General Physics I

Acceleration & Freefall

2D Motion & Projectiles

Ch 2, Secs 3-4

Ch 3, Secs 1-2

Day 3, Video 1

Freefall

Question #1

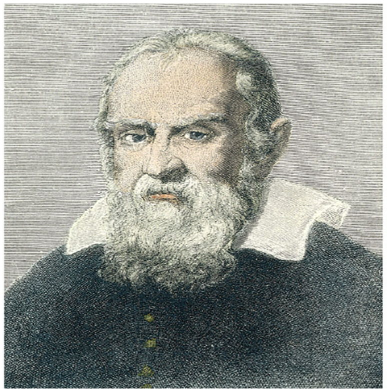
Car A, traveling from New York to Miami, has a speed of 25 m/s. Car B, traveling from New York to Chicago, also has a speed of 25 m/s. Are their velocities equal?

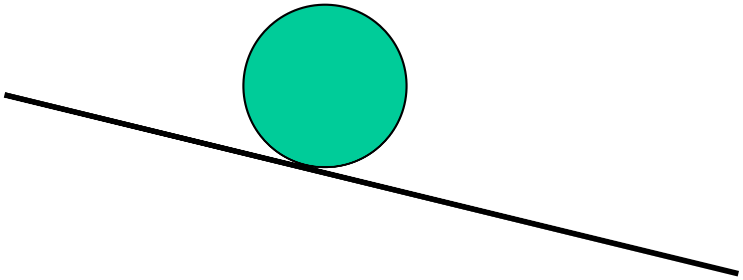
A. Yes

B. No

Freefall

- Objects moving under the influence of gravity only
  - Not touched or pushed
  - Not under influence of other forces (eg a magnet)
  - No air resistance
- Acceleration is constant near earth's surface
  - (a = 9.80 m/s^2 downwards)
- Investigated by Galileo Galilei





