Chapter 3

Kinematics in Two Dimensions

Projetile Motion -- Continued

3.3 Projectile Motion

Under the influence of gravity alone, an object near the surface of the Earth will accelerate downwards at $9.80 m/s^2$.

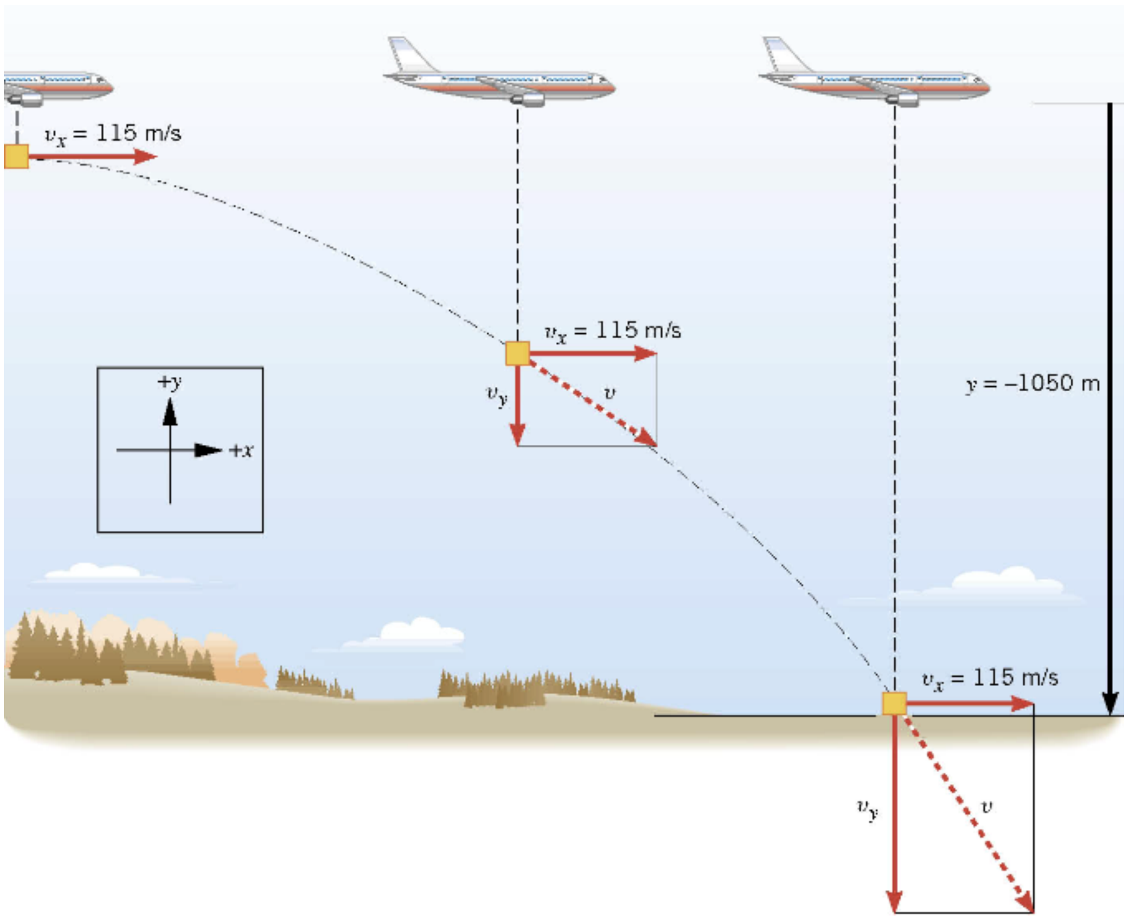
$$a_y = -9.80\,\mathrm{m/s^2} \qquad a_x = 0$$

