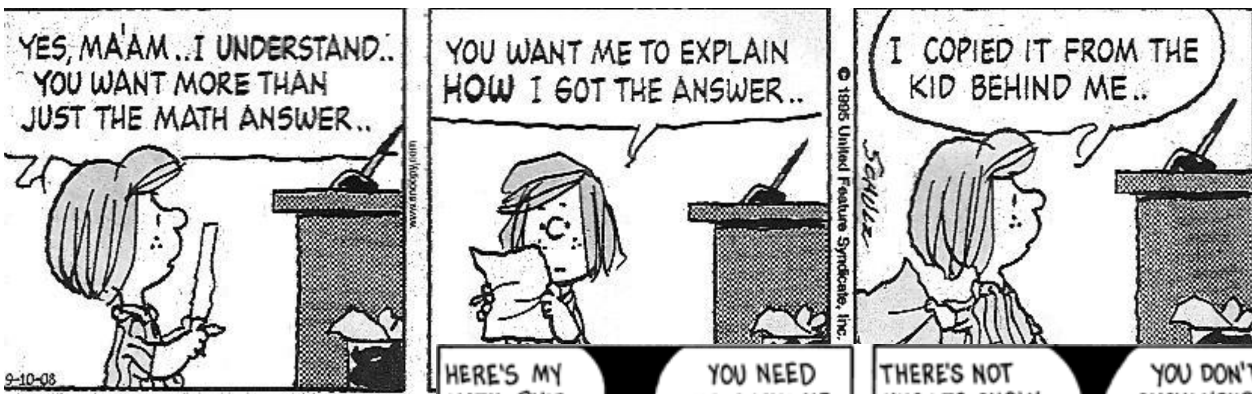
- **<u>Theme Music:</u>**

  Speed Racer Theme

- **<u>Cartoon:</u> Charles Schultz / Jef Mallett**

  Peanuts / Frazz



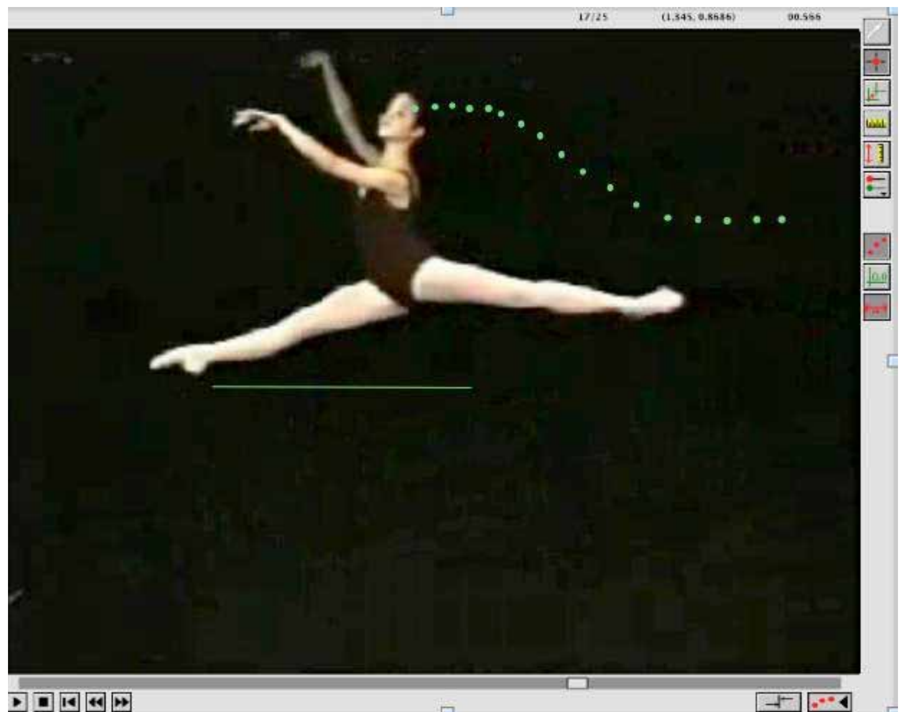
Coordinates and Vectors

- Set up a coordinate system
  - Pick an origin
  - Pick perpendicular directions
  - Choose a measurement scale
- Each point in space in then specified by three numbers: the x, y, and z coordinates.
- The <u>position vector</u> for a particular position is an arrow drawn from the origin to that position.

