November 5, 2010 Physics 121 Prof. E. F. Redish

- **<u>Theme Music:</u> Mary Chapin Carpenter**

Down at the Twist and Shout

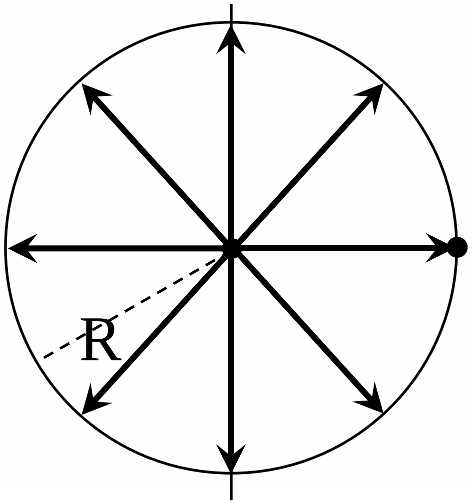
- **<u>Cartoon:</u> Mort & Greg Walker**

Beetle Bailey

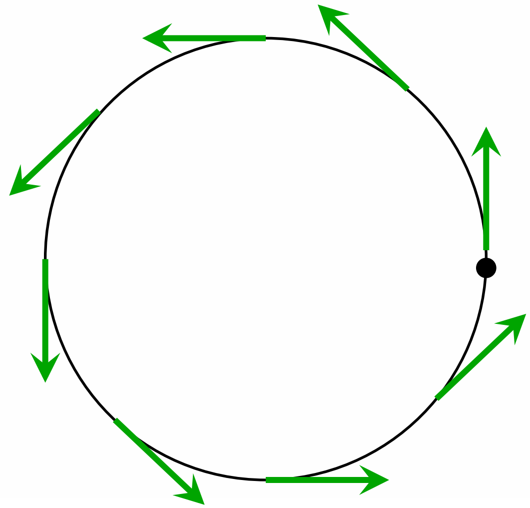
Outline

- Recap of forces in circular motion
- Rotational Kinematics
  - angles (radians)
  - angular velocity and angular acceleration
  - trig for large angles
- Thinking about balance:
  The Rotational Effect of Forces

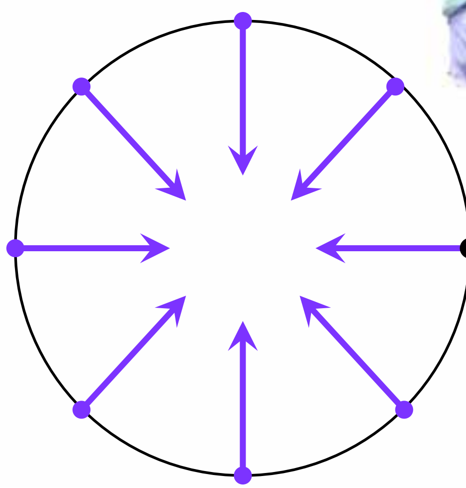
Uniform Circular Motion



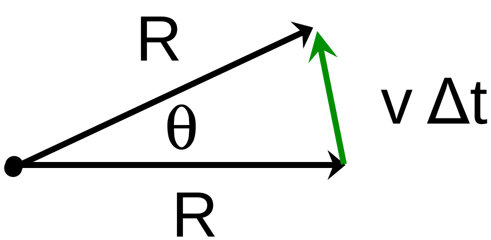
Position

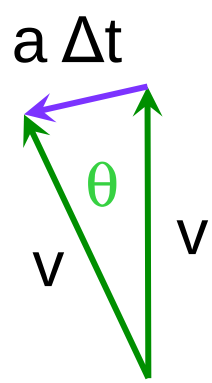


Velocity



Acceleration





$$\frac{v\,\Delta t}{R} = \frac{a\,\Delta t}{v} \qquad \frac{a}{v} = \frac{v}{R} \qquad a = \frac{v^2}{R}$$

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.

$$\vec{F}^{net} = -\frac{mv^2}{R}\hat{r}$$

Radians

- The radian is an angle measure defined as the ratio of the arc length of the circle spanned by the angle to the radius of the circle.