$$v_x = v_{ox} = \mathrm{constant}$$

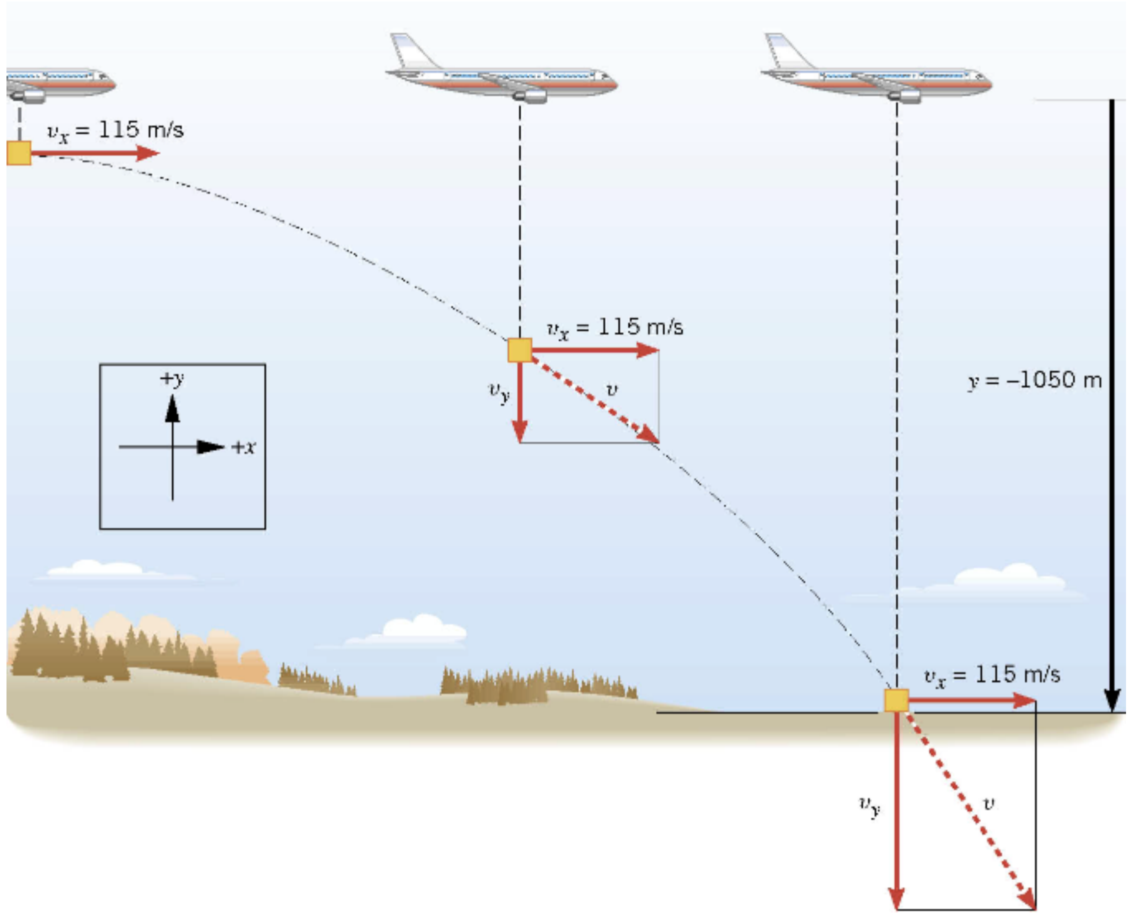
3.3 Projectile Motion

Example 3 A Falling Care Package

The airplane is moving horizontally with a constant velocity of +115 m/s at an altitude of 1050m. Determine the time required for the care package to hit the ground.



3.3 Projectile Motion



y	a_y	v_y	v_{oy}	t
-1050 m	-9.80 m/s^2		0 m/s	?

y	a_y	v_y	v_{oy}	t
-1050 m	-9.80 m/s^2		0 m/s	?