Graphing Position

- Graphs for the eye vs. graphs for the mind.
- Describe where something is in terms of its coordinate at a given time.

  - Choose origin
  - Choose axes
  - Choose scale
  - Set scales on graph
  - Take data from video



Writing the math

- Position at a clock time *t*: $\vec{r}(t) = x(t)\hat{i} + y(t)\hat{j}$
- Position at a clock time *t*: (in 1-D, if we don't want to emphasize direction) $x(t)$
- Change in position between two times (t_1 and t_2) $\Delta\vec{r} = \vec{r}(t_2) - \vec{r}(t_1)$
- Time interval $\Delta t = t_2 - t_1$

Displacement

- The displacement is the total change in position.
- If you make one change and then go back, it could cancel out the first change.

$$\vec{r}(t_1) \rightarrow \vec{r}(t_2) \rightarrow \vec{r}(t_3)$$

$$\Delta\vec{r}_{12} = \vec{r}(t_2) - \vec{r}(t_1)$$

$$\Delta\vec{r}_{23} = \vec{r}(t_3) - \vec{r}(t_2)$$

$$\begin{aligned}\Delta\vec{r}_{13} &= \Delta\vec{r}_{12} + \Delta\vec{r}_{23} \\ &= \vec{r}(t_2) - \vec{r}(t_1) + \vec{r}(t_3) - \vec{r}(t_2) \\ &= \vec{r}(t_3) - \vec{r}(t_1)\end{aligned}$$

Average Velocity

- We need to keep track not only of the fact that something has moved but how long it took to get there.
- Define the <u>average velocity</u> by

$$<\vec{v}> = \frac{\text{displacement}}{\text{time it took to make the displacement}}$$

$$<\vec{v}> = \frac{\Delta\vec{r}}{\Delta t}$$

Uniform motion

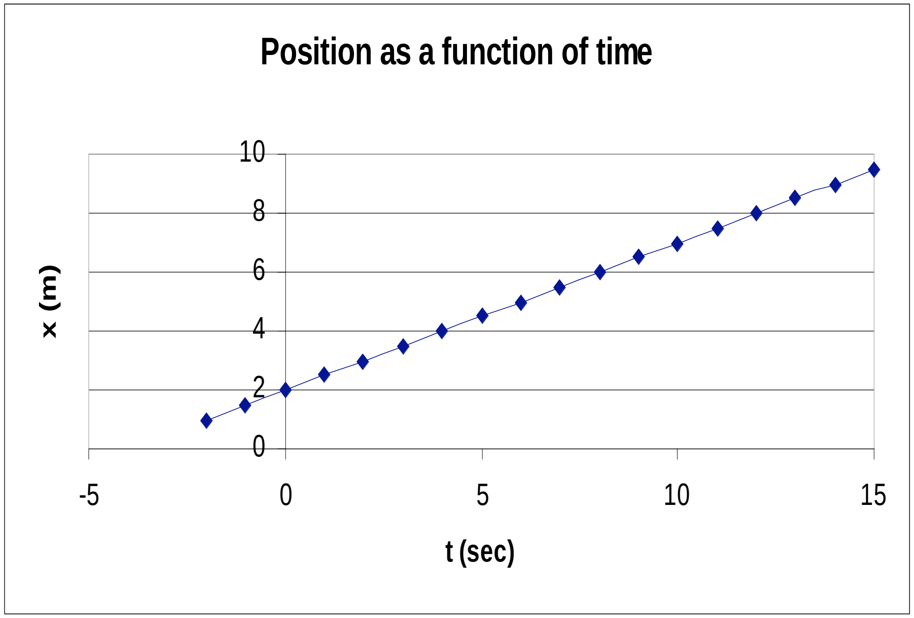
- If an object moves so that it changes its position by the same amount in each unit of time, we say it is in <u>uniform motion</u>.
- This means the average velocity will be the same no matter what interval of time we choose.

