PHY 113 A General Physics I
9-9:50 AM MWF Olin 101

Plan for Lecture 10:

Chapter 6 -- Newton's Laws continued

1. **Newton's Laws and centripetal acceleration**

2. **Newton's Laws and resistive forces**

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5	09/07/2012	Motion in 2d	4.1-4.3	4.3,4.50	09/10/2012
6	09/10/2012	Circular motion	4.4-4.6	4.29,4.30	09/12/2012
7	09/12/2012	Newton's laws	5.1-5.6	5.1,5.13	09/14/2012
8	09/14/2012	Newton's laws applied	5.7-5.8	5.20,5.30,5.48	09/17/2012
	09/17/2012	Review	1-5		
	09/19/2012	Exam	1-5		
9	09/21/2012	More applications of Newton's laws	6.1-6.4	6.3,6.14	09/24/2012
10	09/24/2012	Work	7.1-7.4	7.1,7.15	09/26/2012
11	09/26/2012	Kinetic energy	7.5-7.9	7.31,7.41,7.49	09/28/2012
12	09/28/2012	Conservation of energy	8.1-8.5		10/01/2012
13	10/01/2012	Momentum and collisions	9.1-9.4		10/03/2012

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iclicker exercise:
Exam feedback:
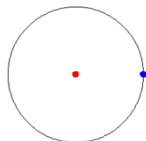   A. **Too hard**
   B. **Too easy**
   C. **Neutral**

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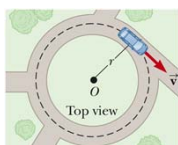
Recall: Uniform circular motion:

animation from
http://mathworld.wolfram.com/UniformCircularMotion.html
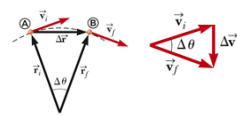
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Uniform circular motion – continued
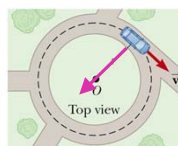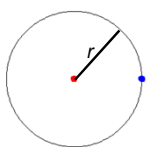
If $v_i = v_f \equiv v$, then the acceleration in the radial direction and the centripetal acceleration is :

$$\mathbf{a}_c = -\frac{v^2}{r}\hat{\mathbf{r}}$$

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Uniform circular motion – continued

$$\mathbf{a}_c = -\frac{v^2}{r}\hat{\mathbf{r}}$$

$$\mathbf{a}_c = -\left(\frac{2\pi}{T}\right)^2 r\hat{\mathbf{r}}$$

$$\mathbf{a}_c = -(2\pi f)^2 r\hat{\mathbf{r}}$$

In terms of time period T for one cycle:

$$v = \frac{2\pi r}{T}$$

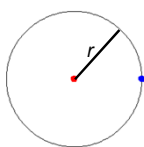**In terms of the frequency f of complete cycles:**

$$f = \frac{1}{T}; \quad v = 2\pi fr$$

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Uniform circular motion and Newton's second law

$$\mathbf{F} = m\mathbf{a}$$

$$\mathbf{a}_c = -\frac{v^2}{r}\hat{\mathbf{r}}$$

iclicker exercise:

For uniform circular motion
  A. Newton's laws are repealed
  B. There is a force pointing radially outward from the circle
  C. There is a force pointing radially inward to the circle
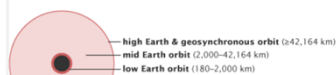
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Example of uniform circular motion:

http://earthobservatory.nasa.gov/Features/OrbitsCatalog/page1.php

There are essentially three types of Earth orbits: high Earth orbit, medium Earth orbit, and low Earth orbit. Many weather and some communications satellites tend to have a high Earth orbit, farthest away from the surface. Satellites that orbit in a medium (mid) Earth orbit include navigation and specialty satellites, designed to monitor a particular region. Most scientific satellites, including NASA's Earth Observing System fleet, have a low Earth orbit.

