PHYS 1441 – Section 002
Lecture #11

Wednesday, Oct. 7, 2009
Dr. Jaehoon Yu

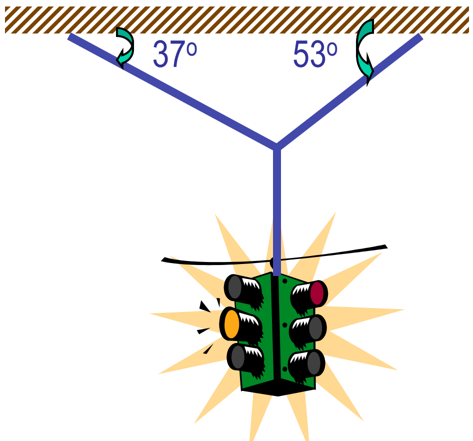
- Example for applications of Newton's Laws
- Force of Friction
  - Example for Motion without friction
  - Example for Motion with friction
- Uniform Circular Motion
- Banked highway

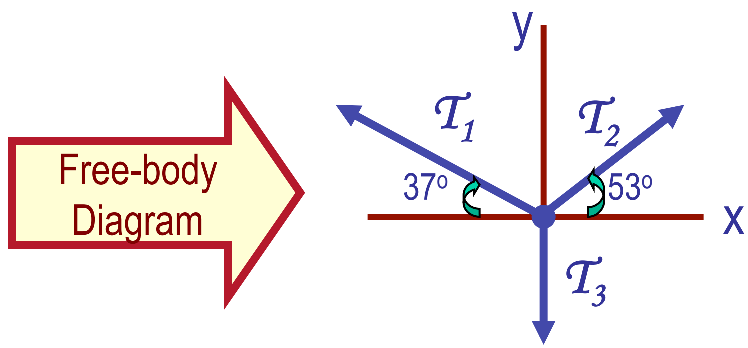
Announcements

- Quiz results
  - Class average: 14.4/30
    - Equivalent to: 48/100
    - Last quiz: 63/100
  - Top score: 29/30
- Just to make sure you all know this on 2nd term exam
  - Non-comprehensive exam
  - Wednesday, Nov. 4
  - Mark your calendars!!

Example of Using Newton's Laws

A traffic light weighing 125 N hangs from the cable tied to two other cables fastened to a support. The upper cables make angles of 37.0° and 53.0° with the horizontal plane. Find the magnitudes of the tensions in the three cables.





$$\vec{F} = \vec{T}_1 + \vec{T}_2 + \vec{T}_3 = m\vec{a} = 0$$ Newton's 2nd law

x-comp. of net force

$$F_x = \sum_{i=1}^{i=3} T_{ix} = 0 \quad -T_1\cos(37^\circ) + T_2\cos(53^\circ) = 0 \quad \therefore T_1 = \frac{\cos(53^\circ)}{\cos(37^\circ)}T_2 = 0.754T_2$$

y-comp. of net force

$$F_y = \sum_{i=1}^{i=3} T_{iy} = 0$$

$$T_1\sin(37^\circ) + T_2\sin(53^\circ) - mg = 0$$

$$T_2\left[\sin(53^\circ) + 0.754\times\sin(37^\circ)\right] = 1.25T_2 = 125N$$

$$T_2 = 100N; \quad T_1 = 0.754T_2 = 75.4N$$

Magnitude of the Static Friction

The magnitude of the static friction force can have any value from zero up to the maximum value.

$$f_s \leq f_s^{MAX}$$

$$f_s^{MAX} = \mu_s F_N$$

$0 < \mu_s < 1$ is called the **coefficient of static friction**.

What is the unit? None

Once the object starts moving, there is **NO MORE** static friction!!

Kinetic friction applies during the move!!

Kinetic Friction

Static friction opposes the *impending* relative motion between two objects.

