September 8, 2010 Physics 121 Prof. E. F. Redish

- **Theme Music: Wynton Marsalis**
  Where or When?
- **Cartoon: Jim Davis**
  Garfield

Outline

- Recap: Dimensional Analysis
- The Main Topic: Motion
- Describing Motion:
  - Coordinates in space and time
  - Vectors
  - Graphs
- The Idea of Velocity

Letting dimensional analysis work for you

- In physics, if we try to add or equate quantities of different dimensions we get nonsense.
- If we didn't maintain dimensional correctness, an equality that worked in one measurement system wouldn't work in another.
- This is a very good way to check your work with equations. (But it's hard to do if you put numbers in too early!*)

** You also won't get much partial credit on exams if you put numbers in too early since we may not be able to tell what equations you are using and why!*

What have we learned? ☑

- In physics we assign numbers to physical objects by comparison counting against a particular standard.
- We have different kinds of quantities depending on how they were measured and these quantities change in different ways when you change your measuring units.
- It matters ***what*** you are counting, not just ***how much!***
- Only quantities of the same type may be equated (or added) otherwise an equality for one person would not hold for another.

$$1\,\text{cm}^3 + 4\,\text{cm}^3 = 5\,\text{cm}^3$$ ☑

$$1\,\text{cm} + 4\,\text{cm}^2 \neq 5\,(\text{anythings})$$ ☒

How would you fix the math exam example?

$$r(x) = 20\frac{1+x}{x^2+1}$$

Fourth icon: Cat television

- When we do science, we don't try to solve the entire universe at once.
- We restrict our considerations to a limited set of data and try to understand it. Only when we get it do we try to expand further to more situations.
- This is like looking out a window onto a small segment of the world. Since cats like to do this, I call the process "choosing a channel on cat television."

The Main Question

(for this term, at least)

- Start by choosing a big question and then refining it:

How do things move?

Why choose this?

- **concepts of measurement, rate of change, force are fundamental**
- **ties to everyday experience so can use and learn to build/refine intuition**

Describing Motion: Space

- Coordinates — telling where something is
- What do we need to do to specify
  the location of something
  so someone else can find it?
  - Note the difference between “length” or “distance” and “position”
  - Representing a position mathematically.

Length vs. Position

- Example: Measure the length of table.
- Example: Measure my position along a line across the room.
- Fish story
- Mathematical model: Associating a number with my position.
- Limitations?

Motion along a straight line (1-dimensional coordinates)

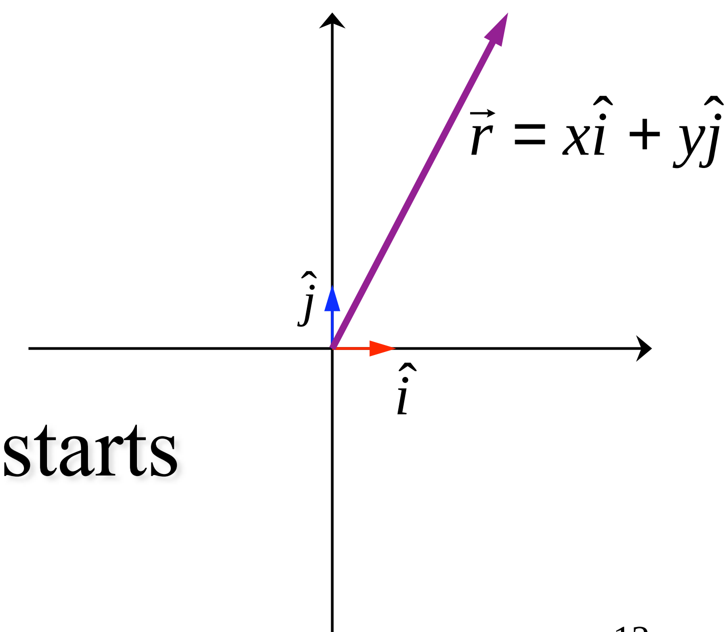
- We specify which direction we are talking about by drawing a little arrow of unit length in the positive direction.
- We specify that we are talking about this arrow in symbols by writing $\hat{i}$
- A position a distance x from the origin is written $\vec{r} = x\hat{i}$
- Note that if x is negative, it means a vector pointing in the direction opposite to $\hat{i}$

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.

Motion in a plane (2-dimensional coordinates)

- We specify the directions we are talking about by drawing two little arrows of unit length in two perpendicular directions.
- "x" and "y" are called the coordinates and can be positive or negative.
- A position vector always starts from the origin.



Describing Motion: Time

- Time — if we're to describe something moving we need to tell when it is where it is.
- Time is a coordinate just like position
  - We need an origin (when we choose $t = 0$)
  - a direction (usually times later than 0 are +)
  - a scale (seconds, years, millennia)
- Note the difference between
  - clock reading, t
  - a time interval, Δt

This is like the difference between position and length!

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.

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

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

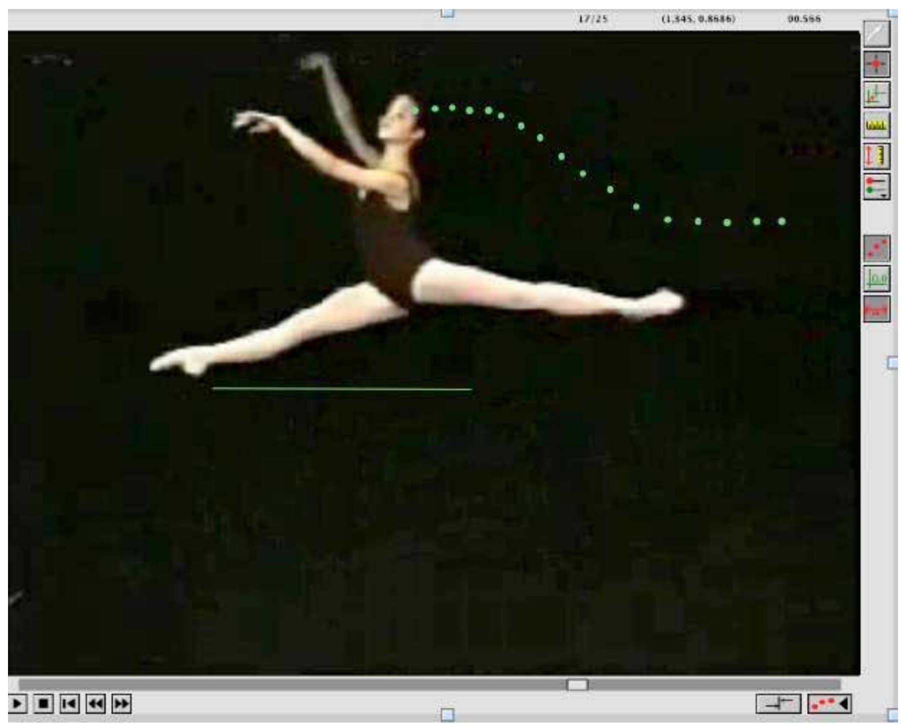
$$\Delta\vec{r}_{23} = \vec{r}(t_3) - \vec{r}(t_2)$$

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

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



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 average velocity 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.

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

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

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

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