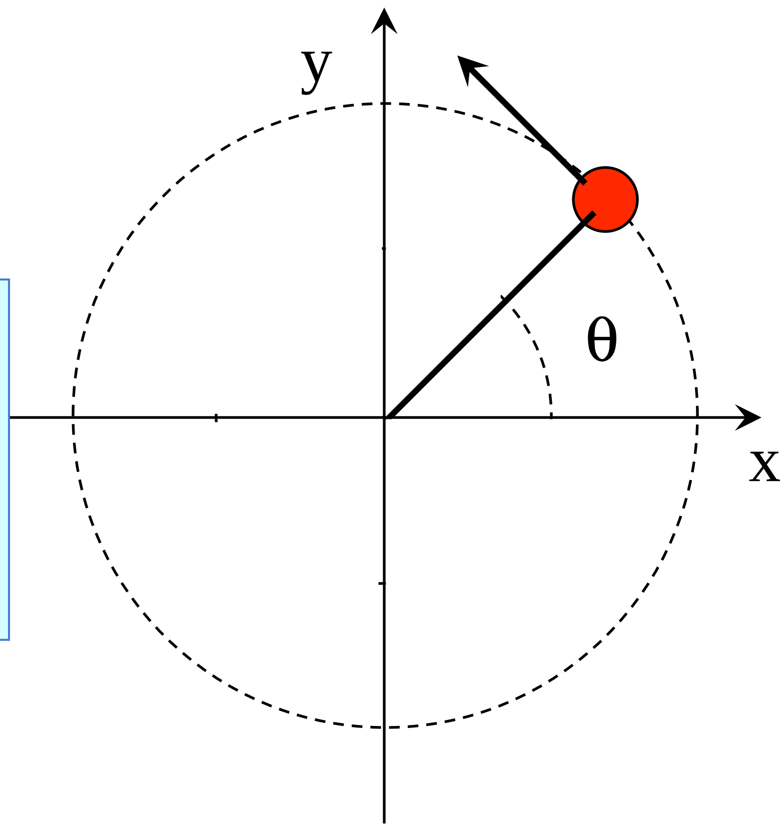
$$\theta = \frac{L}{R} \quad \text{(in radians)}$$

$$\theta_{\text{whole circle}} = \frac{2\pi R}{R} = 2\pi$$

$$\Rightarrow \quad \frac{\theta_{rad}}{\theta_{\text{deg}}} = \frac{2\pi}{360}$$

Rotational Kinematics: Polar Description of Motion

- Describing the angular position of an object.
  - Angle (radians) θ
  - Angular velocity ω
  - Angular acceleration α



$$\theta \text{ (in radians)} = \frac{2\pi}{360}\theta \text{ (in degrees)}$$

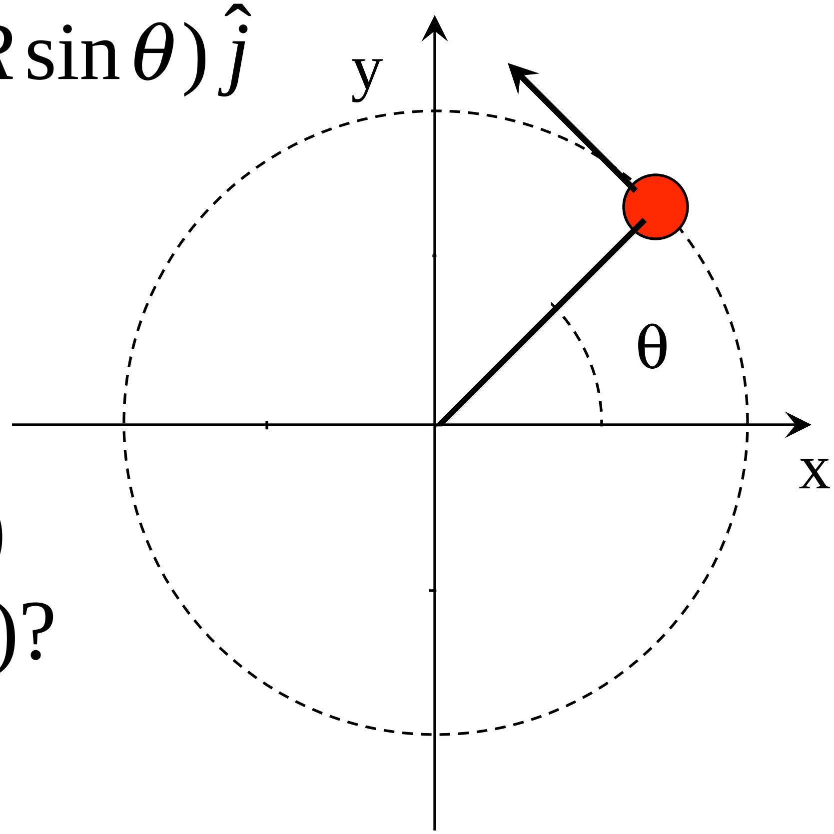
$$\langle\omega\rangle = \frac{\Delta\theta}{\Delta t} \qquad \langle\alpha\rangle = \frac{\Delta\omega}{\Delta t}$$

