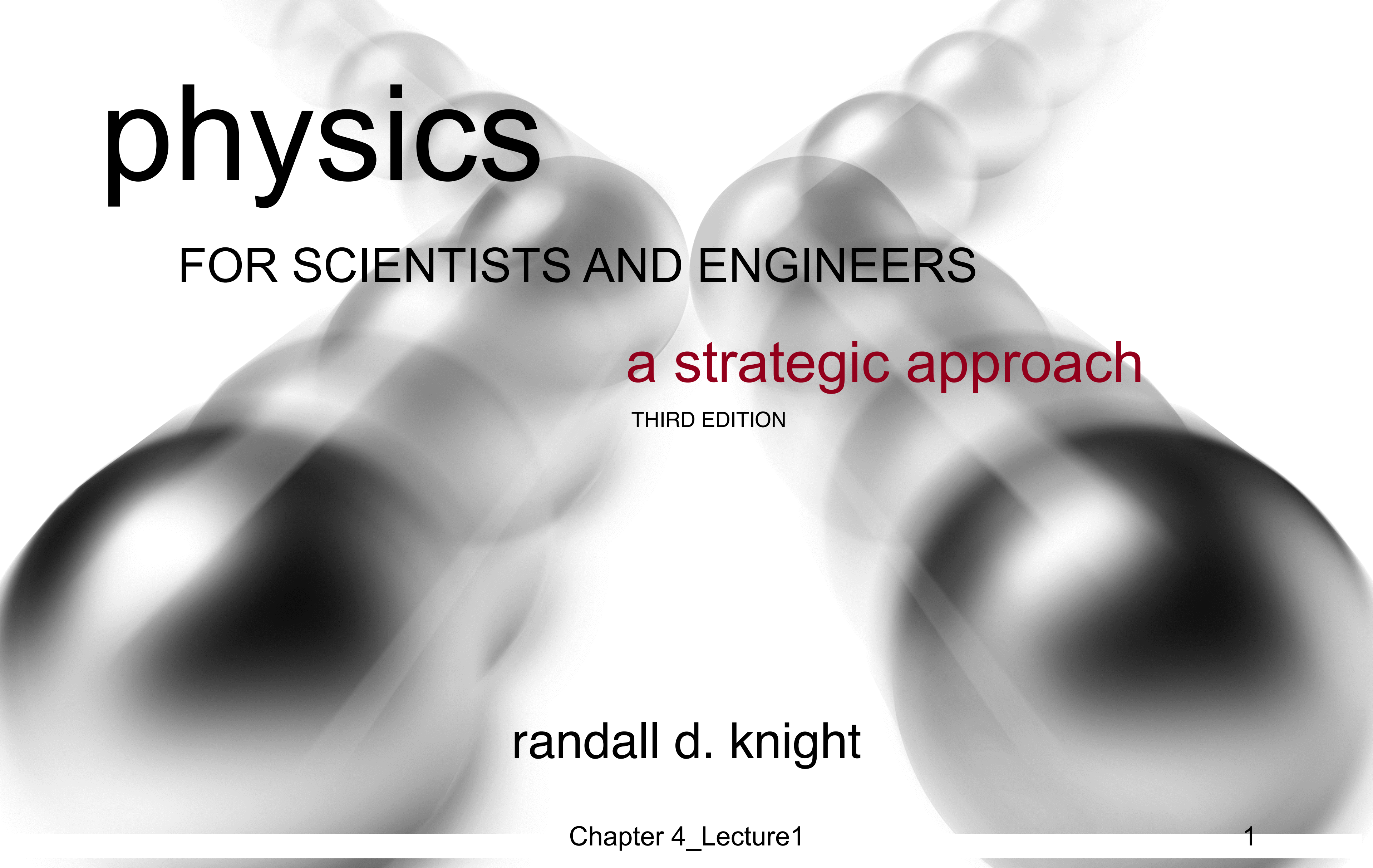


physics

FOR SCIENTISTS AND ENGINEERS

a strategic approach

THIRD EDITION

randall d. knight

Chapter 4 Kinematics in 2D: Projectile Motion (Sec. 4.2)

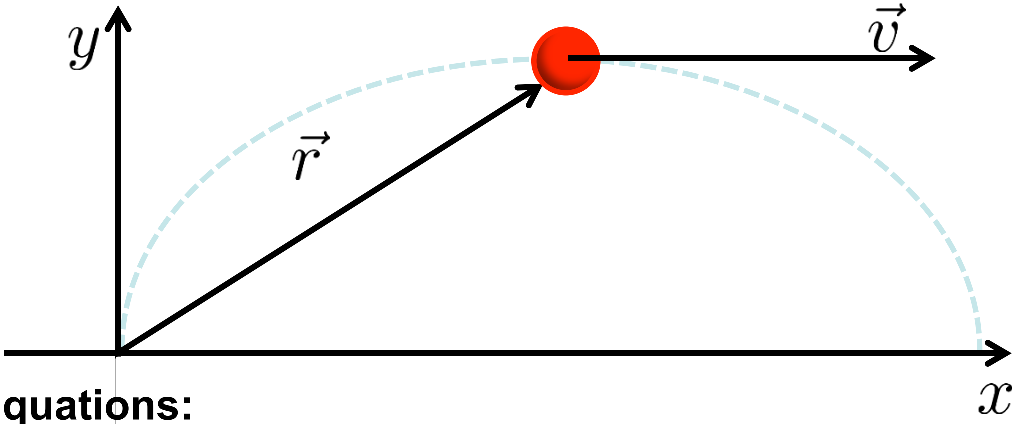
Which fountain soars out the farthest?

