- Last Lecture
  - Kinematics - describing 1D motion
  - Relative velocity (yes, more vectors!)
- Today
  - More dimensions
  - More examples
  - More vectors
- Important Concepts
  - Change=derivative=slope
  - Multiple dimensions are as independent as many objects
  - Think carefully about directions (changes the +/- sign)

Important Reminders

- Pset #2 due here tomorrow at 10 am
- Finish Mastering Physics #3 before next Monday at 10pm
- Exam #1 is next Friday at 10am

Kinematics: Description of Motion

- All measurements require an origin, a coordinate system, and units
  - Next complication is "reference frame", the term used to describe the motion of observer
    - Constant velocity is OK, accelerated observer is not
- Basic definitions:
  - Position
    - Distance versus displacement
  - Velocity - change of position
    - Speed is the magnitude of velocity
  - Acceleration - change of velocity

More complicated situations

- More objects
  - Write an additional set of equations
- More dimensions
  - Write an additional set of equations

$$v_x = \frac{dx}{dt} \qquad a_x = \frac{dv_x}{dt} = \frac{d^2x}{dt^2}$$

$$v_y = \frac{dy}{dt} \qquad a_y = \frac{dv_y}{dt} = \frac{d^2y}{dt^2}$$

Vector Connections

$$\vec{v} = \frac{d\vec{r}}{dt} \qquad \vec{a} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{r}}{dt^2}$$

$$|\vec{v}| = \sqrt{v_x^2 + v_y^2 + v_z^2}$$

$$|\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$$

Multi-dimensional Kinematics Problems

- Need to think carefully about directions (signs!)
- Need to think carefully about initial conditions
- Write separate equations for each dimension
- Read problem carefully to understand the specific constraint to use to solve

Special Case of Constant Acceleration

$$x = x_0 + v_{0x} t + \tfrac{1}{2} a_x t^2$$

$$v_x = v_{0x} + a_x t$$

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

$$v_y = v_{0y} + a_y t$$

◯ Physics

◯ Initial conditions

Extra special case

Trajectories with gravity near the surface of the Earth and no air resistance or other drag forces

$$a_x = 0 \qquad a_y = -g$$

$$v_{0x} = v_0 \cos(\theta) \qquad v_{0y} = v_0 \sin(\theta)$$

Super special case

Range of a projectile near the surface of the Earth and no air resistance or other drag forces

$$x_0 = 0 \quad y_0 = 0 \quad y_{final} = 0 \quad x_{final} = Range$$

$$Range = \frac{v_0^2 \sin(2\theta)}{g}$$

You should immediately forget you ever saw this formula but remember the technique used to find it.

Quadratic Equations

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Important property: Such equations can have 0, 1, or 2 solutions depending on the value of b^2-4ac.

Negative: 0 solutions   Zero: 1 solution   Positive: 2 solutions

Warning: Only one of the 2 solutions may be physical!

Summary

- Study special cases (like range of a projectile) but understand the assumptions that go into all formulas
- Position, velocity, and acceleration are ALL vectors and need to be manipulated using either arrows (qualitative) or components (quantitative)
- Directions (or signs in 1D) of position, velocity, and acceleration can all be different