Freefall

Day 3, Video 2

Freefall Continued

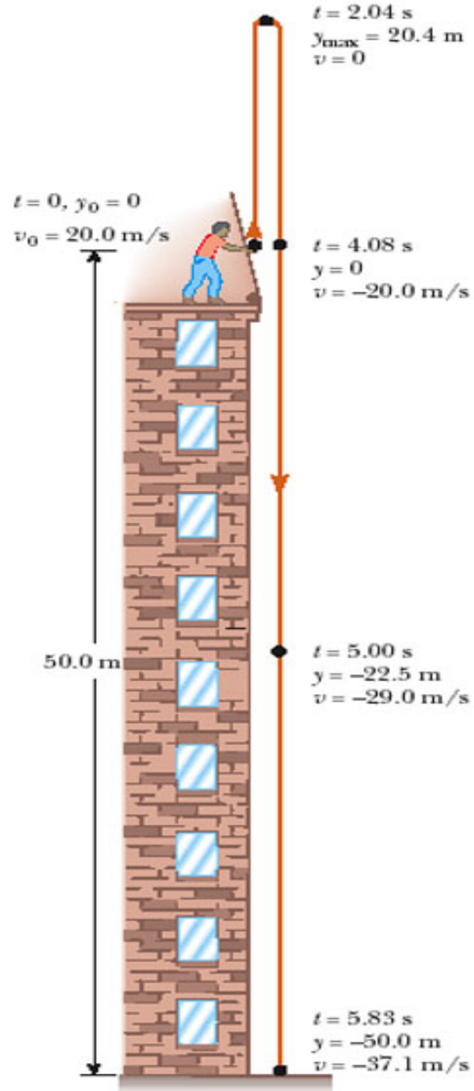
Freefall

- If we choose our coordinate system so +y is up and –y is down

$$g = 9.80\ \text{m/s}^2$$
$$a = -g$$

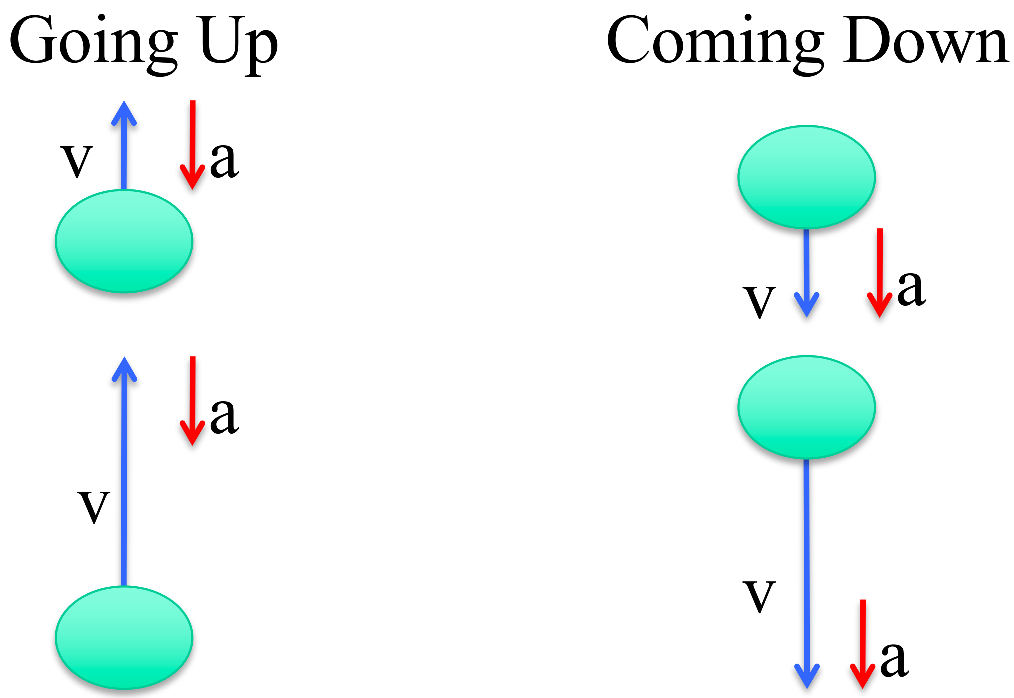
$$v = v_0 - gt$$
$$\Delta y = v_0 t - \tfrac{1}{2} g t^2$$

- Objects may be in freefall even when traveling upwards



Freefall

- Acceleration in freefall is always downward



$$a = \frac{\Delta v}{\Delta t} = -g$$

Freefall Equations

$$v = v_0 - gt$$

$$\Delta y = \tfrac{1}{2}(v_0 + v)t$$

$$\Delta y = v_0 t - \tfrac{1}{2} g t^2$$

$$\Delta y = \frac{v_0^2 - v^2}{2g}$$

$$\bar{v} = \frac{v + v_0}{2}$$

Equations of Motion

Constant Velocity: $\Delta x = vt$

Constant Acceleration:

$$v = v_0 + at$$

$$\Delta x = \tfrac{1}{2}(v_0 + v)t$$

$$\Delta x = v_0 t + \tfrac{1}{2}at^2$$

$$\Delta x = \frac{v^2 - v_0^2}{2a}$$

$$\bar{v} = \frac{v + v_0}{2}$$

Freefall:

$$v = v_0 - gt$$

$$\Delta y = \tfrac{1}{2}(v_0 + v)t$$

$$\Delta y = v_0 t - \tfrac{1}{2}gt^2$$

$$\Delta y = \frac{v_0^2 - v^2}{2g}$$

$$\bar{v} = \frac{v + v_0}{2}$$

Question #2

A tennis player throws a ball straight upwards. While the ball is in the air, does its acceleration

A. Increase
B. Decrease
C. Increase then decrease
D. Decrease then increase
E. Remain constant

Day 3, Video 3

Freefall Example

Example 1

A mailbag is dropped from a helicopter descending at a steady rate of 1.5 m/s

a) After 2 s, what is the speed of the bag?

b) How far is the bag below the helicopter?

Question #3

A student at the top of a building of height h throws one ball upward with a speed v_0 and then throws a second ball downward with the same initial speed v_0. How do the final velocities compare when the balls reach the ground?

