# 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**

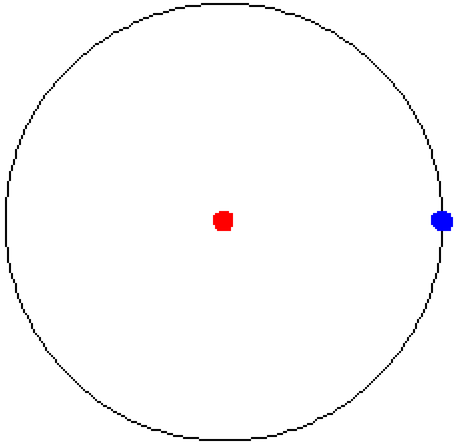
| | | | | | |
|---|---|---|---|---|---|
| **5** | 09/07/2012 | Motion in 2d | 4.1-4.3 | 4.3,4.50 | 09/10/2012 |
| **6** | 09/10/2012 | Circular motion | 4.4-4.6 | 4.29,4.30 | 09/12/2012 |
| **7** | 09/12/2012 | Newton's laws | 5.1-5.6 | 5.1,5.13 | 09/14/2012 |
| **8** | 09/14/2012 | Newton's laws applied | 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 |

***iclicker exercise:***

**Exam feedback:**

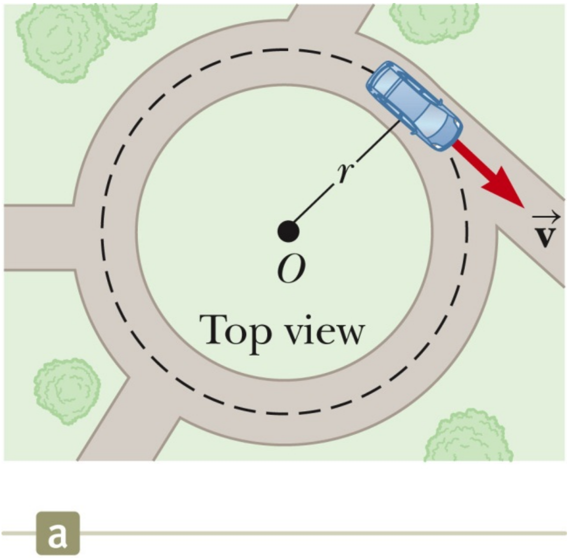
A. **Too hard**
B. **Too easy**
C. **Neutral**

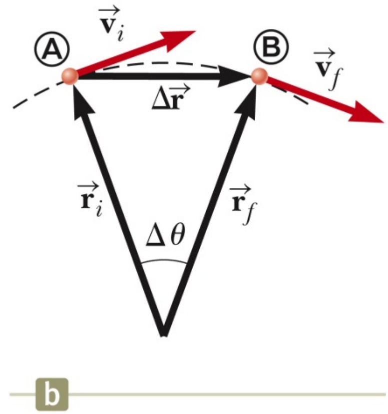
# Recall: Uniform circular motion:

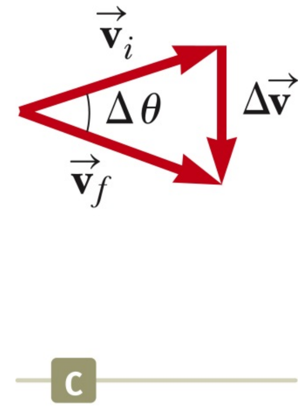


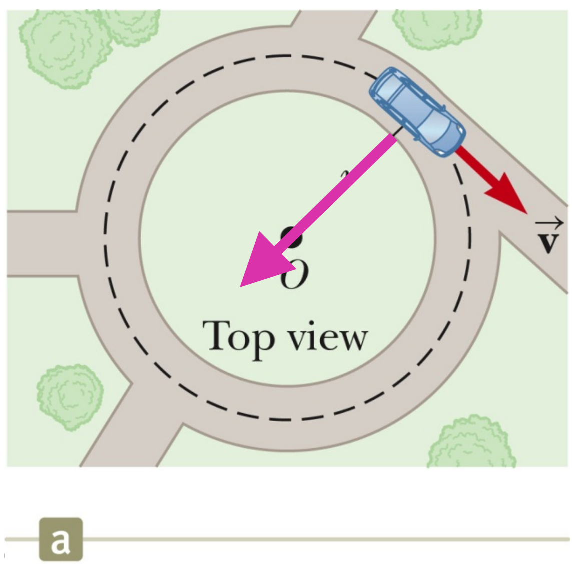
animation from
http://mathworld.wolfram.com/UniformCircularMotion.html