$$< \vec{v} > = \frac{\Delta \vec{r}}{\Delta t} = v_0$$

$$\Delta \vec{r} = v_0 \, \Delta t$$

$$\vec{r}(t_2) - \vec{r}(t_1) = v_0 \, \Delta t$$

$$\vec{r}_{final} = \vec{r}_{initial} + v_0 \, \Delta t$$



Making Sense of the Equation

- Consider a familiar example.
  - If you were to drive North on US 95 for 2 hours (on a Sunday morning when there wasn't much traffic) and could average 60 mi/hr, how far would you have gone?
  - Suppose there was traffic and you could only average 30 mi/hr. How long would it take you to go the same distance?
- Now do it with the equation.
  - 23 mi/hr?

Instantaneous velocity

- Sometimes (often) an object will move so that it is not in uniform motion. Sometimes it moves faster, sometimes slower, sometimes not at all.
- We want to be able to describe this change in motion also.
- If we consider small enough time intervals, the motion will look uniform — for a little while at least.

Instantaneous velocity

- If we consider a small enough time interval so that the object is (approximately) in uniform motion during that time interval, we can define the "velocity at the instant at the center of the time interval" by

$$\vec{v}(t) = \frac{d\vec{r}}{dt}$$

$$\vec{v}(t) = \frac{\vec{r}(t + \Delta t/2) - \vec{r}(t - \Delta t/2)}{\Delta t}$$

Instantaneous velocity

- The instantaneous velocity is like attaching the reading on your car's speedometer to an arrow pointed in the direction you are going.
- Both the size and direction can change from instant to instant.

