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

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


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## 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.

$1\,\text{cm}^3 + 4\,\text{cm}^3 = 5\,\text{cm}^3$ ☑ $1\,\text{cm} + 4\,\text{cm}^2 \neq 5\,(\text{anythings})$ ☒

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## 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."

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## The Main Question

*(for this term, at least)*

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

  ***How do things move?***

- We need
  - to be able to describe motion
  - to understand what causes motion
  - to understand if any motions are "natural", i.e., they don't need any causes.

**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

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## 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.

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## 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?

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## 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 $\hat{i}$

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## 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 position vector for a particular position is an arrow drawn from the origin to that position.

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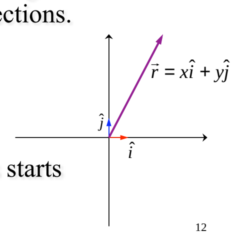
## Motion in a plane (2-dimensional coordinates)

- 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.

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## 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, $\Delta t$

This is like the difference between position and length!

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## 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 $\Delta t = t_2 - t_1$

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## 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.

$$\vec{r}(t_1) \rightarrow \vec{r}(t_2) \rightarrow \vec{r}(t_3)$$
$$\Delta\vec{r}_{12} = \vec{r}(t_2) - \vec{r}(t_1)$$
$$\Delta\vec{r}_{23} = \vec{r}(t_3) - \vec{r}(t_2)$$
$$\Delta\vec{r}_{13} = \Delta\vec{r}_{12} + \Delta\vec{r}_{23}$$
$$= \vec{r}(t_2) - \vec{r}(t_1) + \vec{r}(t_3) - \vec{r}(t_2)$$
$$= \vec{r}(t_3) - \vec{r}(t_1)$$

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## 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

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## 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

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

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

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## Uniform motion

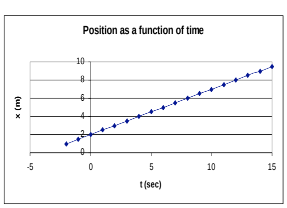
- If an object moves so that it changes its position by the same amount in each unit of time, we say it is in <u>uniform motion</u>.
- This means the average velocity will be the same no matter what interval of time we choose.

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

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

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

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

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