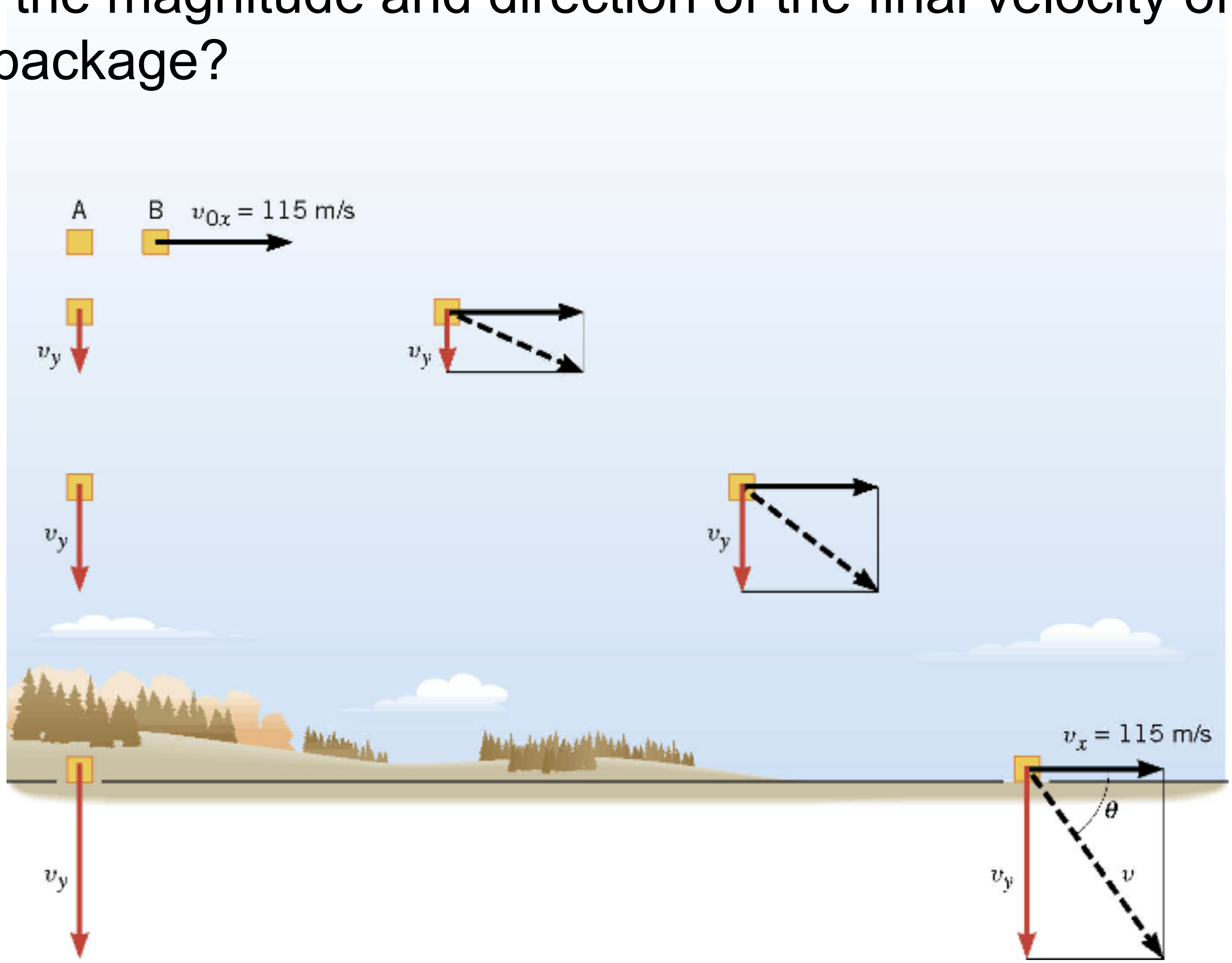
$$y = v_{oy}t + \tfrac{1}{2}a_y t^2 \quad \Longrightarrow \quad y = \tfrac{1}{2}a_y t^2$$

$$t = \sqrt{\frac{2y}{a_y}} = \sqrt{\frac{2(-1050\,\mathrm{m})}{-9.80\,\mathrm{m/s^2}}} = 14.6\,\mathrm{s}$$

