

# Physics 101: Lecture 05

## Free Fall and Apparent Weight

- Today's lecture will cover  
Textbook Sections 4.3, 4.5



# Review from Lecture 4

- Constant Acceleration Equations of Motion

- $x_f = x_0 + v_0 t + \frac{1}{2} a t^2$

- $v_f = v_0 + a t$

- $v_f^2 = v_0^2 + 2a(x - x_0)$

- $F_{\text{Net}} = m a$

- Draw Free Body Diagram

- Write down equations (which variables do you know, which don't you know?)

- Solve

- Today: look at Gravity as force

# Free Fall

- Only force acting on object is GRAVITY

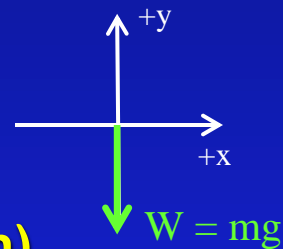
→ Newton's 2<sup>nd</sup> Law  $F_{\text{Net}, y} = ma_y$

→ Force is **Weight** =  $mg$  (near surface of earth)

»  $F_{\text{Net}, y} = ma_y$

»  $-mg = ma_y$

»  $a_y = -g$  (- sign tells us it is in  $-y$  direction or down).



- Acceleration is **ALWAYS**  $g$  downwards

→ Position may be positive, zero, or negative

→ Velocity may be positive, zero, or negative

→ Acceleration is ALWAYS  $g$  downwards

●  $x = x_0 + v_0 t + 1/2 at^2$

●  $v = v_0 + at$

●  $v^2 = v_0^2 + 2a(x-x_0)$

$\xrightarrow{a = -g}$

●  $x = x_0 + v_0 t - 1/2 gt^2$

●  $v = v_0 - gt$

●  $v^2 = v_0^2 - 2g(x-x_0)$

# Free Fall

- Only force acting on object is GRAVITY
- Acceleration is ALWAYS  $g$  downwards
- Which will hit the ground first?

A) Ball

B) Same

C) Feather



Note: Free fall only works when air resistance is negligible!

# ACT

- The speed of an object in free fall (Neglect Air Resistance!)
  - A. Always increases.
  - B. is constant.
  - C. Always decreases.
  - D. May increase or decrease or be constant.
  - E. May increase or decrease but is never constant.

$a = -g$ . Velocity becomes more and more negative. If  $v > 0$ , speed decreases. If  $v \leq 0$  speed increases.

# Free Fall ACTS

Fred throws a ball 30 mph vertically upward. Which of the following statements are true about the ball's velocity and acceleration. (Let up be the positive direction)

On the way up?

A)  $v < 0$

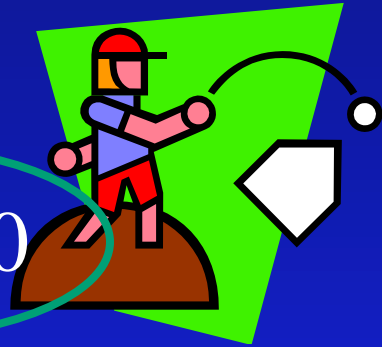
B)  $v = 0$

C)  $v > 0$

A)  $a < 0$

B)  $a = 0$

C)  $a > 0$



On the way down?

A)  $v < 0$

B)  $v = 0$

C)  $v > 0$

A)  $a < 0$

B)  $a = 0$

C)  $a > 0$

# ACT

Fred throws a ball 30 mph vertically upward and then catches it again at the same height he threw it from. What is the speed of the ball when he catches it? (Neglect air resistance)

- 1)  $v < 30 \text{ mph}$  2)  $v = 30 \text{ mph}$  3)  $v > 30 \text{ mph}$

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

$$\triangleright v_y^2 = v_{y0}^2$$

# Free Fall Example

Fred throws a ball 30 m/s vertically upward. What is the maximum height the ball reaches? How long does it take to reach this height?

