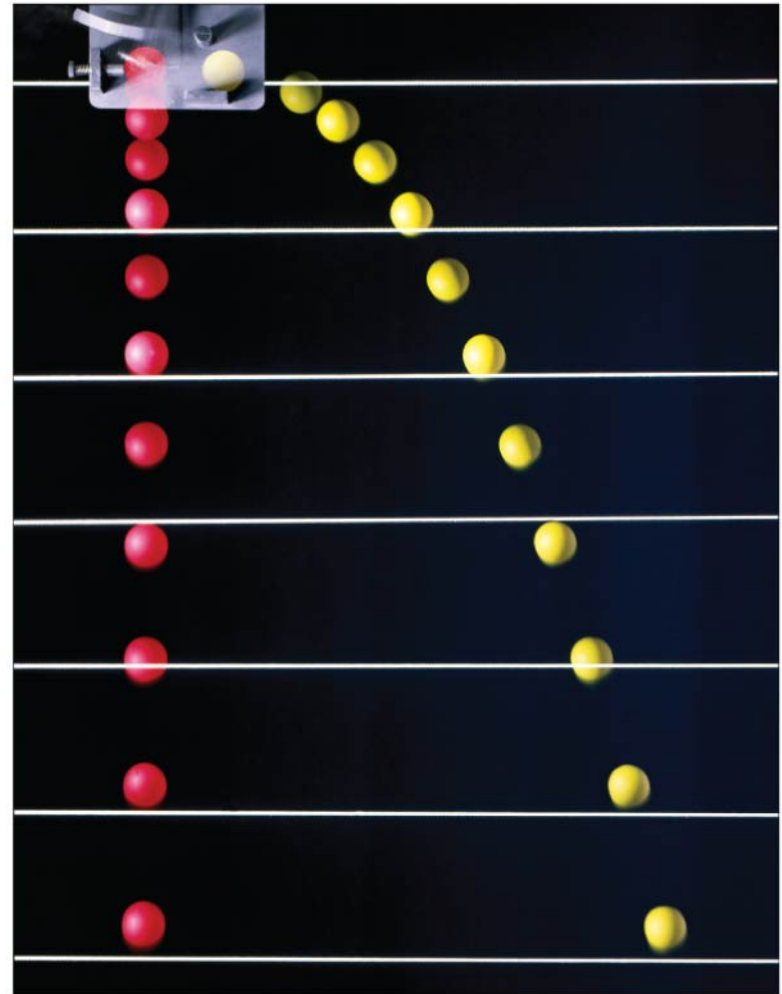


Projectile motion can be understood by analyzing the horizontal and vertical motions separately.