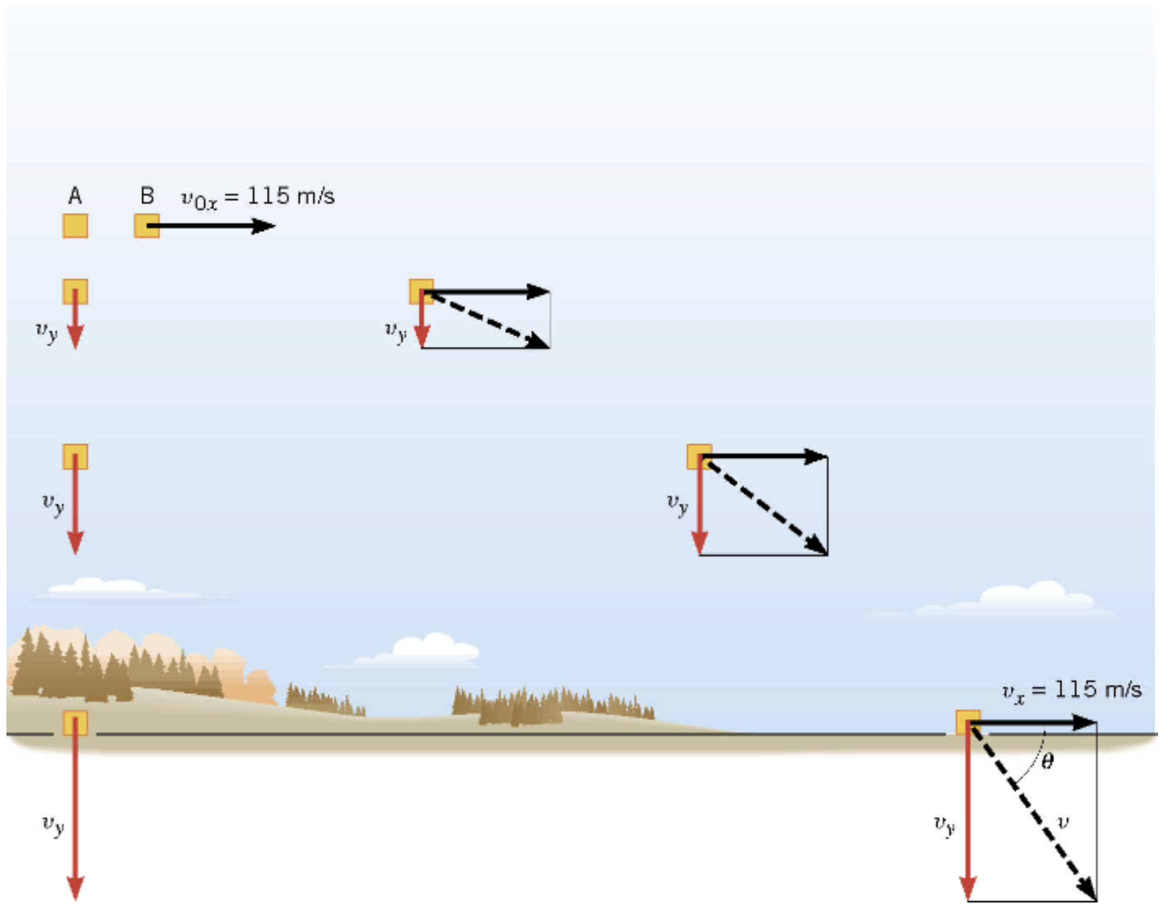
3.3 Projectile Motion

Example 4 The Velocity of the Care Package

What are the magnitude and direction of the final velocity of the care package?



3.3 Projectile Motion



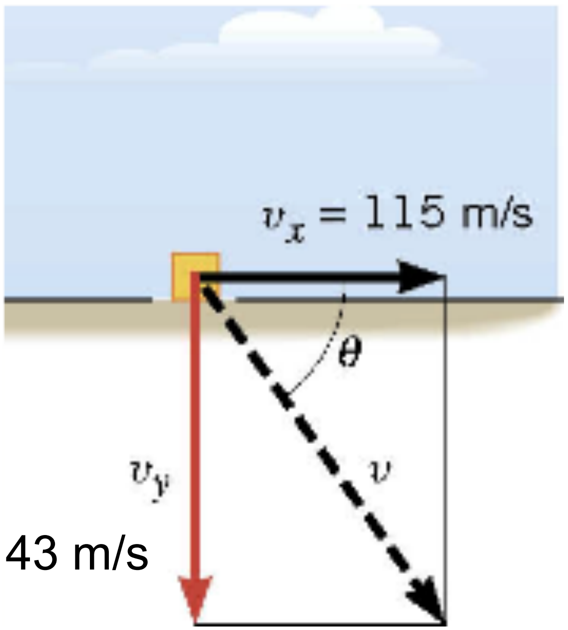
y	a_y	v_y	v_{oy}	t
-1050 m	-9.80 m/s^2	?	0 m/s	14.6 s

y	a_y	v_y	v_{oy}	t
-1050 m	-9.80 m/s^2	?	0 m/s	14.6 s

$$v_y = v_{oy} + a_y t = 0 + \left(-9.80\,\text{m/s}^2\right)\left(14.6\,\text{s}\right)$$

$$= -143\,\text{m/s}$$

Find the final velocity of the package.