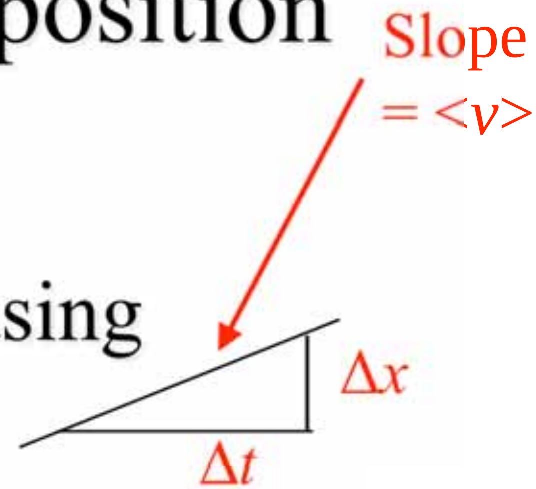
How the Sonic Ranger works

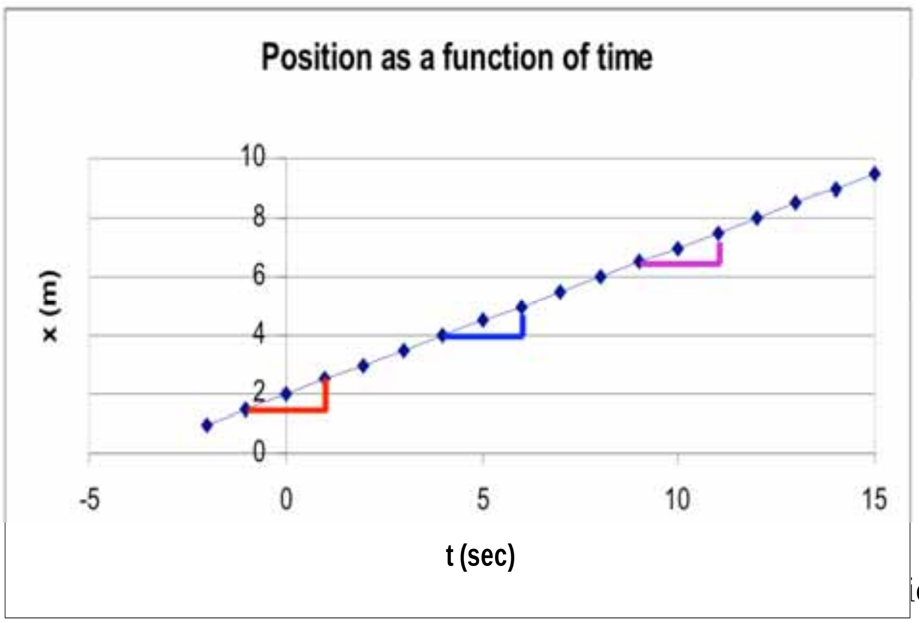
- The sonic ranger has a speaker and a microphone.
- The speaker makes clicks (about 30 per second)
- The microphone detects the echo from the nearest object in front of it.
- The computer measures the time delay between sending the click and receiving the echo.
- The computer calculates the distance using the speed of sound.

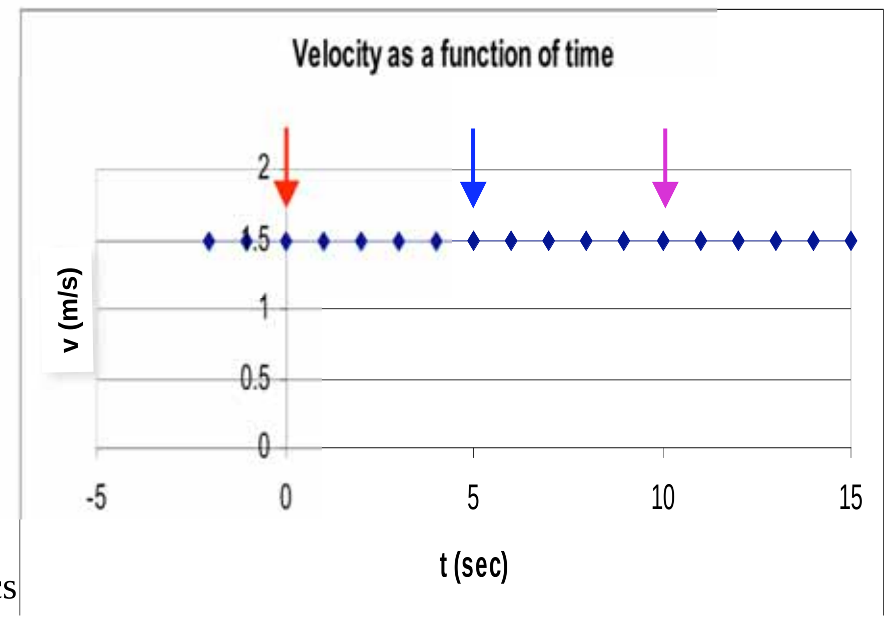
Graphing velocity: Figuring it out from the position

- You can figure out the velocity graph from the position graph using

$$\langle v \rangle = \frac{\Delta x}{\Delta t} \qquad \Delta x = \langle v \rangle \Delta t$$







Graphing Velocity: Figuring it out from the motion

- An object in uniform motion has constant velocity.
- This means the instantaneous velocity does not change with time. Its graph is a horizontal line.
- You can make sense of this by putting your mind in “velocity mode” and running a mental movie.

What have we learned? ☑

$$\langle \vec{v} \rangle = \frac{\text{displacement}}{\text{time it took to make the displacement}}$$

$$\langle v \rangle = \frac{\Delta x}{\Delta t} \qquad \Delta x = \langle v \rangle \Delta t$$