Physics 101: Lecture 05

Free Fall and Apparent Weight

- Today's lecture will cover

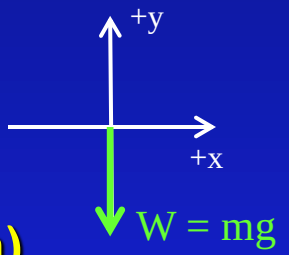
  Textbook Sections 4.3,4.5

Review from Lecture 4

- Constant Acceleration Equations of Motion
  - $x = x_0 + v_0 t + 1/2\ a t^2$
  - $v = v_0 + a t$
  - $v^2 = v_0^2 + 2a(x-x_0)$
- $F_{Net} = m\ a$
  - 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 2nd Law $F_{Net,\,y} = ma_y$
  - ➔Force is Weight = mg (near surface of earth)
    - » **$F_{Net,\,y} = ma_y$**
    - » **$-mg = ma_y$**
    - » **$a_y = -g$ (- 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

- $x = x_0 + v_0t + 1/2\ at^2$
- $v = v_0 + at$
- $v^2 = v_0^2 + 2a(x-x_0)$

$a = -g$ ⟶

- $x = x_0 + v_0t - 1/2\ gt^2$
- $v = v_0 - gt$
- $v^2 = v_0^2 – 2g(x-x_0)$

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

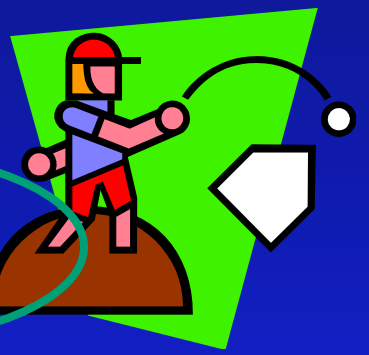
- The speed of an object in free fall (Neglect Air Resistance!)

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 <= 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 mph 2) v = 30 mph 3) v > 30 mph

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

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?

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

$\Delta y = (v^2 - v_o^2)/(-2\ g)$

$= -30^2 / (-2 * 9.8)$

$= 46$ m.