# Uniform circular motion – continued



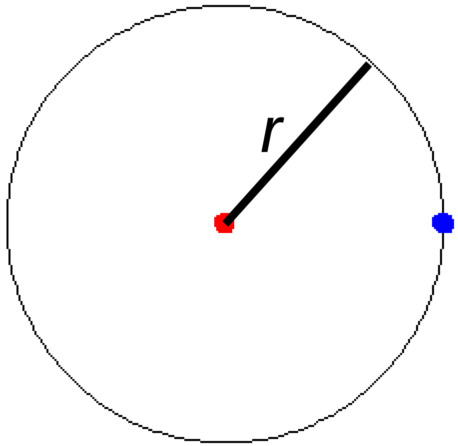




If $v_i = v_f \equiv v$, then the acceleration in the radial direction and the centripetal acceleration is :

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

# Uniform circular motion – continued




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

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

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

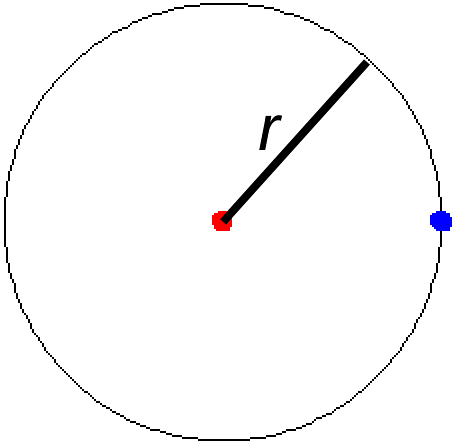
**In terms of time period *T* for one cycle:**

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

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

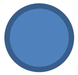
$$f = \frac{1}{T}; \qquad v = 2\pi f r$$

# 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**

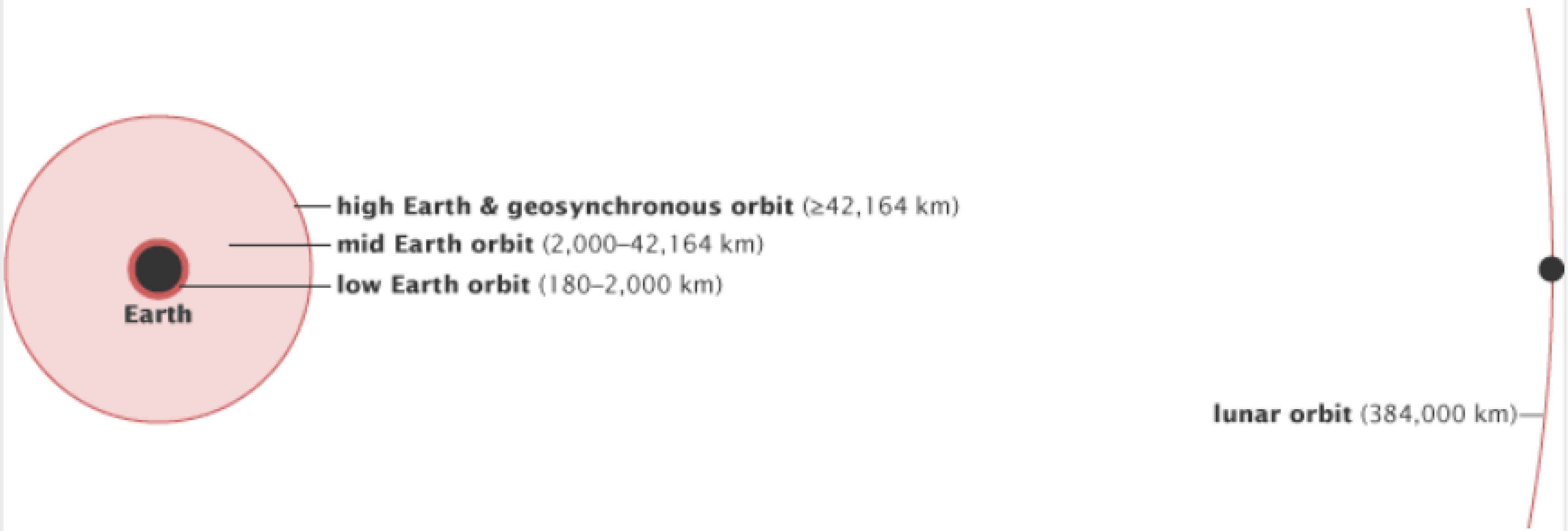
A. Newton's laws are repealed
B. There is a force pointing radially outward from the circle
C. There is a force pointing radially inward to the circle