Flying hundreds of kilometers above the Earth, the International Space Station and other orbiting satellites provide a unique perspective on our planet. (NASA Photograph S126-E-014918.)
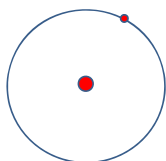
high Earth & geosynchronous orbit (≥42,164 km)
mid Earth orbit (2,000–42,164 km)
Earth
low Earth orbit (180–2,000 km)

lunar orbit (384,000 km)

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Example of uniform circular motion:
Consider the moon in orbit about the Earth

Mass of Moon : $\quad M_M = 7.35 \times 10^{22}\, kg$

Distance from center of Earth : $\quad R_M = 3.84 \times 10^8\, m$

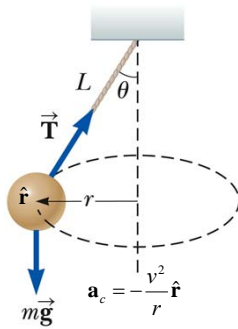Rotational period of Moon : $\quad T = 27.3\ days = 2.36 \times 10^6\, s$

$$\left| a_c \right| = \left(\frac{2\pi}{T}\right)^2 R_M = 2.72 \times 10^{-3}\, m/s^2$$

Newton's Second Law $\Rightarrow F = M_M a_c = 2.0 \times 10^{20}\, N$

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Example of uniform circular motion:

Vertical component of Newton's second law :
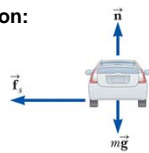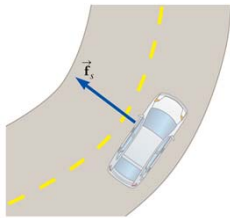$$T\cos\theta - mg = 0$$
Horizontal (radial) component of Newton's second law :
$$T\sin\theta = ma_c = \frac{mv^2}{r} = \frac{mv^2}{L\sin\theta}$$

$$\mathbf{a}_c = -\frac{v^2}{r}\hat{\mathbf{r}}$$

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Example of uniform circular motion:

Horizontal (radial) component of Newton's second law :
$$f = ma_c = \frac{mv^2}{r}$$
Maximum condition :
$$\mu_s n = \mu_s mg \geq \frac{mv^2}{r} \Rightarrow v_{max} = \sqrt{\mu_s gr}$$

Vertical component of Newton's second law :
$$n - mg = 0 \qquad n = mg$$

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Curved road continued:

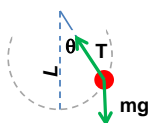$$v_{max} = \sqrt{\mu_s gr}$$

Example : $\mu_s = 0.5$
$r = 35m$
$$v_{max} = \sqrt{\mu_s gr} = \sqrt{0.5\cdot 9.8\cdot 35}m/s$$
$$= 13.1 m/s = 29 mi/hr$$

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Mass on a swing:

iclicker exercise:
**Which of these statements
about the tension T in the rope
is true?**
A. T is the same for all θ.
B. T is smallest for θ=0.
C. T is largest for θ=0.

Newton's laws in the direction along the rope :

$$T - mg\cos\theta = m\frac{v^2}{L}$$
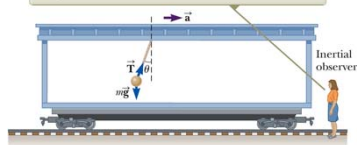
For $\theta = 0$: $\quad T = mg + m\frac{v^2}{L}$

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Newton's law in accelerating train car

Vertical direction : $\quad T\cos\theta - mg = 0$

Horizontal direction : $T\sin\theta = ma$
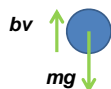
$$\Rightarrow \tan\theta = \frac{a}{g}$$

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Models of air friction forces

For small velocities : $F_{air} = -bv$

For larger velocities : $F_{air} = -Dv^2$

Denoting up direction as + and assuming $v < 0$:

$-bv - mg = ma$

*S*olution to differential equation :

$$-bv - mg = m\frac{dv}{dt}$$

$$v(t) = -\frac{mg}{b}\left(1 - e^{-bt/m}\right)$$

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