Human males can throw more than 3X faster than adult male chimps. Why? How? Read "Slinging our way to the top of the foodchain" posted on the course website.

Chapter Goal: To learn how to solve problems about motion in a plane.

Two Dimensional Kinematics (Sec 4.1)

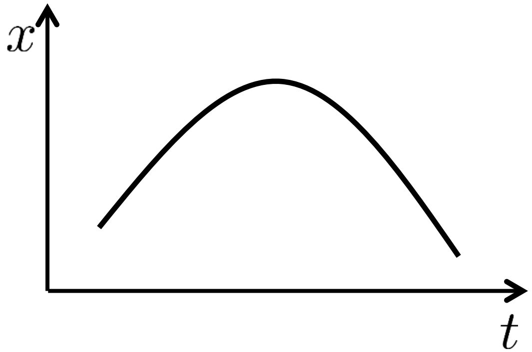
Trajectory - Picture or movie of the object's motion in real space

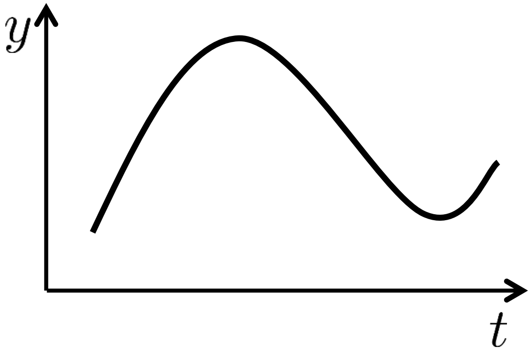


Basic Equations:

$$\vec{v}(t) = \frac{d\vec{r}(t)}{dt} \qquad \text{and} \qquad \vec{a}(t) = \frac{d\vec{v}(t)}{dt}$$

These equations of motion are extremely simple, but their application can be tricky!



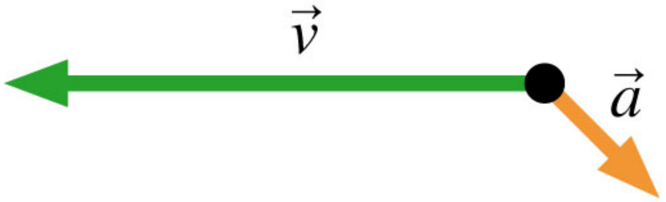


Do not confuse these graphs with trajectories!

We also learned about Vector Components!

Like Conceptual Question 4.1 at end of chapter 4

This acceleration will cause the particle to



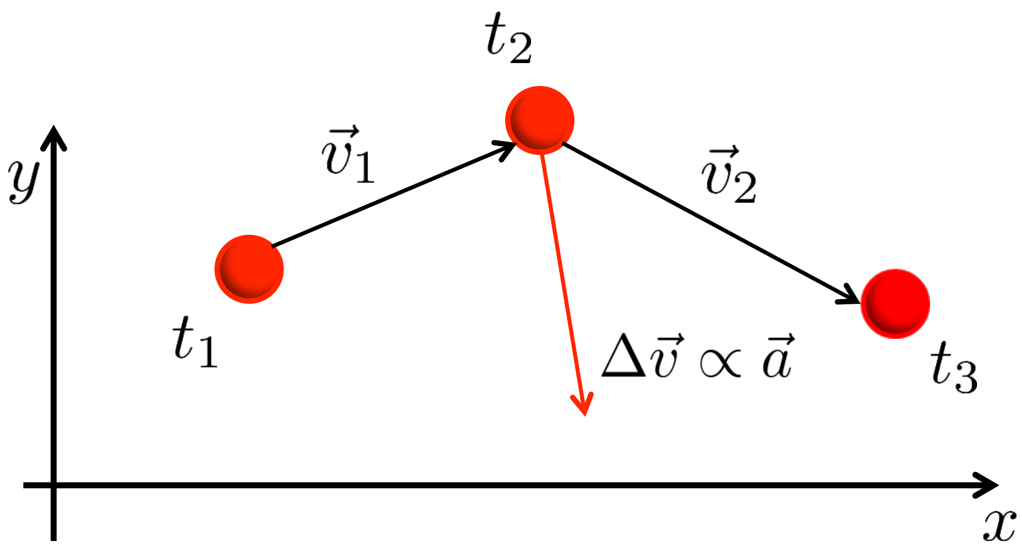
a. Speed up and curve upward
b. Speed up and curve downward
c. Slow down and curve upward
d. Slow down and curve downward
e. Move to the right and down
f. Reverse direction

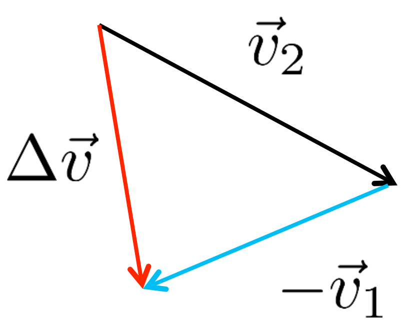
Key Point: *Change* in Velocity *vector* results in Acceleration!!