What is the speed at max height?

$$v^2 = v_0^2 - 2 g \Delta y$$

$$v^2 - v_0^2 = -2 g \Delta y$$

$$\begin{aligned}\Delta y &= (v^2 - v_0^2) / (-2 g) \\ &= -30^2 / (-2 * 9.8) \\ &= 46 \text{ m}\end{aligned}$$

$$v = v_0 - g t$$

$$\begin{aligned}t &= (v - v_0) / (-g) \\ &= (0 - 30 \text{ m/s}) / (-9.8 \text{ m/s}^2) \\ &= 3.1 \text{ seconds}\end{aligned}$$



# ACT

Dennis and Carmen are standing on the edge of a cliff. Dennis throws a basketball vertically upward, and at the same time Carmen throws a basketball vertically downward with the same initial speed. You are standing below the cliff observing this strange behavior. **Whose ball hits the ground first?**

A. Dennis' ball

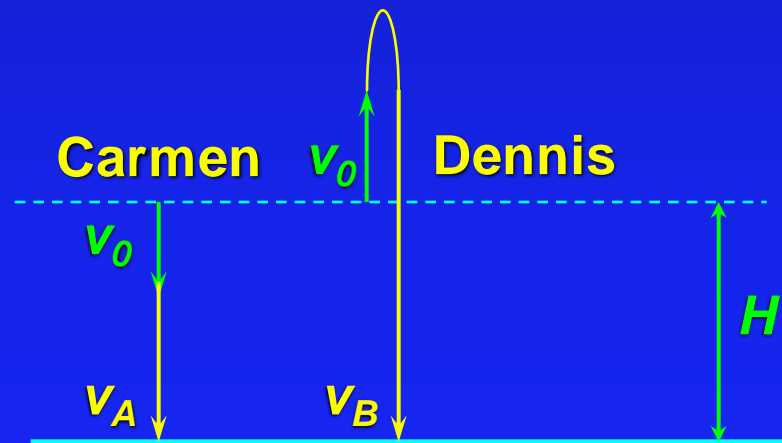
B. Carmen's ball

C. Same

$$y = y_0 + v_0 t + \frac{1}{2} a t^2$$

$$\text{Dennis: } 0 = H + v_0 t - \frac{1}{2} g t^2$$

$$\text{Carmen: } 0 = H - v_0 t - \frac{1}{2} g t^2$$

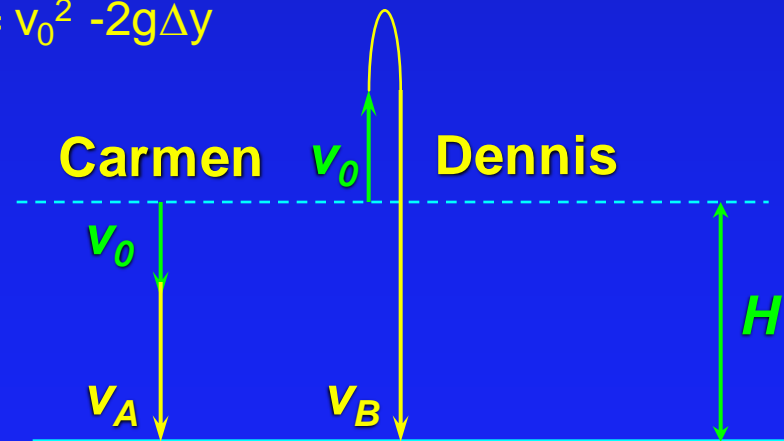


# ACT

Dennis and Carmen are standing on the edge of a cliff. Dennis throws a basketball vertically upward, and at the same time Carmen throws a basketball vertically downward with the same initial speed. You are standing below the cliff observing this strange behavior. **Whose ball is moving fastest when it hits the ground?**

- A. Dennis' ball
- B. Carmen's ball
- C. Same

← Correct:  $v^2 = v_0^2 - 2g\Delta y$



# Apparent Weight

- Recall:  $F_{\text{Net}} = m a$

→ Consider a person accelerating up in an elevator.