Uniform motion: $\Delta\theta = \omega_0 \, \Delta t$

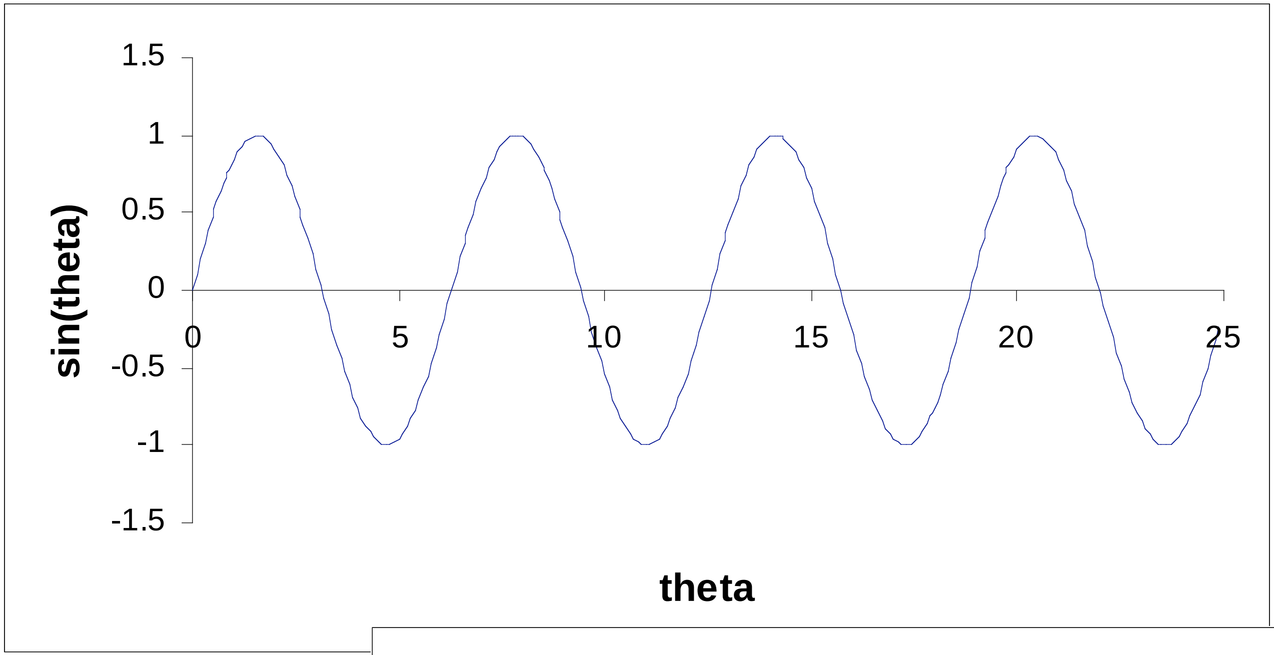
Trigonometry for big angles

$$\vec{r} = x\hat{i} + y\hat{j} = (R\cos\theta)\hat{i} + (R\sin\theta)\hat{j}$$

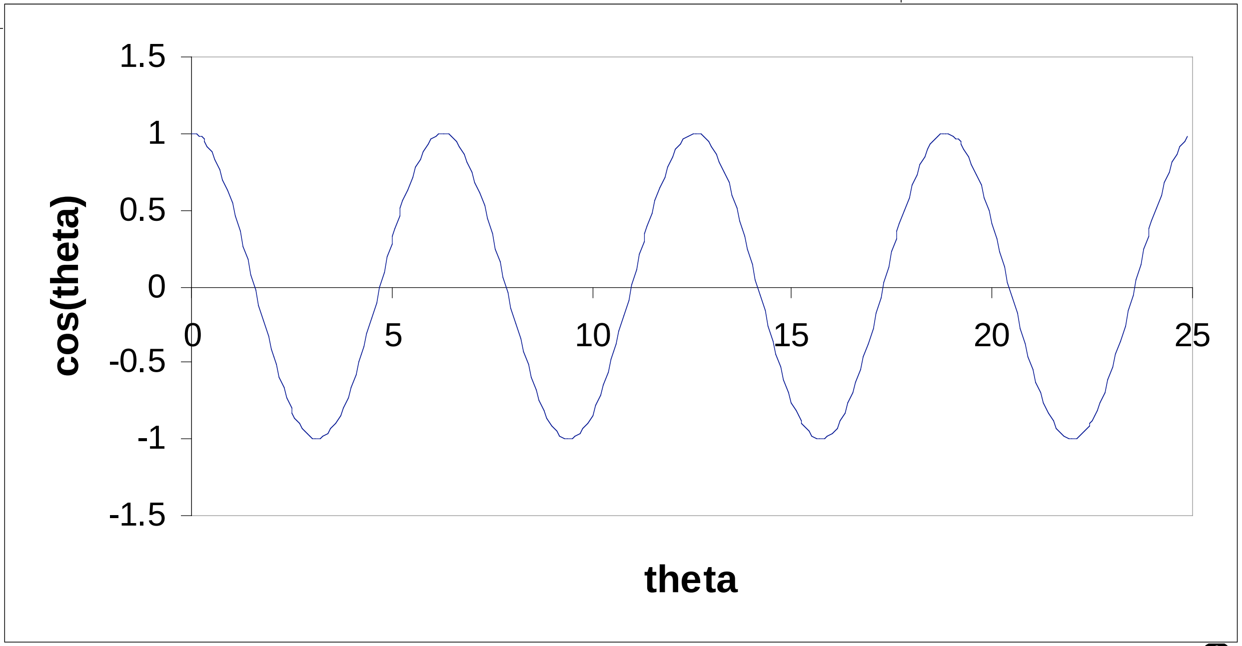
$$\theta = \theta_0 + \omega_0(t - t_0)$$



What happens as t (and θ) gets large (bigger than 2π)?



1.5
1
0.5
0
-0.5
-1
-1.5
sin(theta)
0
5
10
15
20
25
theta



1.5
1
0.5
0
-0.5
-1
-1.5
cos(theta)
0
5
10
15
20
25
theta