Kinetic friction opposes the relative sliding motions that is happening. ***The resistive force exerted on the object during its movement.*** ***Normally much smaller than static friction!!***

$$f_k = \mu_k F_N$$

$0 < \mu_k < 1$ is called the **coefficient of kinetic friction**.

What is the direction of friction forces? **opposite to the movement**

Coefficient of Friction

Table 4.2 **Approximate Values of the Coefficients of Friction for Various Surfaces***

Materials	Coefficient of Static Friction, μ_s	Coefficient of Kinetic Friction, μ_k
Glass on glass (dry)	0.94	0.4
Ice on ice (clean, 0 °C)	0.1	0.02
Rubber on dry concrete	1.0	0.8
Rubber on wet concrete	0.7	0.5
Steel on ice	0.1	0.05
Steel on steel (dry hard steel)	0.78	0.42
Teflon on Teflon	0.04	0.04
Wood on wood	0.35	0.3

*The last column gives the coefficients of kinetic friction, a concept that will be discussed shortly.

What are these?

Forces of Friction Summary

Resistive force exerted on a moving object due to viscosity or other types frictional property of the medium in or surface on which the object moves.

These forces are either proportional to the velocity or the normal force.

Force of static friction, f_s: *The resistive force exerted on the object until just before the beginning of its movement*

Empirical Formula

$$\left|\vec{f}_s\right| \le \mu_s \left|\vec{F}_N\right|$$

What does this formula tell you?

Frictional force increases till it reaches the limit!!

Beyond the limit, the object moves, and there is **NO MORE** static friction but kinetic friction takes it over.

Force of kinetic friction, f_k: *The resistive force exerted on the object during its movement*

$$\left|\vec{f}_k\right| = \mu_k \left|\vec{F}_N\right|$$

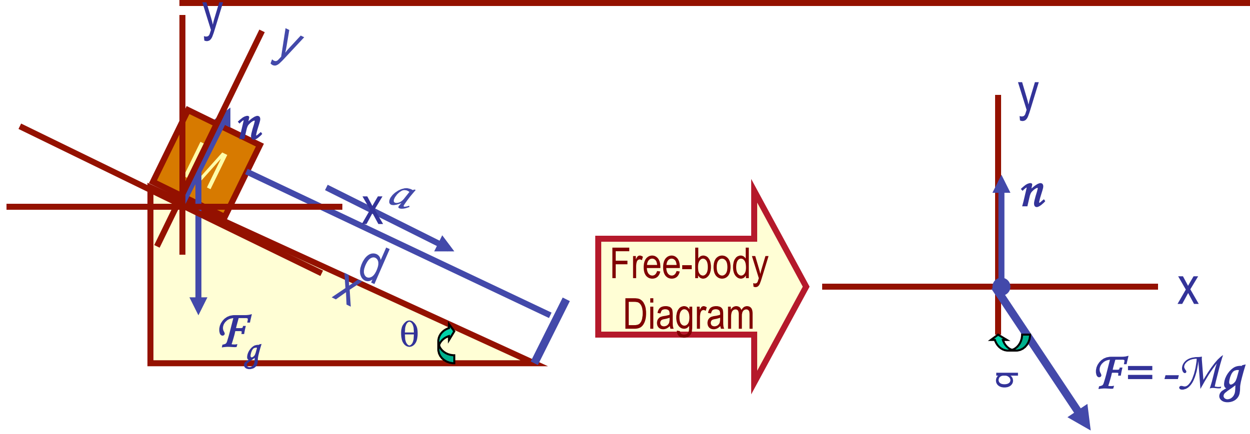
Which direction does kinetic friction apply?

Opposite to the motion!