Sec 4.1

$$\vec{v}(t) = \frac{d\vec{r}(t)}{dt} \quad \text{and} \quad \vec{a}(t) = \frac{d\vec{v}(t)}{dt}$$

Extending velocity to multiple dimensions: an acceleration may change the *magnitude* and/or *direction* of the velocity!



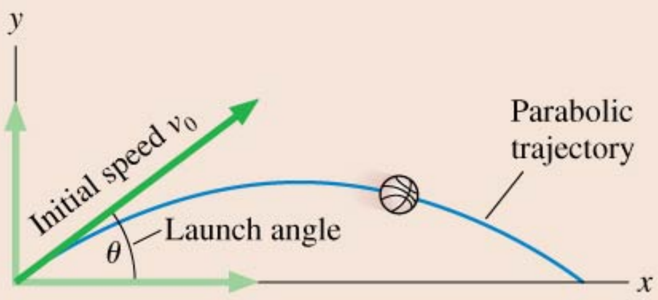


$$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$$

Sec 4.2

Projectile Motion

Projectile motion is two-dimensional motion under the influence of only gravity.



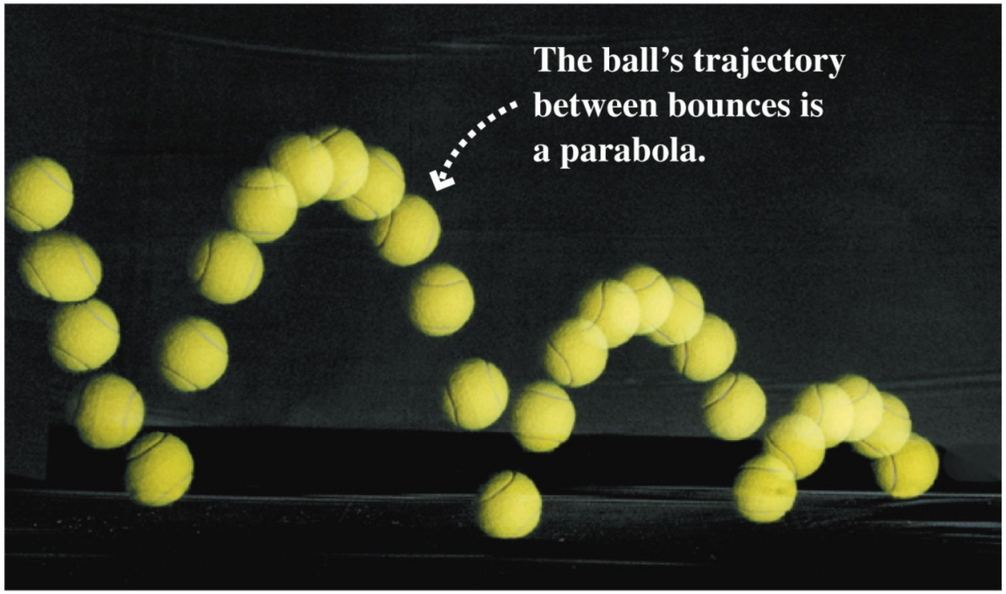
Projectile motion follows a *parabolic trajectory* characterized by the initial speed and the launch angle.

You'll learn to calculate how high and how far a projectile travels.

Projectile Motion…continued

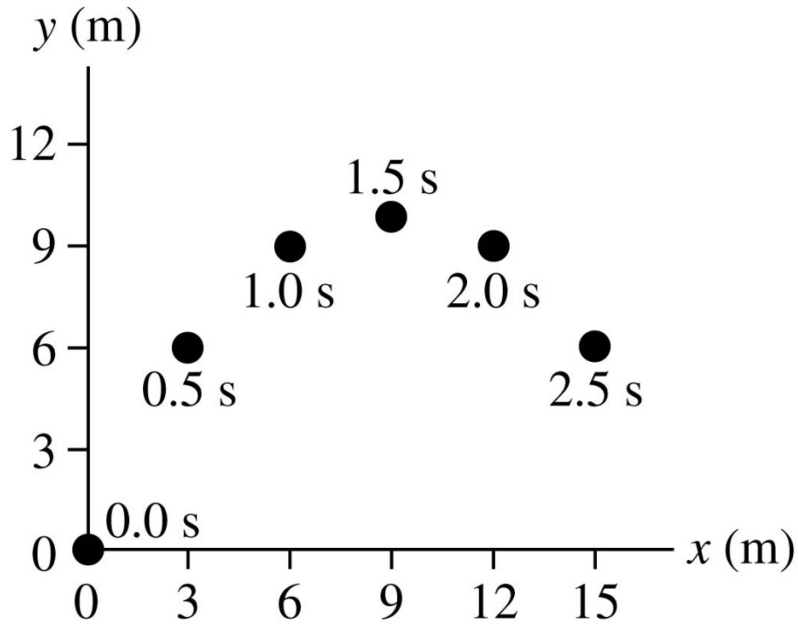
Sec 4.2

- Baseballs, tennis balls, Olympic divers, etc. all exhibit *projectile motion*.
- A **projectile** is an object that moves in two dimensions under the influence of *only* gravity.
- Projectile motion extends the idea of free-fall motion to include a horizontal component of velocity.
- Air resistance is neglected.
- Projectiles in two dimensions follow a *parabolic trajectory* as shown in the photo.