A. The upward thrown ball is faster

B. The downward thrown ball is faster

C. The velocities of both balls are equal

Question #4

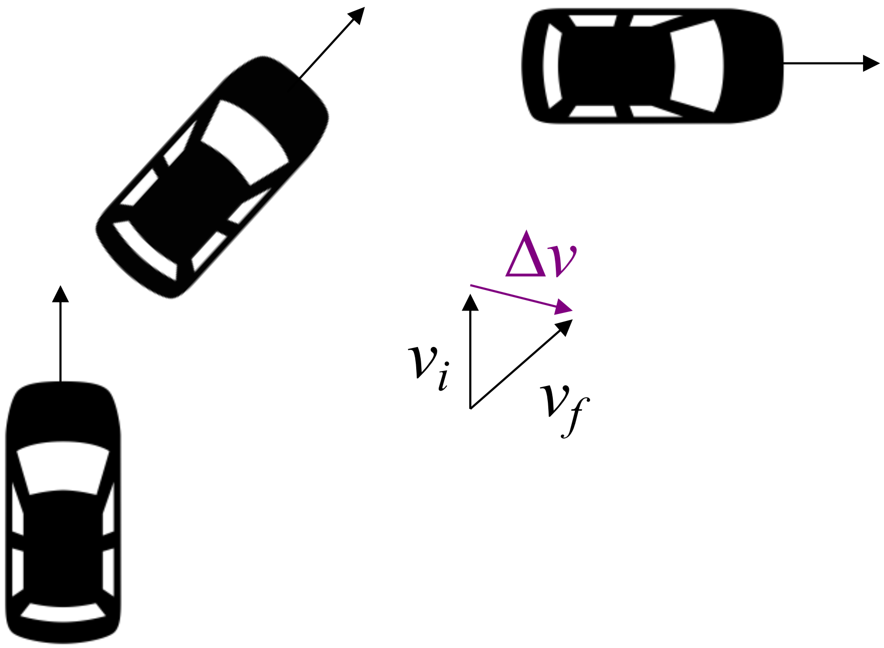
A child throws a marble into the air with an initial speed v_0. Another child drops a ball at the same instant. Which object's acceleration is greater?

A. The ball
B. The marble
C. The ball and marble have the same acceleration

Day 3, Video 4

2D Motion

2-D Motion



$$\bar{a}_x = \frac{\Delta v_x}{\Delta t}$$

$$\bar{a}_y = \frac{\Delta v_y}{\Delta t}$$

- **v, a, Δx** are vectors
- Can analyze motion in each direction separately

Question #5

Consider the following controls on a car: gas pedal, brake, steering wheel. Which of these can cause the car to accelerate?

A. All 3

B. Gas pedal and brake

C. Brake only

D. Gas pedal only

E. Steering wheel only

Example 2

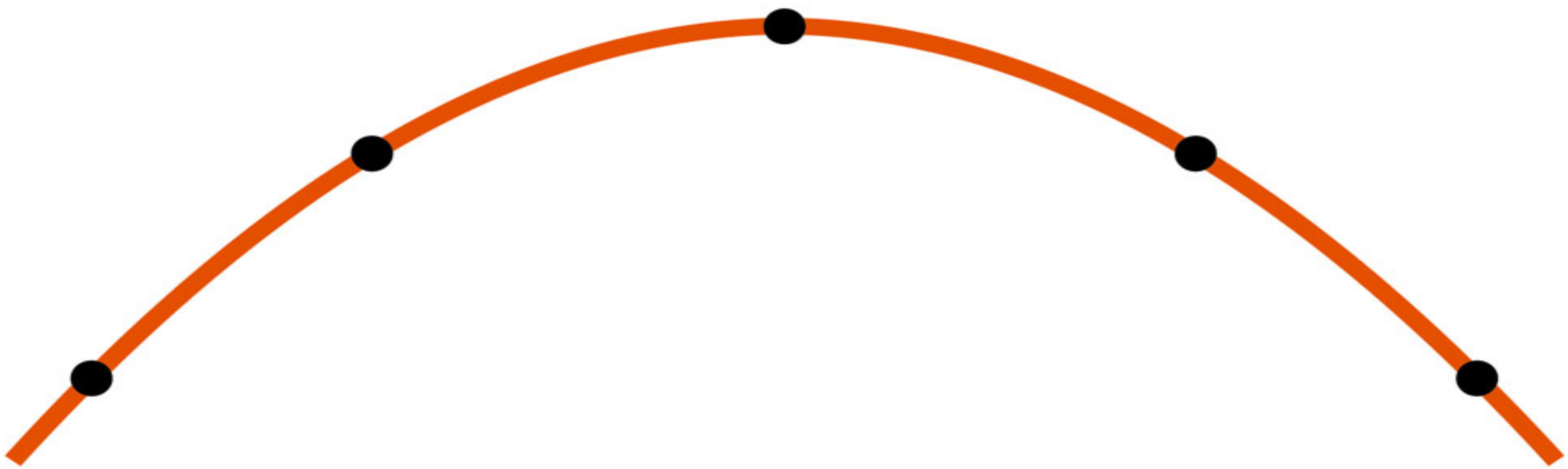
Bob is on a Ferris wheel which is turning clockwise at a constant rate. At some point, he is moving 3 m/s directly downward. 4 seconds later, the Ferris wheel has rotated by 30 degrees. What average acceleration did Bob experience?