= - 143 m/s

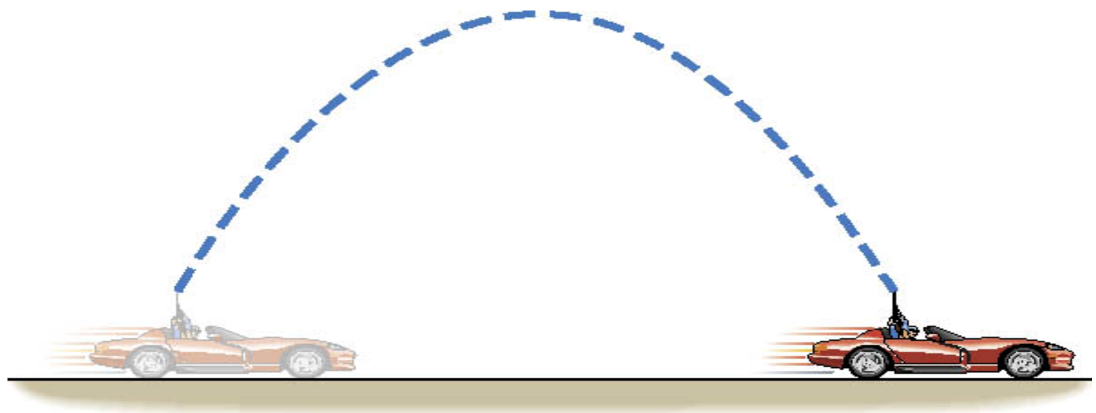
$$v^2 = v_x^{\,2} + v_y^{\,2}$$
$$= (115\text{ m/s})^2 + (-143\text{ m/s})^2$$
$$= 33700\ (\text{m/s})^2$$

→ v = **184 m/s**

$\theta = \tan^{-1}(143/115) =$ **51.2°**

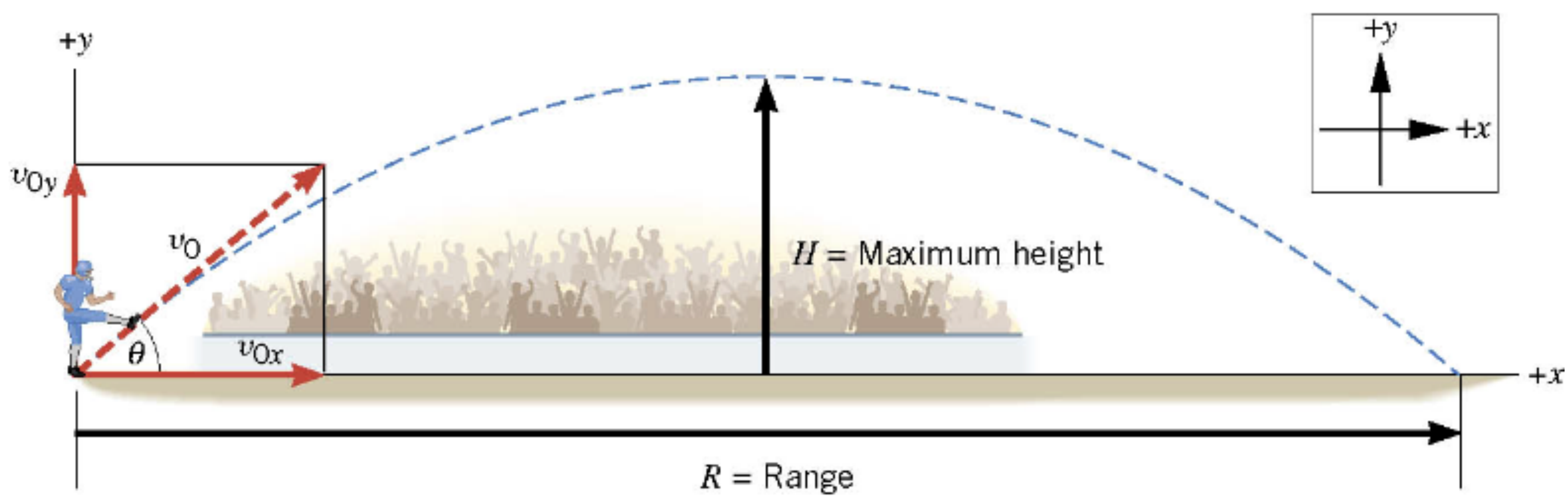
Conceptual Example 5 I Shot a Bullet into the Air...

Suppose you are driving a convertible with the top down. The car is moving to the right at constant velocity. You point a rifle straight up into the air and fire it. In the absence of air resistance, where would the bullet land – behind you, ahead of you, or in the barrel of the rifle?