Example w/o Friction

A crate of mass M is placed on a frictionless inclined plane of angle θ.

a) Determine the acceleration of the crate after it is released.



$$\vec{F} = \vec{F}_g + \vec{n} = m\vec{a}$$

$$F_x = Ma_x = F_{gx} = Mg\sin\theta$$

$$a_x = g\sin\theta$$

$$F_y = Ma_y = n - F_{gy} = n - mg\cos\theta = 0$$

Supposed the crate was released at the top of the incline, and the length of the incline is d. How long does it take for the crate to reach the bottom and what is its speed at the bottom?

$$d = v_{ix}t + \frac{1}{2}a_x t^2 = \frac{1}{2} g\sin\theta\, t^2$$

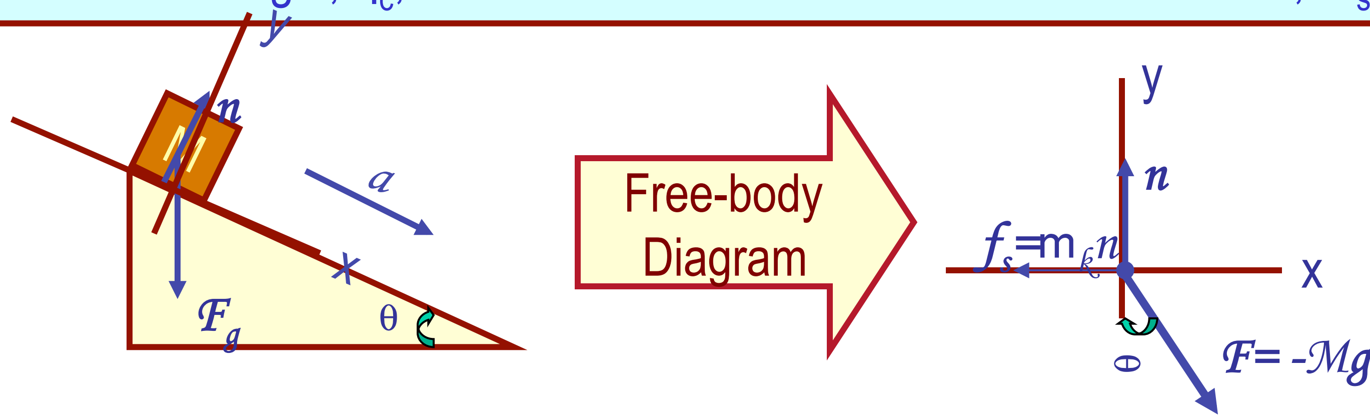
$$\therefore t = \sqrt{\frac{2d}{g\sin\theta}}$$

$$v_{xf} = v_{ix} + a_x t = g\sin\theta\sqrt{\frac{2d}{g\sin\theta}} = \sqrt{2dg\sin\theta}$$

$$\therefore v_{xf} = \sqrt{2dg\sin\theta}$$

Example w/ Friction

Suppose a block is placed on a rough surface inclined relative to the horizontal. The inclination angle is increased till the block starts to move. Show that by measuring this critical angle, q_c, one can determine coefficient of static friction, m_s.



Net force

$$\vec{F} = M\vec{a} = \vec{F}_g + \vec{n} + \vec{f}_s$$

x comp.

$$F_x = F_{gx} - f_s = Mg\sin\theta - f_s = 0 \qquad f_s = \mu_s n = Mg\sin\theta_c$$

