September 15, 2010 Physics 121 Prof. E. F. Redish

- **Theme Music:** **Lester Lanin**
  Acceleration Waltz
- **Cartoon:** **Pat Brady**
  Rose is Rose

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Outline

- Go over Quiz 1
- Finish example
- ILD 1
- Acceleration
  - average
  - instantaneous
  - examples
- Summary: Kinematics

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ILD 1

The Case of
Motion Graphs

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What have we learned? Position

- We specify position (along a given line) by
  - choosing a reference point (origin)
  - choosing a line
  - choosing a scale
- We specify a direction with a (dimensionless) arrow $\hat{i}$ and multiply it by a (positive or negative) distance to tell us where we are.

$$\hat{r} = x\hat{i} \quad \text{(where } x \text{ is a length)}$$

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What have we learned? Velocity

- Average velocity is defined by

$$\langle \vec{v} \rangle = \frac{\Delta \vec{r}}{\Delta t} = \frac{\text{displacement}}{\text{time it took to do it}}$$

Note: an average velocity goes with a time interval.

- Instantaneous velocity is what we get when we consider a very small time interval (compared to times we care about)

$$\vec{v} = \frac{d\vec{r}}{dt}$$

Note: an instantaneous velocity goes with a specific time.

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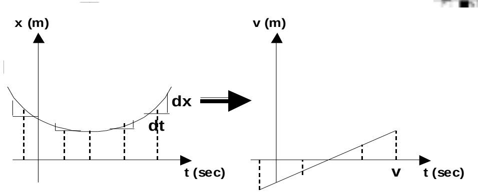
Position to velocity



$$v(t) = \frac{dx}{dt}$$

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

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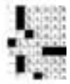
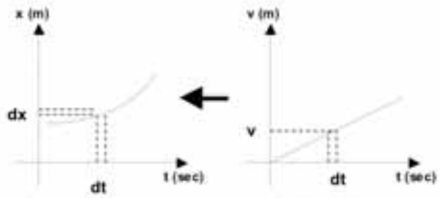
Velocity to position





$$dx = v(t)\,dt$$

change in position over a small time interval

sum ("Σ") in the changes in position over many small time intervals

$$x = \sum dx = \int v(t)\,dt$$

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Multiple Representations

- We choose different ways of representing things depending on what we want to do.

- Adding multiple sensory modes adds to our sense of an object's reality.

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Seventh Icon: Multiple Representations

- We have many different ways that we represent information:
  - Words
  - Equations
  - Diagrams
  - Pictures

- Each gives its own way of building up something "real" in our minds.

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What have we learned? Representations and consistency

- Visualizing where an object is at different times → a position graph
- Visualizing how fast an object is moving at different times → a velocity graph
- Position graph → velocity graph — slopes $v = \frac{\Delta x}{\Delta t}$
- Velocity graph → position graph — areas $\Delta x = v\,\Delta t$

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Average Acceleration

- We need to keep track not only of the fact that something is moving but how that motion is changing.
- Define the average acceleration by

$$<\vec{a}> = \frac{\text{change in velocity}}{\text{time it took to make the change}}$$

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

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Instantaneous acceleration

- Sometimes (often) an object will move so that sometimes it speeds up or slows down at different rates.
- We want to be able to describe this change in motion also.
- If we consider small enough time intervals, the change in velocity will look uniform — for a little while at least.

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Instantaneous acceleration

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

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

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

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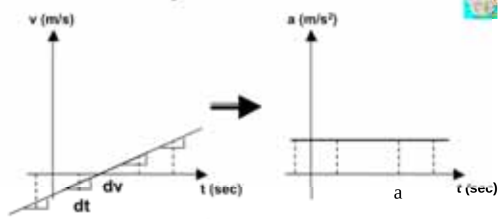
Velocity to acceleration



$$a(t) = \frac{dv}{dt}$$

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

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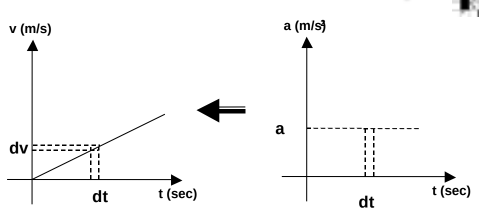
Acceleration to velocity



$$dv = a(t)\, dt$$

change in velocity over a small time interval

sum ("Δ") in the changes in velocity over many small time intervals.

$$v = \sum dv = \int a(t)\, dt$$

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