## 3-5 Projectile Motion

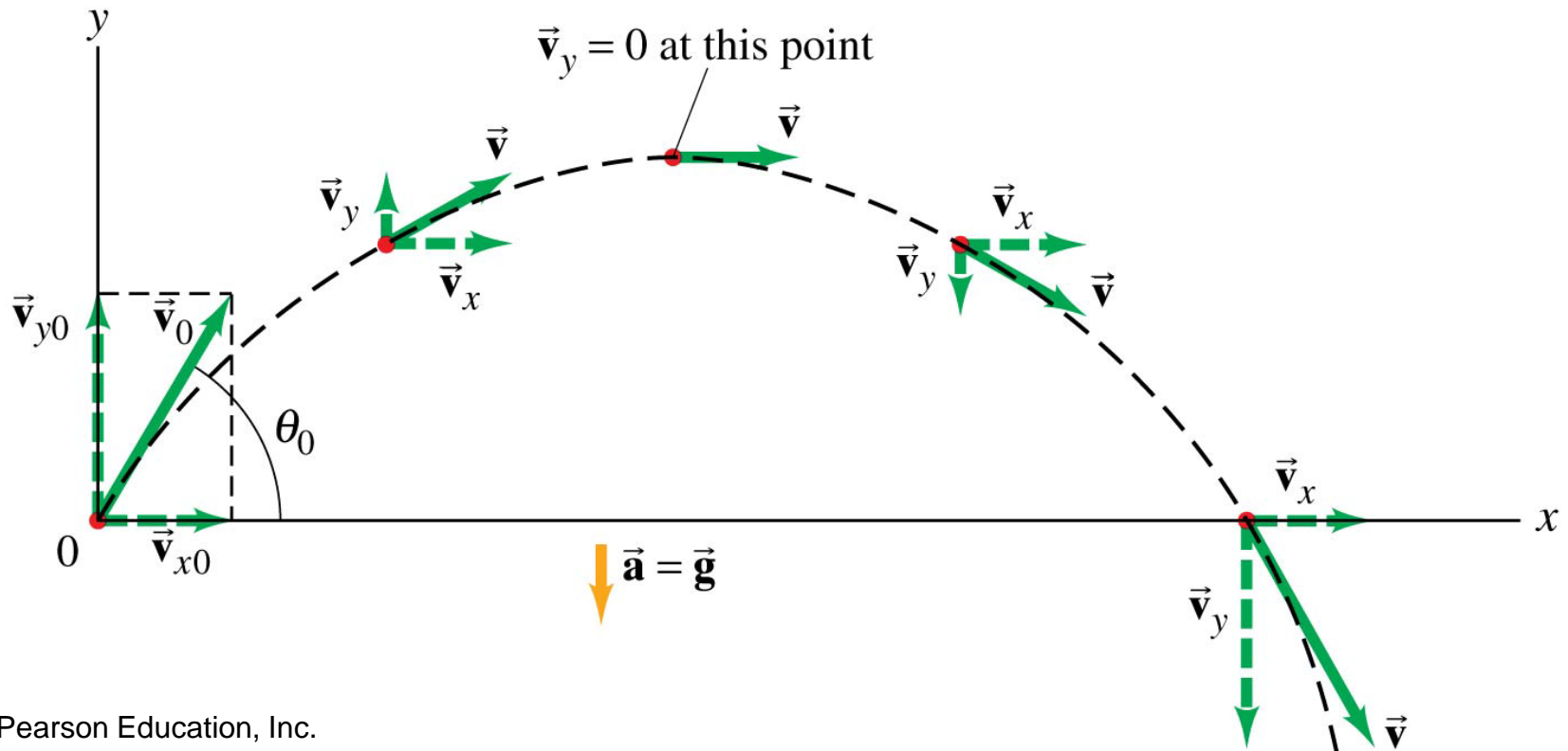
The speed in the  $x$ -direction is constant; in the  $y$ -direction the object moves with constant acceleration  $g$ .

This photograph shows two balls that start to fall at the same time. The one on the right has an initial speed in the  $x$ -direction. It can be seen that vertical positions of the two balls are identical at identical times, while the horizontal position of the yellow ball increases linearly.



# 3-5 Projectile Motion

If an object is launched at an initial angle of  $\theta_0$  with the horizontal, the analysis is similar except that the initial velocity has a vertical component.



## 3-6 Solving Projectile Motion Problems

Projectile motion is motion with constant acceleration in two dimensions, where the acceleration is  $g$  and is down.

**TABLE 3–2 Kinematic Equations for Projectile Motion**

( $y$  positive upward;  $a_x = 0$ ,  $a_y = -g = -9.80 \text{ m/s}^2$ )

**Horizontal Motion**  
( $a_x = 0$ ,  $v_x = \text{constant}$ )

**Vertical Motion<sup>†</sup>**  
( $a_y = -g = \text{constant}$ )

$$v_x = v_{x0} \quad (\text{Eq. 2-11a})$$

$$v_y = v_{y0} - gt$$

$$x = x_0 + v_{x0}t \quad (\text{Eq. 2-11b})$$

$$y = y_0 + v_{y0}t - \frac{1}{2}gt^2$$

$$(\text{Eq. 2-11c})$$

$$v_y^2 = v_{y0}^2 - 2g(y - y_0)$$

<sup>†</sup> If  $y$  is taken positive downward, the minus ( $-$ ) signs in front of  $g$  become  $+$  signs.