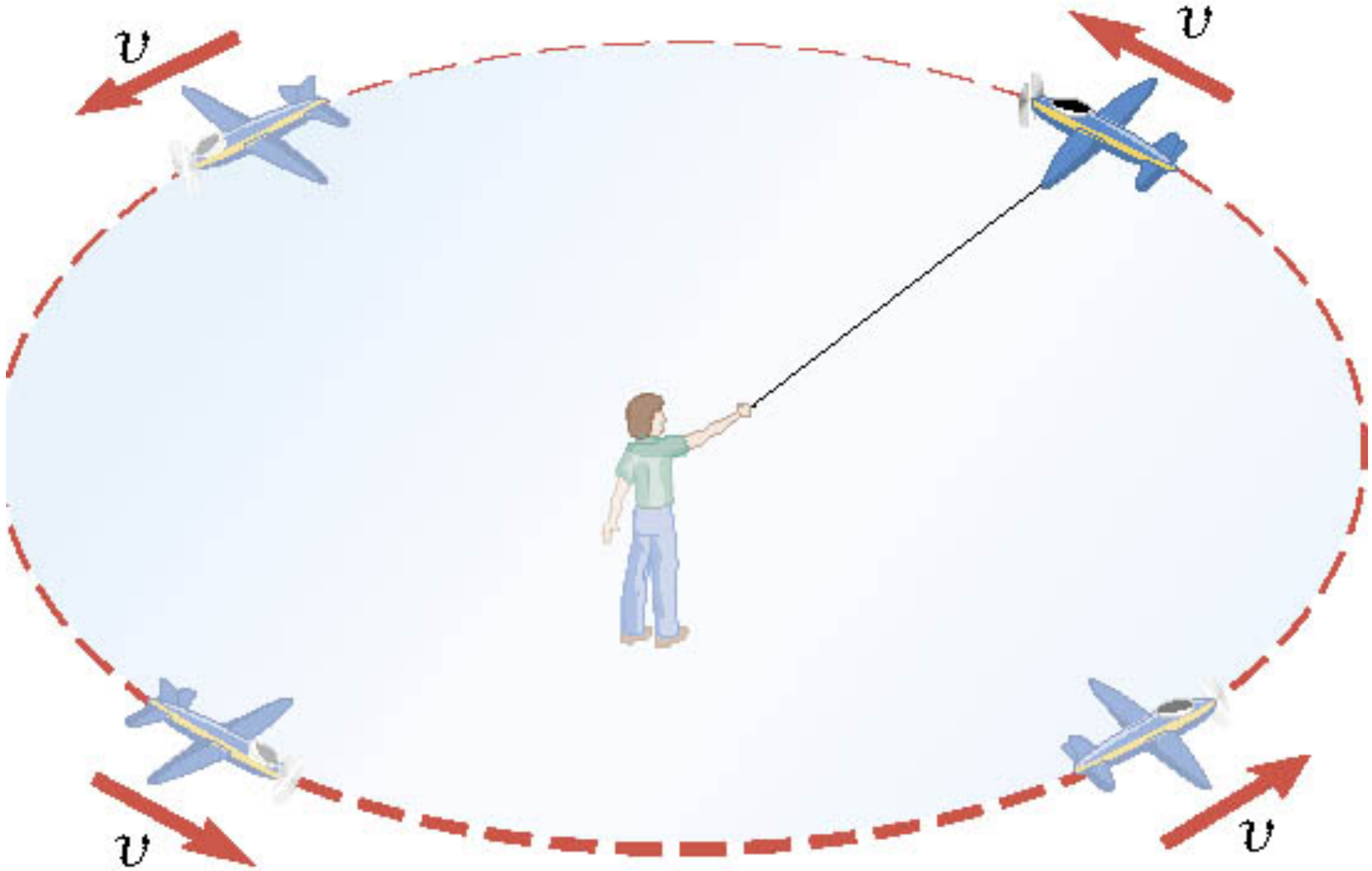
y comp.

$$F_y = Ma_y = n - F_{gy} = n - Mg\cos\theta_c = 0 \qquad n = F_{gy} = Mg\cos\theta_c$$

$$\mu_s = \frac{Mg\sin\theta_c}{n} = \frac{Mg\sin\theta_c}{Mg\cos\theta_c} = \tan\theta_c$$

