October 30, 2009 Physics 121 Prof. E. F. Redish

- **<u>Theme Music:</u> by Joni Mitchell***

  Circle Game

- **<u>Cartoon:</u> Bill Watterson**

  Calvin & Hobbes

***playing the original cover by Tom Rush**

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Outline

- Quiz 7: Energy
- ILD 5: Circular motion
- Circular Motion
  - position
  - velocity
  - acceleration
  - equations
  - force

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Circular Motion

- We've focused so far on motion along a line (1D motions) or 2D where the motions along two perpendicular directions are each independent 1D motions.
- Let's consider an example (the simplest one) in which the only change in a velocity is its direction.
- Uniform circular motion = motion in a circle at a constant speed.

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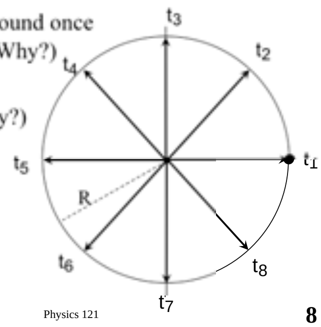
Circular Motion:
Checking for coherence
and reconciling

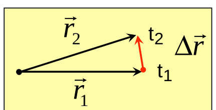
Uniform Circular Motion: Position

Period = time to go around once
$T = 4\,(t_3 - t_1)$ (Why?)

Speed = $2\pi R\,/\,T$ (Why?)

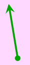


Uniform Circular Motion: Velocity

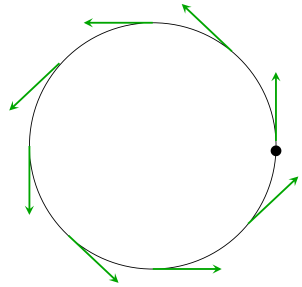


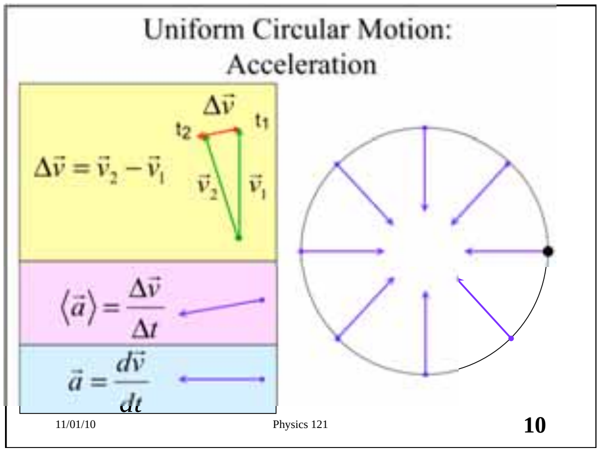
$\Delta\vec{r} = \vec{r}_2 - \vec{r}_1$

$\langle\vec{v}\rangle = \dfrac{\Delta\vec{r}}{\Delta t}$



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




Uniform Circular Motion: Acceleration
$\Delta\vec{v}$
t_2
t_1
$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$
$\vec{v}_2$
$\vec{v}_1$
$\langle\vec{a}\rangle = \frac{\Delta\vec{v}}{\Delta t}$
$\vec{a} = \frac{d\vec{v}}{dt}$
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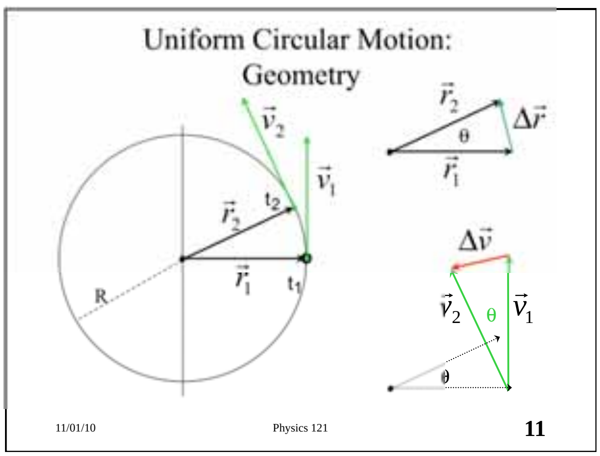
Uniform Circular Motion: Geometry
$\vec{v}_2$
$\vec{v}_1$
$\vec{r}_2$
t_2
$\vec{r}_1$
t_1
R
$\vec{r}_2$
$\Delta\vec{r}$
θ
$\vec{r}_1$
$\Delta\vec{v}$
$\vec{v}_2$
θ
$\vec{v}_1$
θ
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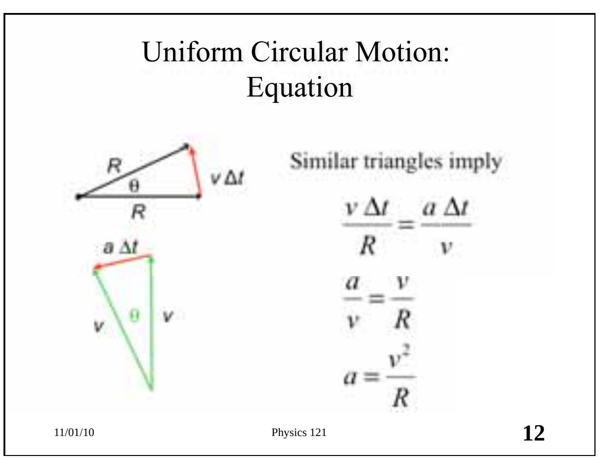
Uniform Circular Motion: Equation
R
θ
R
$v\,\Delta t$
$a\,\Delta t$
v
θ
v
Similar triangles imply
$\frac{v\,\Delta t}{R} = \frac{a\,\Delta t}{v}$
$\frac{a}{v} = \frac{v}{R}$
$a = \frac{v^2}{R}$
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Uniform Circular Motion: Acceleration vector

$a = \frac{v^2}{R}$ pointing in to center

$\vec{r}$ = position vector

$\frac{\vec{r}}{R} = \hat{r}$ = unit vector in direction of position vector

$\vec{a} = -\frac{v^2}{R}\hat{r}$

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Uniform Circular Motion: Forces

- Newton 1 says an object with no net force acting on it moves in a straight line with a constant speed.
- So if an object moves in a circle at a constant speed, there must be a net force on it.
  (The velocity is changing direction,
  so there is an acceleration.)
- How much force is needed to cause an object to move in a circle at a constant speed?

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Uniform Circular Motion: Forces

$\vec{a} = \frac{\vec{F}^{net}}{m}$ always

$\vec{a} = -\frac{v^2}{R}\hat{r}$ in order for the object to move in a circle with constant speed.

$\frac{\vec{F}^{net}}{m} = -\frac{v^2}{R}\hat{r}$ Therefore, to do this, we need a net force.

$\vec{F}^{net} = -\frac{mv^2}{R}\hat{r}$ A(n inward) radial net force is needed to maintain circular motion.

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