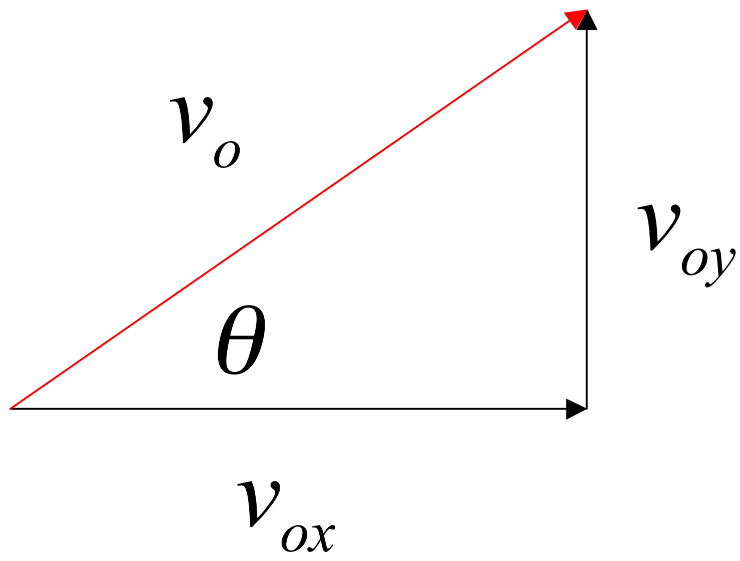


Example 6 The Height of a Kickoff

A placekicker kicks a football at and angle of 40.0 degrees and the initial speed of the ball is 22 m/s. Ignoring air resistance, determine the maximum height that the ball attains.