Remember?? Position vs. Time Graphs for Projectile Motion

Sec 4.2



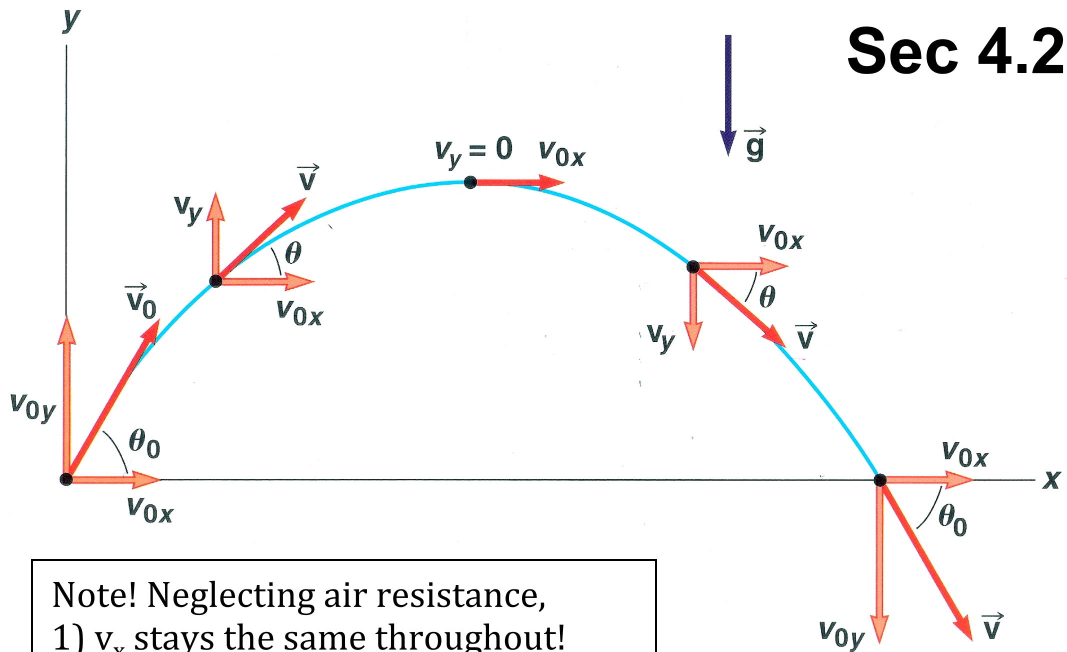
Shown is the motion diagram of a basketball, with 0.5 s intervals between frames.

x-motion vs. t

***y*-motion vs. t**

Kinematics in 2D – thrown ball

Sec 4.2

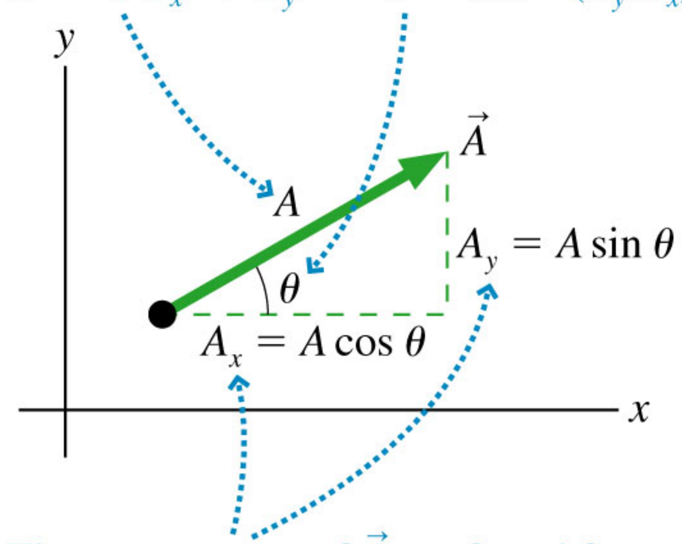


Note! Neglecting air resistance,
1) v_x stays the same throughout!
2) velocity is not zero *anywhere!*
3) acceleration is not zero *anywhere!*
4) final velocity is same as initial