Day 3, Video 5

Parabolic Motion

Parabolic Motion

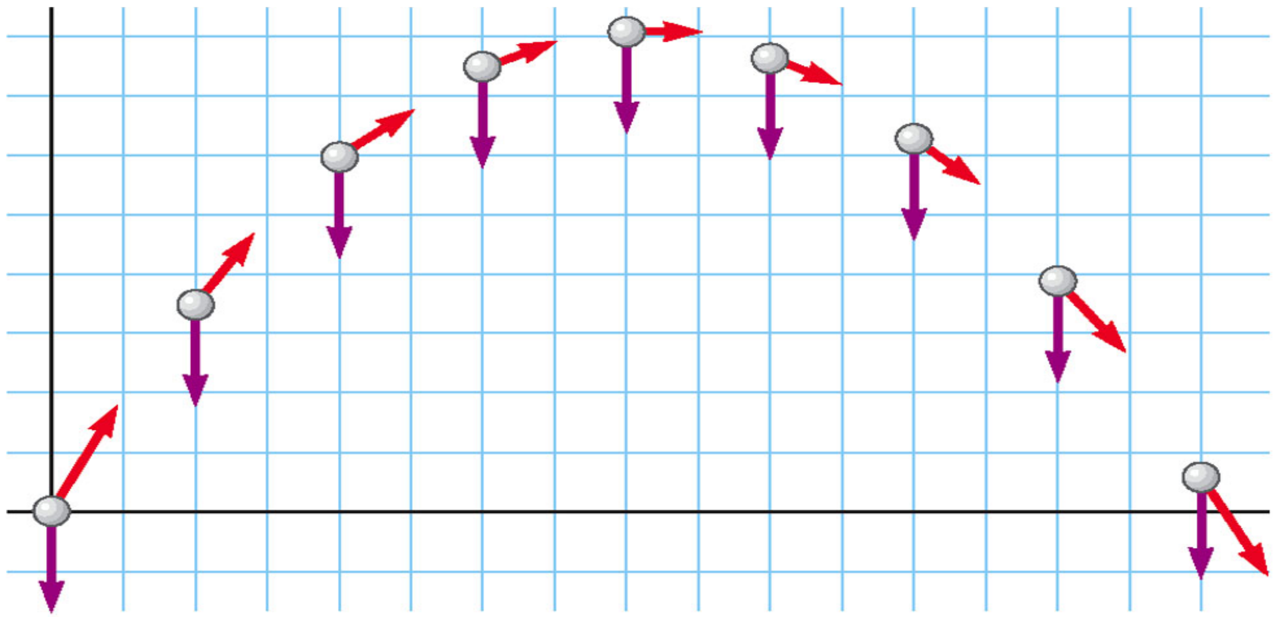
- Thrown object moves in both x and y directions (unless thrown straight up)
- Path looks like a parabola