$v = v_0 + a\ t$

$t = (v - v_0) / a$

$= (0 - 30\ \text{m/s})/(-9.8\ \text{m/s}^2)$

$= 3.1$ seconds

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

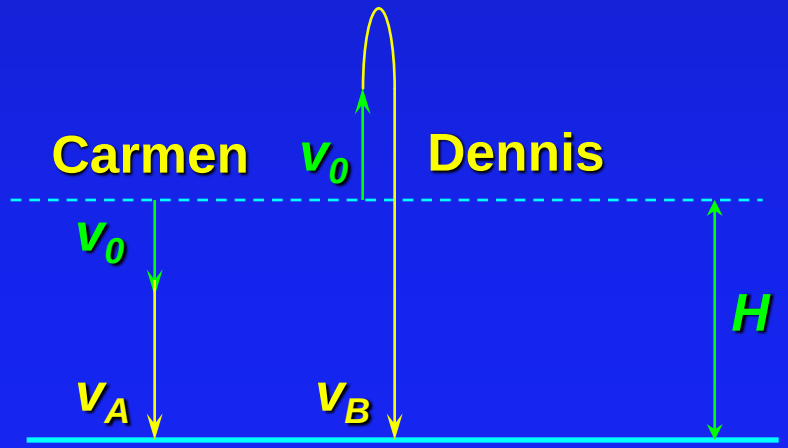
B. Carmen's ball

C. Same

$y = y_o + v_o t + \frac{1}{2} a t^2$

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

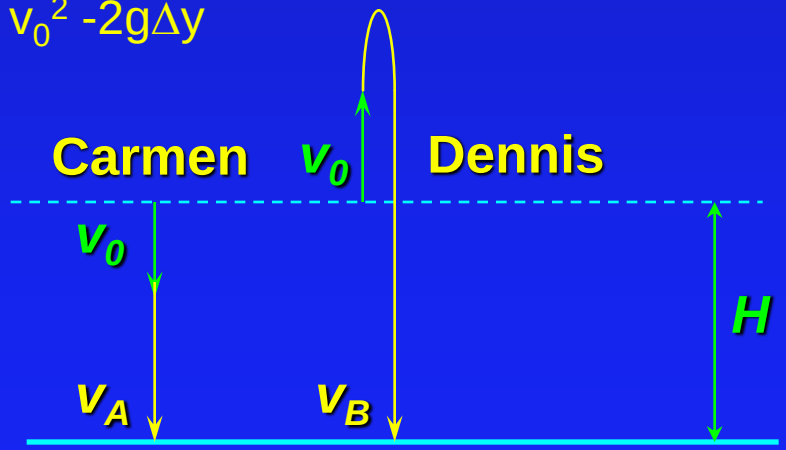
Carmen: $0 = H - v_o t - \frac{1}{2} g t^2$



ACT

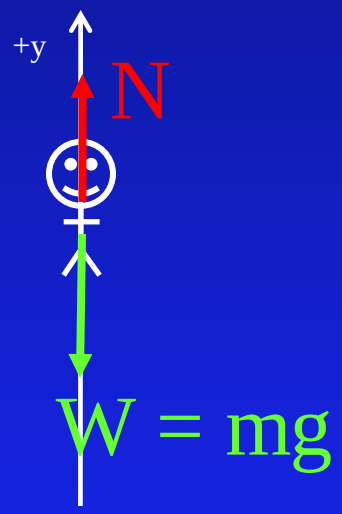
Dennis and Carmen are standing on the edge of a cliff. Dennis throws a basketball vertically upward, and at the same time Carmen throws a basketball vertically downward with the same initial speed. You are standing below the cliff observing this strange behavior. Whose ball is moving fastest when it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

A. Dennis' ball
B. Carmen's ball
C. Same ← Correct: $v^2 = v_0^2 - 2g\Delta y$



Apparent Weight

- Recall: $F_{Net} = m\,a$
  - ➔Consider a person accelerating up in an elevator.
  - ➔Draw FBD
  - ➔Apply Newton's 2nd!
    - » **N – mg = ma**
    - » **N = m(g+a)**



- 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 30th floor of the Sears (OK, Willis) tower. As it nears the 30th floor, your weight appears to be

29% 1) heavier

18% 2) the same

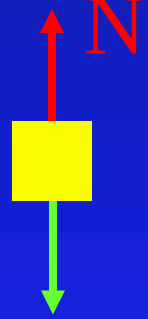
53% 3) lighter

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

$N - mg = ma_y$

$N = m(g+a)$

$a < 0$. so $N < mg$



"As you approach the 30th floor, the elevator will start to slow down. As the elevator slows down it means that the acceleration is downwards, therefore you press less hard on the elevator floor then before. That's why in really fast elevators sometimes you feel a little weightless or a funny feeling in your stomach."

Great Explanations! (Wrong Answer)

"Because accelerating up increases apparent weight."

"g will be smaller due to the equation we learn from class. W=GMm/r^2 "

"Unless the elevator was accelerating, which it does not state in the question that it is, the weight would be unchanged because the acceleration is 0."

"I like potatoes." "what jose said" "d"

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

   $a = 0$ so $N = mg = 490\ N$

2. Going down with constant speed 9.8 m/s

   $a = 0$ so $N = mg = 490\ N$

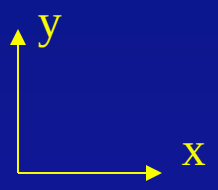
3. Accelerating up at a rate of 9.8 m/s^2

   $a = +9.8\ m/s$ so $N = 2\ mg = 980\ N$

4. Accelerating down at a rate of 9.8 m/s^2

   $a = -9.8\ m/s$ so $N = 0\ mg = 0\ N$

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 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