# Example of uniform circular motion:

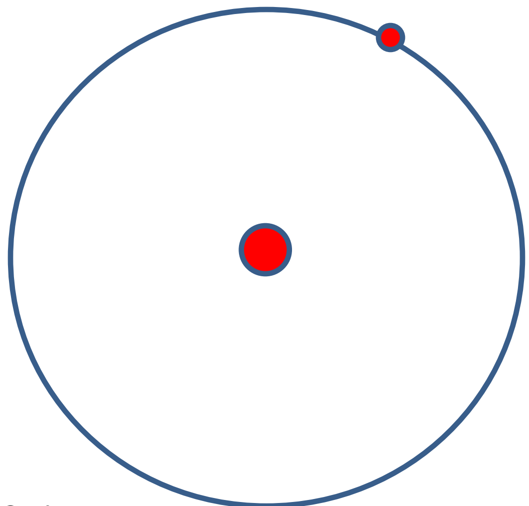
**http://earthobservatory.nasa.gov/Features/OrbitsCatalog/page1.php**

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.)



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



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

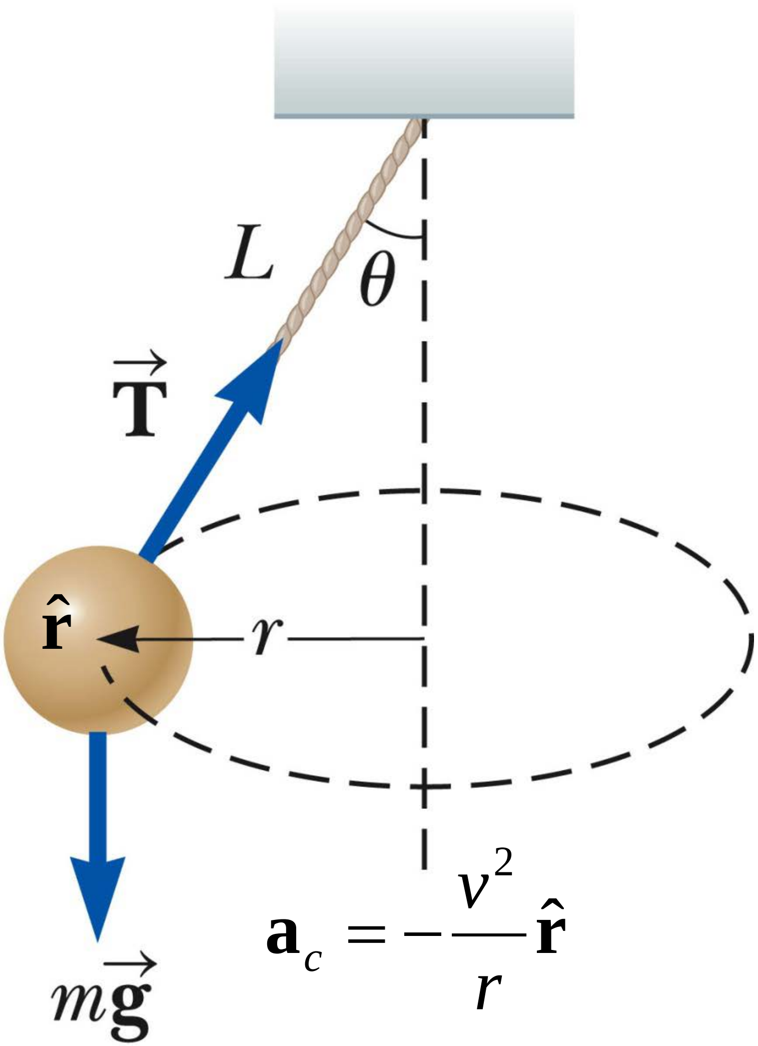
Distance from center of Earth: $R_M = 3.84 \times 10^{8}\, m$