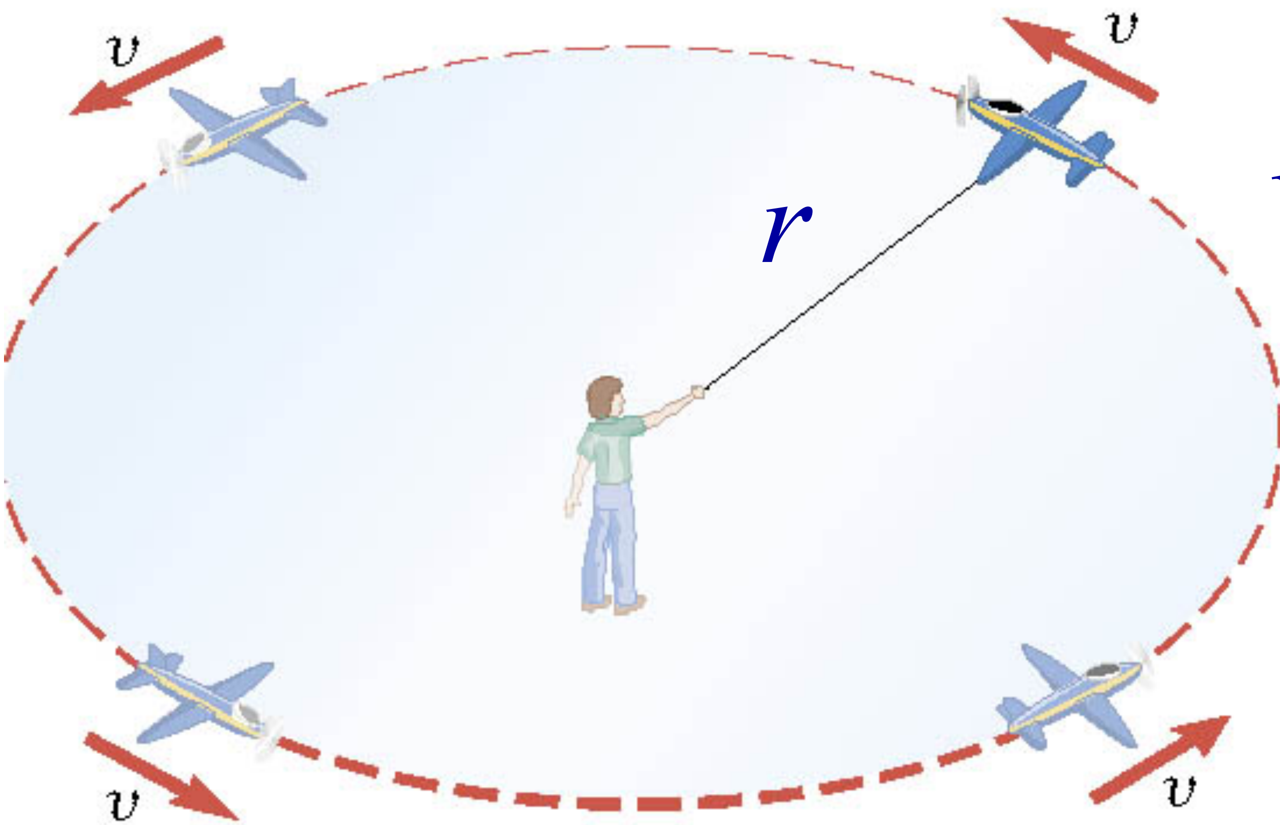
Definition of the Uniform Circular Motion

Uniform circular motion is the motion of an object traveling at a constant speed on a circular path.



Speed of a uniform circular motion?

Let *T* be the period of this motion, the time it takes for the object to travel once around the complete circle whose radius is r.



$$v = \frac{\text{distance}}{\text{time}}$$

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

Ex. : A Tire-Balancing Machine

The wheel of a car has a radius of 0.29m and is being rotated at 830 revolutions per minute on a tire-balancing machine. Determine the speed at which the outer edge of the wheel is moving.

$$\frac{1}{830\,\text{revolutions/min}} = 1.2\times10^{-3}\ \text{min/revolution}$$

$$T = 1.2\times10^{-3}\ \text{min} = 0.072\ \text{s}$$

$$v = \frac{2\pi r}{T} = \frac{2\pi(0.29\ \text{m})}{0.072\ \text{s}} = 25\,\text{m/s}$$