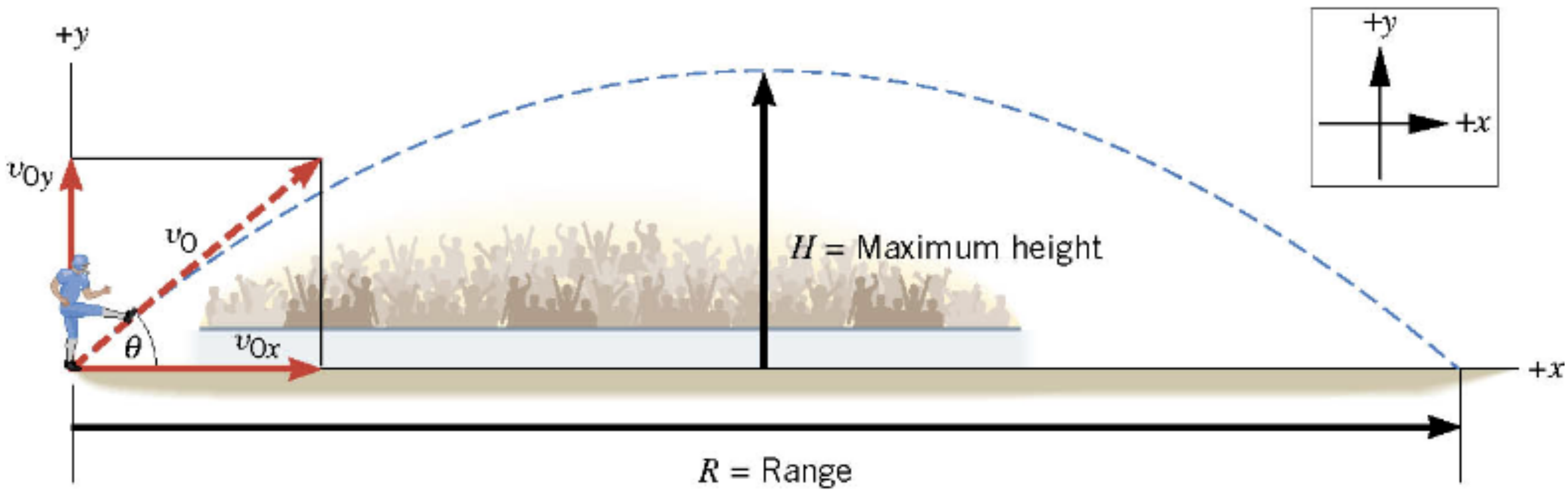
3.3 Projectile Motion



$$v_{oy} = v_o \sin\theta = (22\,\text{m/s})\sin 40^\circ = 14\,\text{m/s}$$

$$v_{ox} = v_o \cos\theta = (22\,\text{m/s})\cos 40^\circ = 17\,\text{m/s}$$

3.3 Projectile Motion



y	a_y	v_y	v_{oy}	t
?	-9.80 m/s^2	0	14 m/s	

3.3 Projectile Motion

y	a_y	v_y	v_{oy}	t
?	-9.80 m/s^2	0	14 m/s	

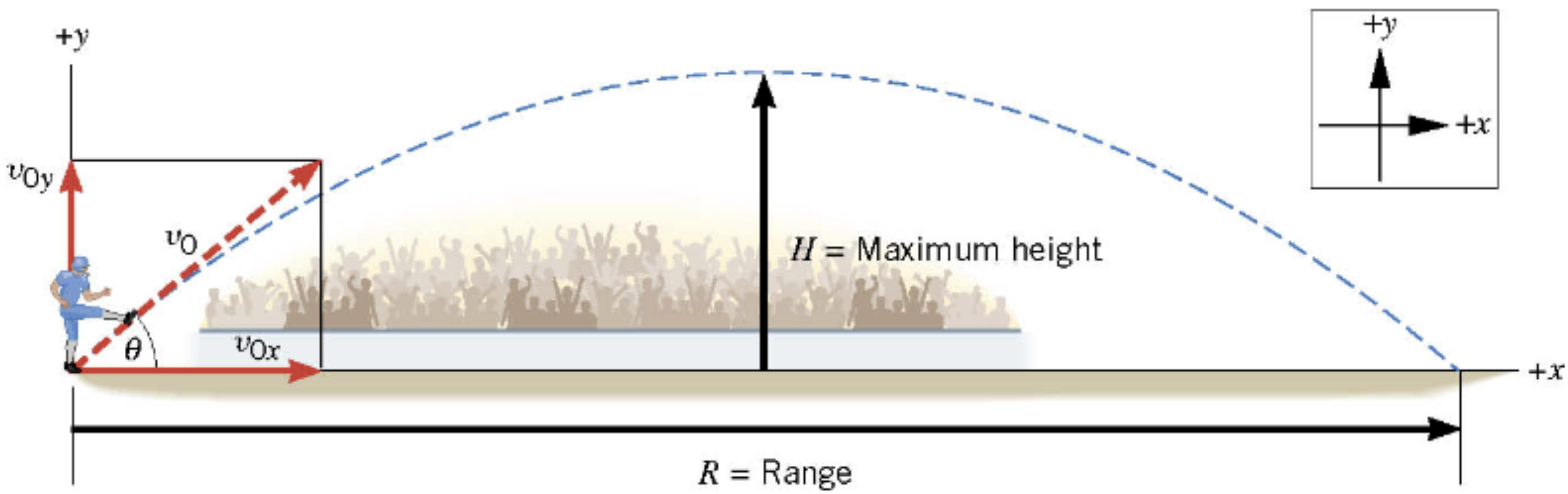
$$v_y^2 = v_{oy}^2 + 2a_y y \quad \Rightarrow \quad y = \frac{v_y^2 - v_{oy}^2}{2a_y}$$