## 3-6 Solving Projectile Motion Problems

1. Read the problem carefully, and choose the object(s) you are going to analyze.
2. Draw a diagram.
3. Choose an origin and a coordinate system.
4. Decide on the time interval; this is the same in both directions, and includes only the time the object is moving with constant acceleration  $g$ .
5. Examine the  $x$  and  $y$  motions separately.

## 3-6 Solving Projectile Motion Problems

6. List known and unknown quantities. Remember that  $v_x$  never changes, and that  $v_y = 0$  at the highest point.
7. Plan how you will proceed. Use the appropriate equations; you may have to combine some of them.

# 3-7 Projectile Motion Is Parabolic

In order to demonstrate that projectile motion is parabolic, we need to write  $y$  as a function of  $x$ . When we do, we find that it has the form:

$$y = Ax - Bx^2$$

This is indeed the equation for a parabola.



## 3-8 Relative Velocity

We already considered relative speed in one dimension; it is similar in two dimensions except that we must add and subtract velocities as vectors.

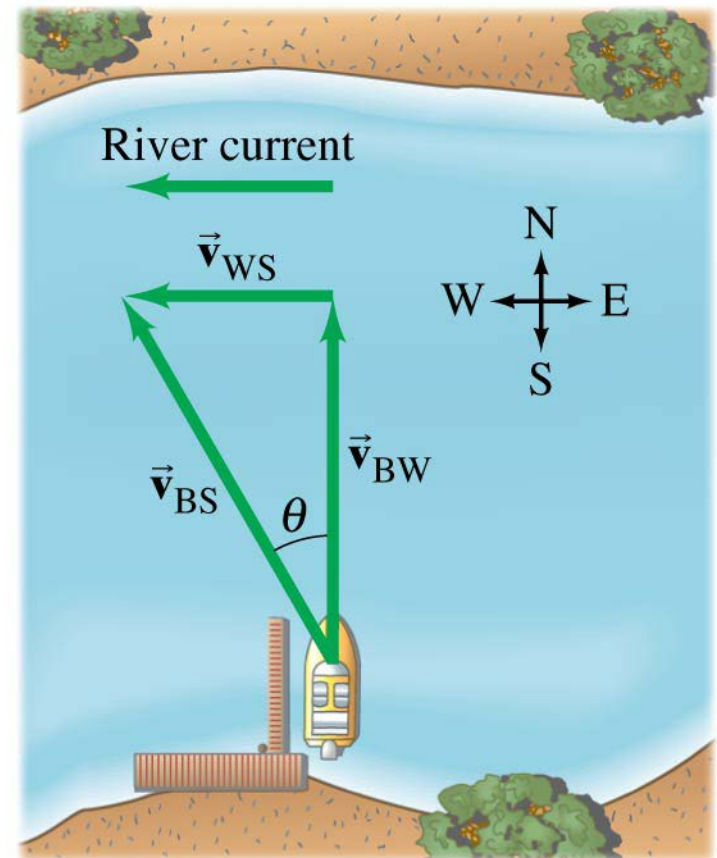
Each velocity is labeled first with the object, and second with the reference frame in which it has this velocity. In the following example,  $v_{WS}$  is the velocity of the water in the shore frame,  $v_{BS}$  is the velocity of the boat in the shore frame, and  $v_{BW}$  is the velocity of the boat in the water frame.



## 3-8 Relative Velocity

In this case, the relationship between the three velocities

$$\text{is: } \vec{v}_{BS} = \vec{v}_{BW} + \vec{v}_{WS}. \quad (3-7)$$



# Summary of Chapter 3

- A quantity with magnitude and direction is a vector.
- A quantity with magnitude but no direction is a scalar.
- Vector addition can be done either graphically or using components.
- The sum is called the resultant vector.
- Projectile motion is the motion of an object near the Earth's surface under the influence of gravity.