Vector Components

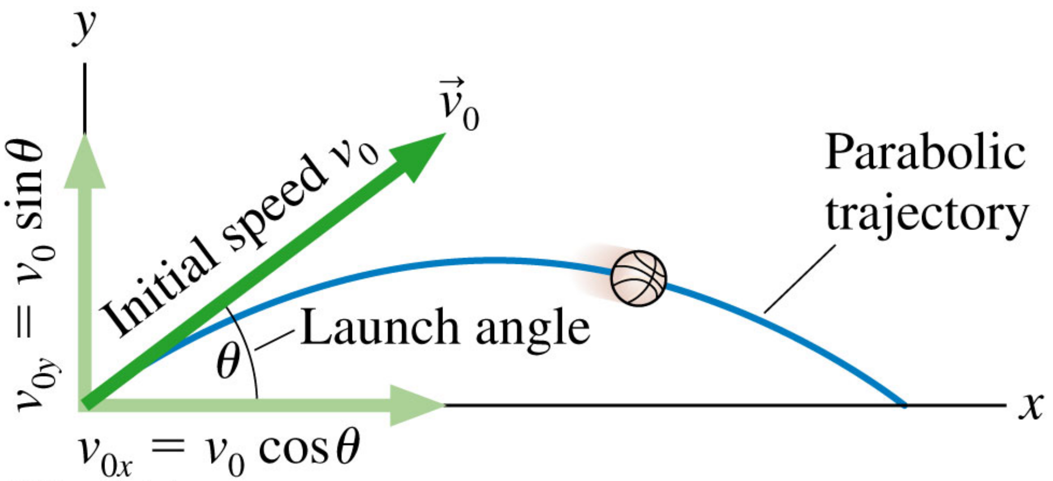
The magnitude and direction of $\vec{A}$ are found from the components. In this example,

$$A = \sqrt{A_x^{\,2} + A_y^{\,2}} \qquad \theta = \tan^{-1}(A_y/A_x)$$



The components of $\vec{A}$ are found from the magnitude and direction. In this example, $A_x = A\cos\theta$ and $A_y = A\sin\theta$.

Projectile Motion (Sec 4.2)



- The start of a projectile's motion is called the *launch*.
- The angle θ of the initial velocity v_0 above the *x*-axis is called the **launch angle**.
- The initial velocity vector can be broken into components.

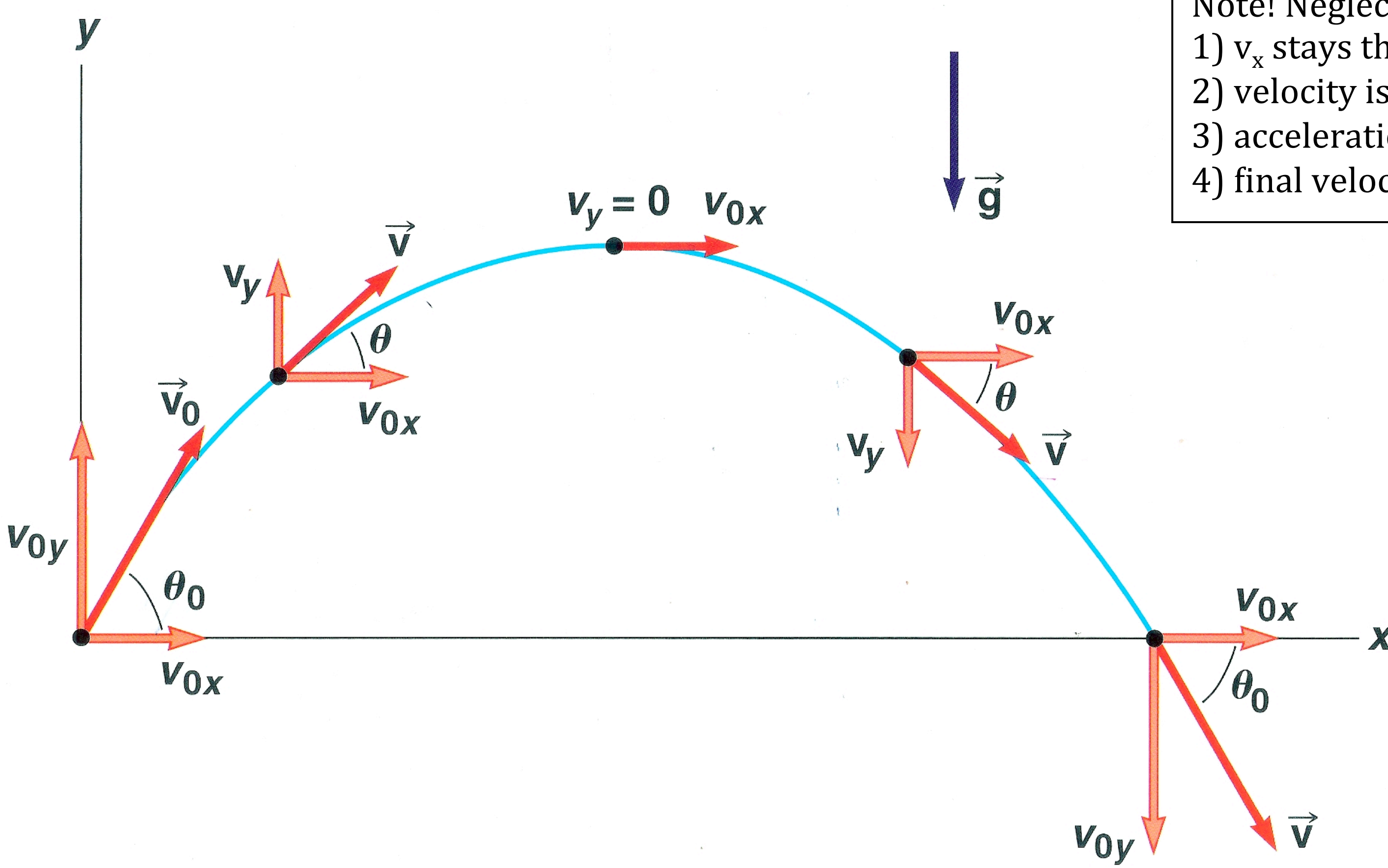
$$v_{0x} = v_0 \cos\theta$$

$$v_{0y} = v_0 \sin\theta$$

where v_0 is the initial speed.