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

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

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

# Example of uniform circular motion:




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

Vertical component of

Newton's second law :

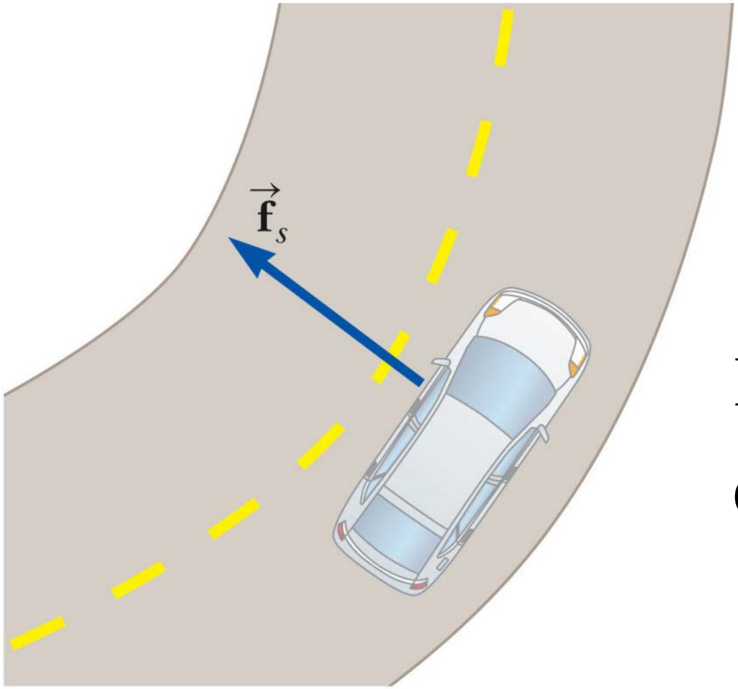
$$T\cos\theta - mg = 0$$

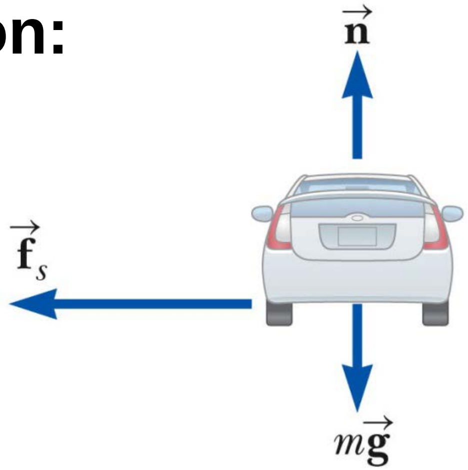
Horizontal (radial) component

of Newton's second law :

$$T\sin\theta = ma_c = \frac{mv^2}{r} = \frac{mv^2}{L\sin\theta}$$

# Example of uniform circular motion:




Horizontal (radial) component of Newton's second law:

$$f = ma_c = \frac{mv^2}{r}$$

Maximum condition:

$$\mu_s n = \mu_s mg \geq \frac{mv^2}{r} \quad \Rightarrow v_{\max} = \sqrt{\mu_s gr}$$

Vertical component of Newton's second law:

$$n - mg = 0 \qquad n = mg$$

## Curved road continued:

$$v_{\max} = \sqrt{\mu_s g r}$$

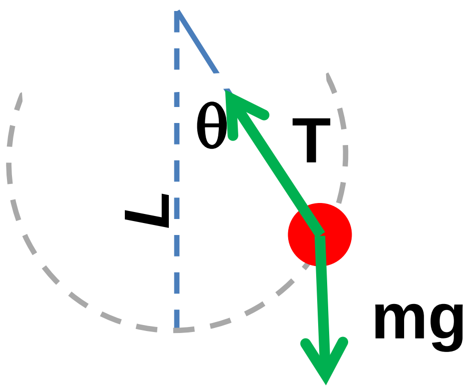
$$\text{Example:} \quad \mu_s = 0.5$$

$$r = 35m$$

$$v_{\max} = \sqrt{\mu_s g r} = \sqrt{0.5 \cdot 9.8 \cdot 35} m/s$$

$$= 13.1 m/s = 29 mi/hr$$

## Mass on a swing:




*iclicker exercise:*

**Which of these statements about the tension T in the rope is true?**

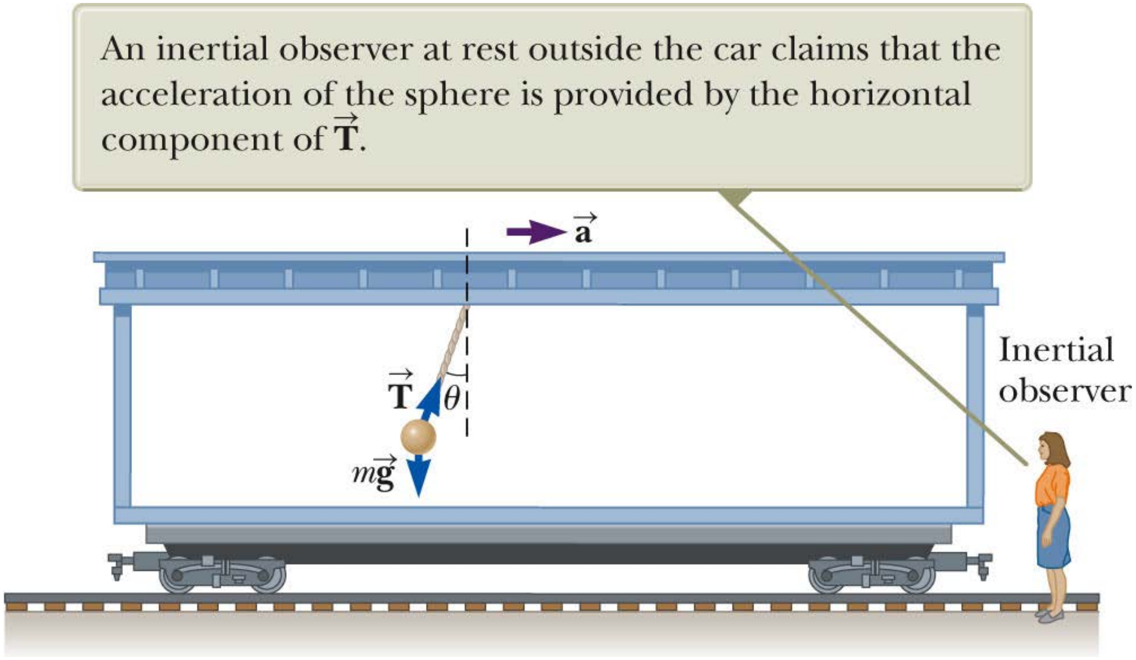
**A. T is the same for all θ.**
**B. T is smallest for θ=0.**
**C. T is largest for θ=0.**

Newton's laws in the direction along the rope:

$$T - mg\cos\theta = m\frac{v^2}{L}$$

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

# Newton's law in accelerating train car

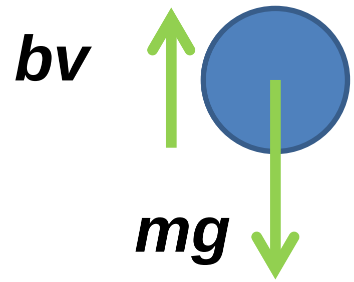



$$\text{Vertical direction}: \quad T\cos\theta - mg = 0$$

$$\text{Horizontal direction}: \; T\sin\theta = ma$$

$$\Rightarrow \tan\theta = \frac{a}{g}$$

## Models of air friction forces




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

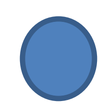
$$\text{For larger velocities: } F_{air} = -Dv^2$$

$$\text{Denoting up direction as + and assuming } v < 0:$$

$$-bv - mg = ma$$

$$\text{Solution to differential equation:}$$

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



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