Parabolic Motion

http://www.phy.ilstu.edu/events/trebuchet2002.html

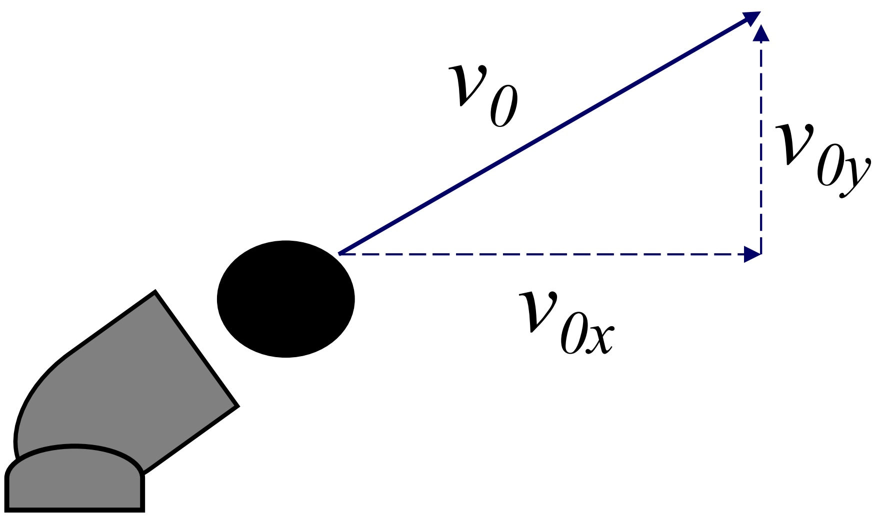
Parabolic Motion



- Horizontal (x dir) motion and vertical (y dir) motion are independent of each other
  - Gravity acts in the vertical direction only
  - Can break motion into 2 components and analyze each component separately

Initial Velocity

- Break initial velocity into components



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

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

Motion Components

- X-direction motion
  - a = 0 so v is constant
  - Use constant velocity equation

$$x = x_0 + v_{0x} t$$

- Y-direction motion
  - a = -g
  - Can use freefall equations

$$y = y_0 + v_{0y} t - \tfrac{1}{2} g t^2$$

Equations are Linked by time!

Day 3, Video 6

Parabolic Motion Examples

Example 3

A kayak goes over Palouse falls (186 ft) at a point where the current is 10 ft/s. How far from the base of the cliff does it hit the river?

Example 4

A golfer hits a ball with an initial speed of 30 m/s at an angle of 30° above the horizontal. The ball lands on a green that is 5.00 m above the level where the ball is struck.

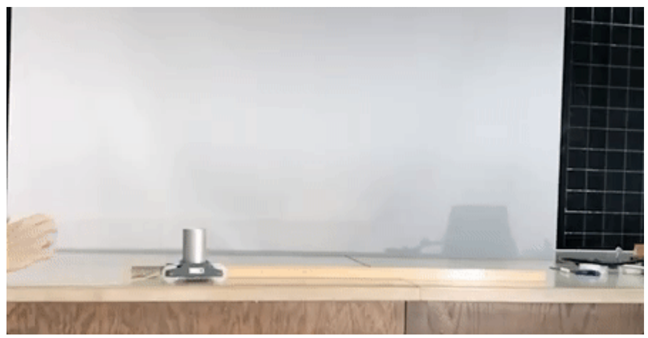
a) How long is the ball in the air?
b) How far has the ball traveled in the horizontal direction when it lands?

Question #6

Suppose you are carrying a ball and running at constant speed and want to throw the ball and catch it when it comes back down. You should:

A. Throw the ball at an angle of 45° and maintain speed
B. Throw the ball straight up in the air and slow down
C. Throw the ball straight up and maintain speed

Ball Launch



Big Ideas

- Freefall a = -g = -9.8 m/s^2
- Projectile motion
  – x-direction constant velocity
  – y-direction freefall

$$\Delta x = v_{0,x} t$$

$$\Delta y = v_{0,y} t - \tfrac{1}{2} g t^2$$