Sec 4.2

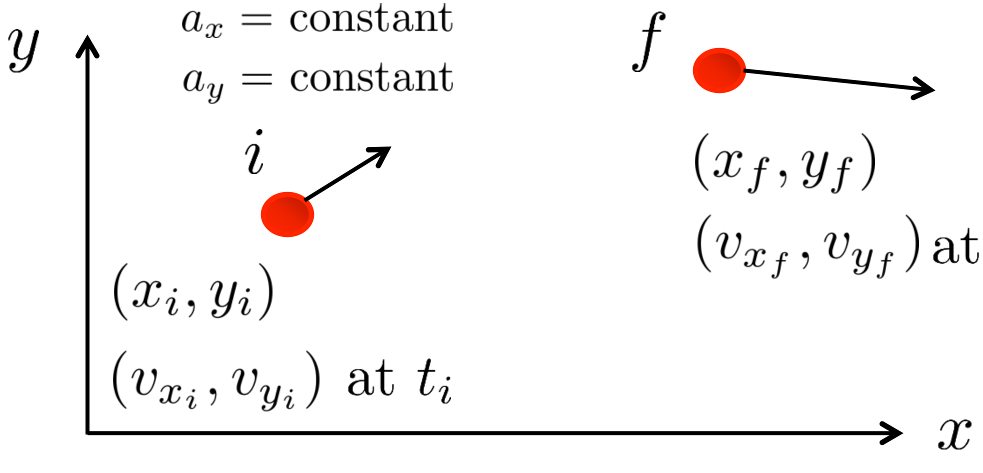
The thrown ball



Note! Neglecting air resistance,
1) v_x stays the same throughout!
2) velocity is not zero *anywhere!*
3) acceleration is not zero *anywhere!*
4) final velocity is same as initial

Constant Acceleration (2D case)

Sec 4.2



Note: Your author writes v_{i_x}
I will write v_{x_i}

x-motion

$$x_f = x_i + v_{x_i}\Delta t + \frac{1}{2}a_x(\Delta t)^2$$

$$v_{x_f} = v_{x_i} + a_x\Delta t$$

$$v_{x_f}^2 = v_{x_i}^2 + 2a_x\Delta x$$

$$\Delta x = x_f - x_i$$

$$\Delta t = t_f - t_i$$

y-motion

$$y_f = y_i + v_{y_i}\Delta t + \frac{1}{2}a_y(\Delta t)^2$$

$$v_{y_f} = v_{y_i} + a_y\Delta t$$

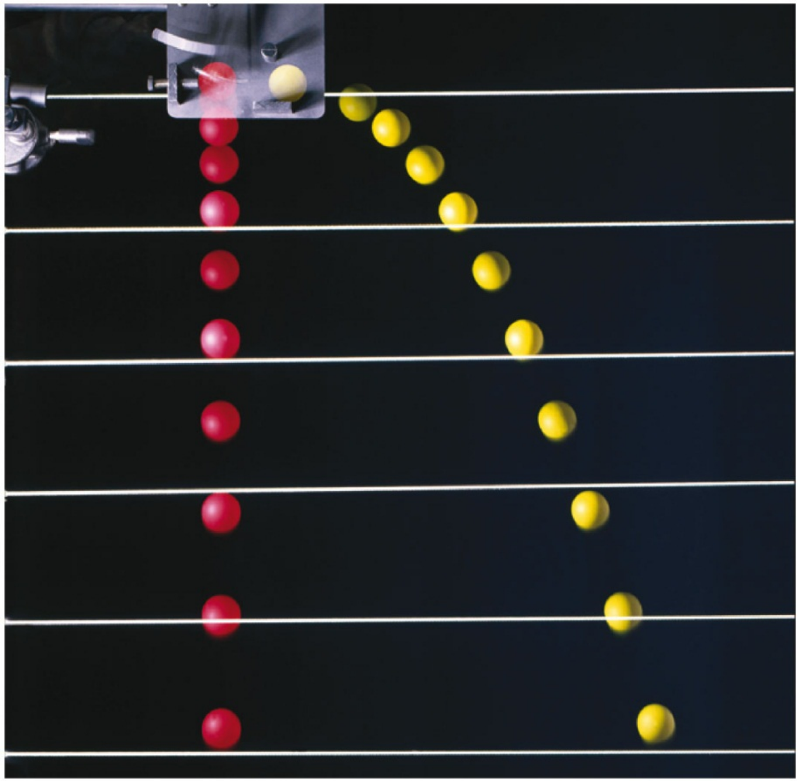
$$v_{y_f}^2 = v_{y_i}^2 + 2a_y\Delta x$$

$$\Delta y = y_f - y_i$$

For projectiles: $a_x = 0$, $a_y = g$ downward

Whiteboard Problem 4.1 (Sec. 4.2)

A heavy ball is launched exactly horizontally at height h above a horizontal field. At the exact instant that the ball is launched, a second ball is simply dropped from height h. Calculate the time taken by each ball to hit the ground in terms of h and other known constants. Which ball hits the ground first?