→ Draw FBD

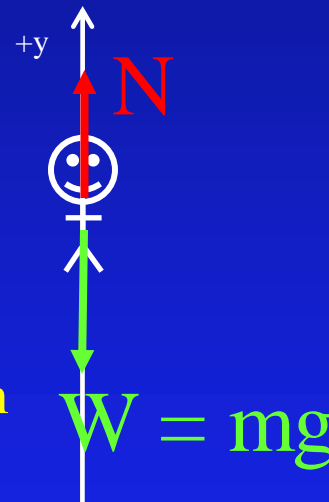
→ Apply Newton's 2<sup>nd</sup>!

$$\gg N - mg = ma$$

$$\gg N = m(g+a)$$

Apparent weight

Elevator's acceleration



- Apparent weight is *normal force* from scale or floor.

- Note: in free fall  $a_y = -g$  so  $N=0$



# Apparent Weight Prelecture

- You are traveling up on an elevator to the 30<sup>th</sup> floor of the Willis tower. As it nears the 30<sup>th</sup> floor, your weight appears to be

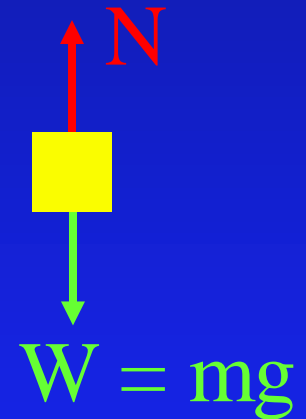
1) heavier <sup>30%</sup>      2) the same <sup>15%</sup>      3) lighter <sup>55%</sup>

$$F_{\text{Net}, y} = ma_y$$

$$N - mg = ma_y$$

$$N = m(g+a)$$

$$a < 0. \text{ so } N < mg$$



"As the elevator reaches the 30th floor it will start to slow down, meaning that it will have a downward or negative acceleration making you not press on the floor of the elevator as hard making your body feel lighter than it actually is."



# Great Explanations! (Wrong Answer)

"Because accelerating up increases apparent weight."

"The gravitational force is less strong"

"I looked up the answer on Google... sorry. This will be embarrassing if I'm wrong."

"I do not like heights and I can feel my body wanting to be back on the ground."

"N/A"

"thank you very much"

# Apparent Weight Examples

A person's mass is 50 kg. What is the person's apparent weight when riding on an elevator

$$N = m(g+a)$$

1. Going up with constant speed 9.8 m/s

$$a = 0 \text{ so } N = mg = 490 \text{ N}$$

2. Going down with constant speed 9.8 m/s

$$a = 0 \text{ so } N = mg = 490 \text{ N}$$

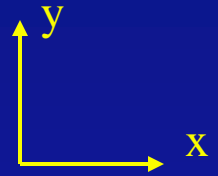
3. Accelerating up at a rate of 9.8 m/s<sup>2</sup>

$$a = +9.8 \text{ m/s}^2 \text{ so } N = 2mg = 980 \text{ N}$$

4. Accelerating down at a rate of 9.8 m/s<sup>2</sup>

$$a = -9.8 \text{ m/s}^2 \text{ so } N = 0 \text{ mg} = 0 \text{ N}$$

# Apparent Weight ACTs



- You are standing on a scale inside an elevator. You weigh 125 pounds, but the scale reads 140 pounds.

The elevator is going (up down can't tell)

A

B

C

The elevator is accelerating (up down can't tell)

A

B

C

$$N = m(g+a)$$

Weight increases when accelerating up  
decreases when accelerating down.



# Summary of Concepts

- Free Fall

- Only force is gravity
- Acceleration is  $9.8 \text{ m/s}^2$  down

- Apparent Weight (Normal Force)

- If object is accelerating in vertical direction weight appears different
- Accelerating up, increases apparent weight
- Accelerating down decreases apparent weight