$$y = \frac{0 - (14\,\text{m/s})^2}{2(-9.8\,\text{m/s}^2)} = +10\,\text{m}$$

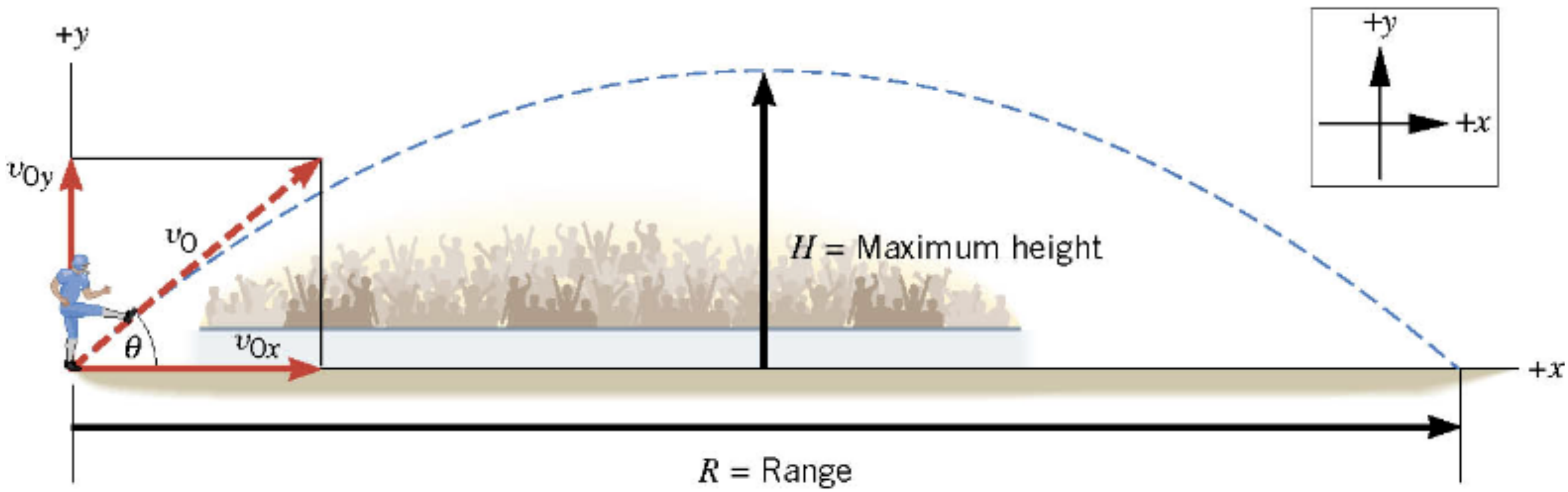
3.3 Projectile Motion

Example 7 The Time of Flight of a Kickoff

What is the time of flight between kickoff and landing?



3.3 Projectile Motion



y	a_y	v_y	v_{oy}	t
0	-9.80 m/s^2		14 m/s	?

3.3 Projectile Motion

y	a_y	v_y	v_{oy}	t
0	-9.80 m/s^2		14 m/s	?

$$y = v_{oy}t + \tfrac{1}{2}a_y t^2$$

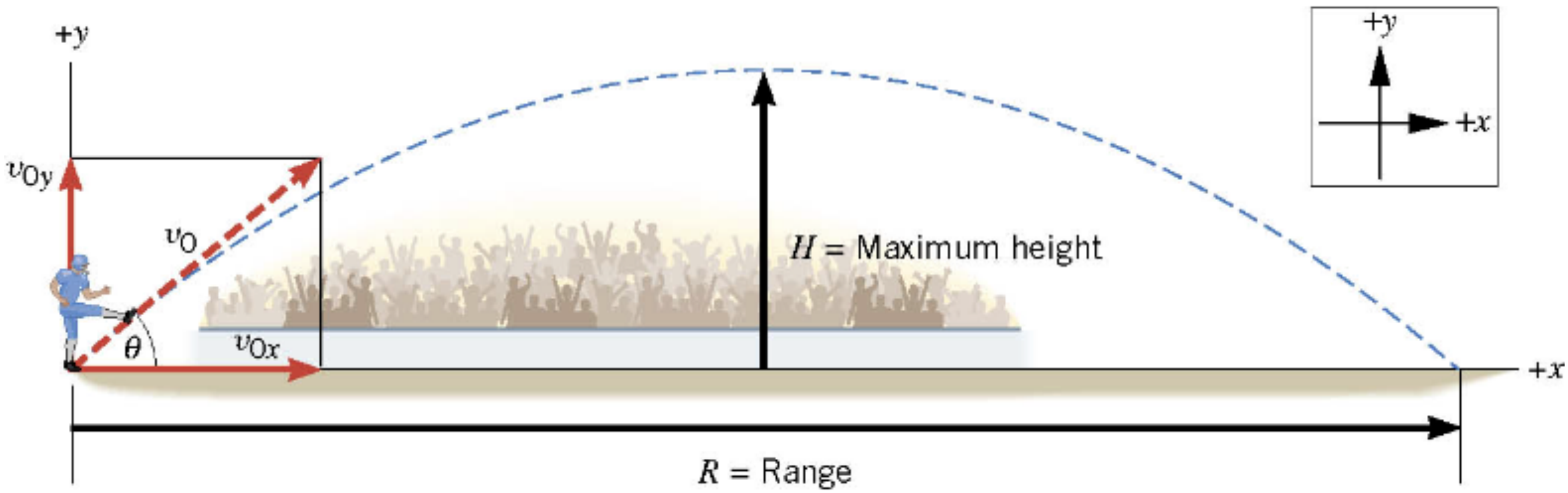
$$0 = (14\,\text{m/s})t + \tfrac{1}{2}(-9.80\,\text{m/s}^2)t^2$$

$$0 = 2(14\,\text{m/s}) + (-9.80\,\text{m/s}^2)t$$

$$t = 2.9\,\text{s}$$

Example 8 The Range of a Kickoff

Calculate the range R of the projectile.



$$x = v_{ox}t + \tfrac{1}{2}a_x t^2 = v_{ox}t$$

$$= (17\,\text{m/s})(2.9\,\text{s}) = +49\,\text{m}$$

Conceptual Example 10 Two Ways to Throw a Stone

From the top of a cliff, a person throws two stones. The stones have identical initial speeds, but stone 1 is thrown downward at some angle above the horizontal and stone 2 is thrown at the same angle below the horizontal. Neglecting air resistance, which stone, if either, strikes the water with greater velocity?