Conceptual Question 4.2 (Fig. 4.14 in book)

Sec 4.2

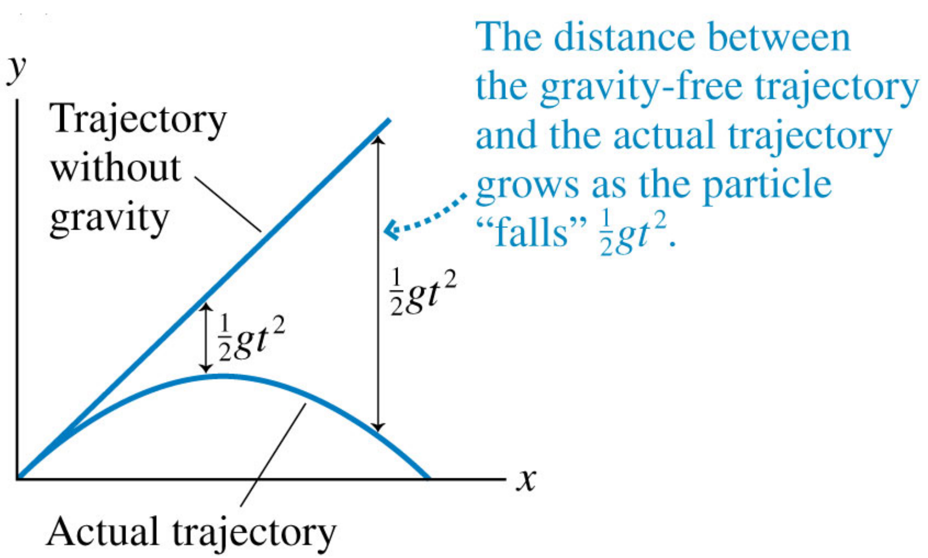
A hunter points his rifle directly at a coconut that he wishes to shoot off a tree. It so happens that the coconut falls from the tree at the exact instant the hunter pulls the trigger. Consequently,

A. The bullet passes above the coconut.
B. The bullet hits the coconut.
C. The bullet passes beneath the coconut.
D. This wasn’t discussed in Chapter 4.

Reasoning About Projectile Motion (Sec 4.2)

A hunter in the jungle wants to shoot down a coconut that is hanging from the branch of a tree. He points his arrow directly at the coconut, but the coconut falls from the branch at the *exact* instant the hunter shoots the arrow. Does the arrow hit the coconut?

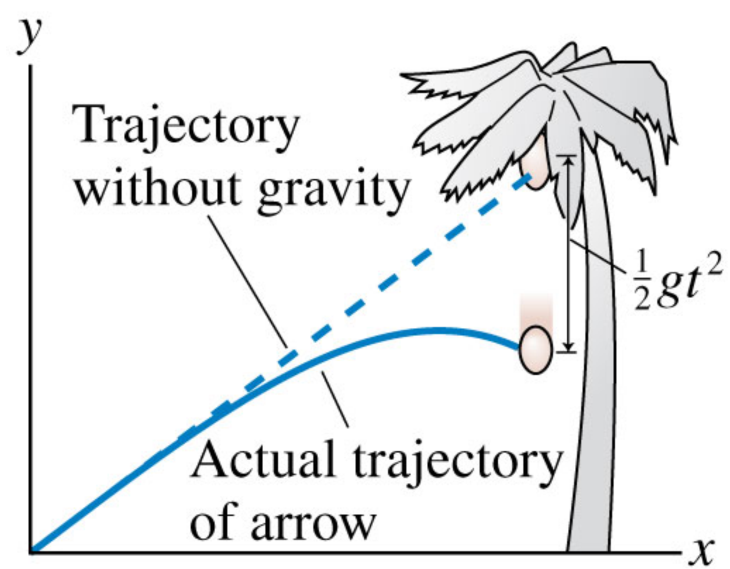
- Without gravity, the arrow would follow a straight line.
- Because of gravity, the arrow at time *t* has "fallen" a distance $\frac{1}{2}gt^2$ below this line.
- The separation grows as $\frac{1}{2}gt^2$, giving the trajectory its parabolic shape.



Reasoning About Projectile Motion (Sec 4.2)

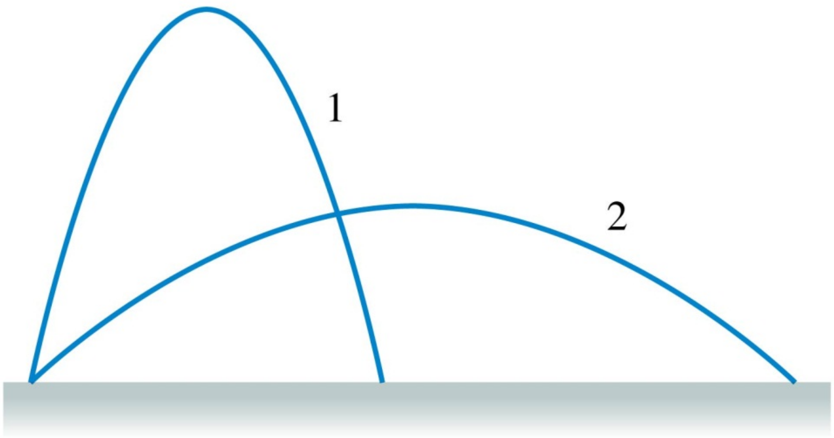
A hunter in the jungle wants to shoot down a coconut that is hanging from the branch of a tree. He points his arrow directly at the coconut, but the coconut falls from the branch at the *exact* instant the hunter shoots the arrow. Does the arrow hit the coconut?

- Had the coconut stayed on the tree, the arrow would have curved under its target as gravity causes it to fall a distance $\frac{1}{2}gt^2$ below the straight line.
- But $\frac{1}{2}gt^2$ is also the distance the coconut falls while the arrow is in flight.
- So *yes*, the arrow hits the coconut!



Conceptual Question 4.3 (Sec 4.2)

Projectiles 1 and 2 are launched over level ground with the same speed but at different angles. Which hits the ground first? Ignore air resistance.



A. Projectile 1 hits first.

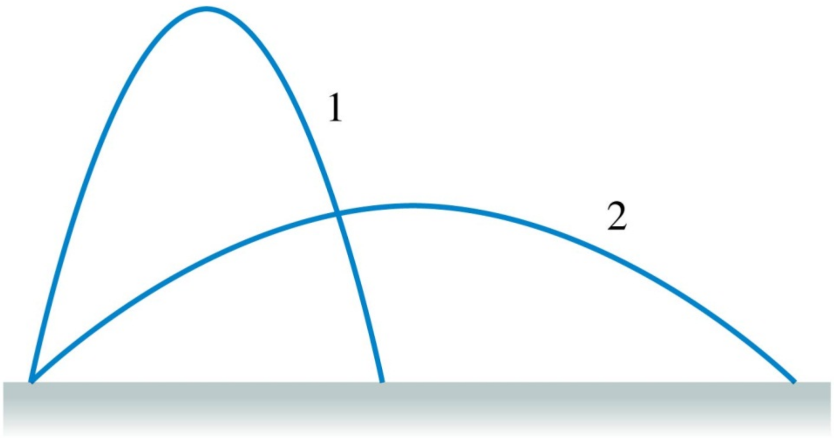
B. Projectile 2 hits first.

C. They hit at the same time.

D. There's not enough information to tell.

Conceptual Question 4.4 (Sec 4.2)

Projectiles 1 and 2 are launched over level ground with *different* speeds and at different angles. Which hits the ground first? Ignore air resistance.



A. Projectile 1 hits first.

B. Projectile 2 hits first.

C. They hit at the same time.

D. There's not enough information to tell.

Whiteboard Problem 4.2

A batted ball is launched at 45^0 and just clears a fence 15 m higher than the launch point and 20 m away.

a) Find the launch speed and time required for the ball to reach the fence.

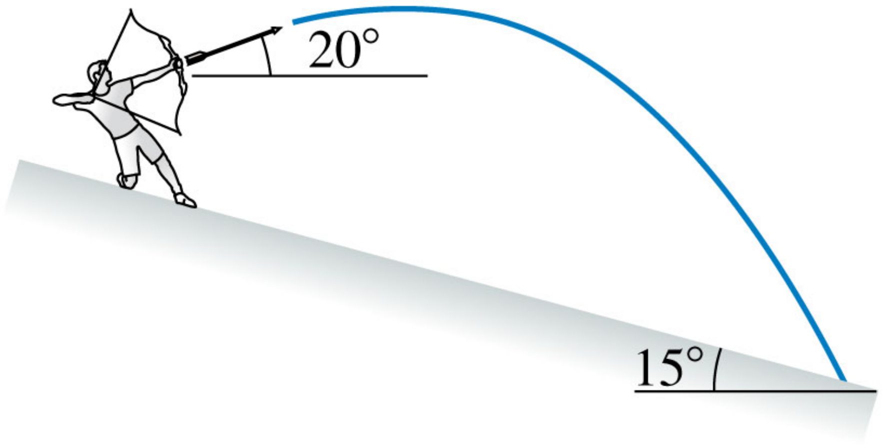
b) Is the ball on the way up or down when it clears the fence?

Whiteboard Problem 4.3

A punter kicks a football such that it leaves his foot at a speed of 22 m/s at an angle of 40^0 with respect to the ground. The returner has positioned himself 60 m from the kicker. How fast (average speed) must the returner run to catch the ball before it hits the ground?

Whiteboard Problem 4.4: Challenge problem

An archer standing on a 15^0 slope shoots an arrow 20^0 above the horizontal, as shown. How far down the slope does the arrow hit if it is shot with a speed of 50 m/s from 1.75 m above the ground?



Discuss Challenge problem

In one contest at the county fair, seen below, a spring-loaded plunger launches a ball at a speed of 3.0 m/s from one corner of a smooth, flat board that is tilted at a 20° angle. To win, you must make the ball hit a small target at the adjacent corner, 2.50m away. At what angle should you tilt the ball launcher?