PHYS 1441 – Section 002
Lecture #11

Monday, Feb. 25, 2013

Dr. Jaehoon Yu

- Application of Newton's Laws
  - Motion without friction
- Force of Friction
  - Motion with friction
- Centripetal Acceleration
- Uniform Circular Motion

Announcements

- Quiz #3 this Wednesday, Feb. 27
  - At the beginning of the class
  - Covers CH4.1 through what we learn today
- Please make sure that you pay for Quest homework access today!!
  - The deadline is today!!
  - You will lose all access to your homework site and grades if you do not pay by Feb. 25
  - No extension will be granted for a lost access!

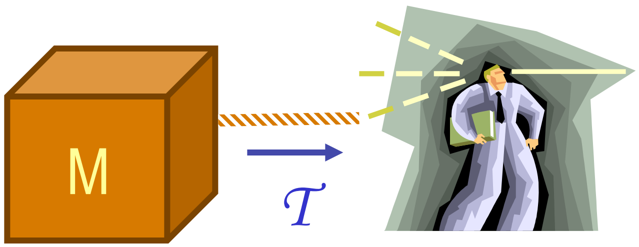
Special Project #3 for Extra Credit

A large man and a small boy stand facing each other on **frictionless ice**. They put their hands together and push against each other so that they move apart. a) Who moves away with the higher speed, by how much and why? b) Who moves farther in the same elapsed time, by how much and why?

- Derive the formulae for the two problems above in much more detail and explain your logic in a greater detail than what is in pages 7 and 8 of this lecture note.
- Be sure to clearly define each variable used in your derivation.
- Each problem is 10 points.
- Due is this Wednesday, Feb. 27

Applications of Newton's Laws

Suppose you are pulling a box on frictionless ice, using a rope.



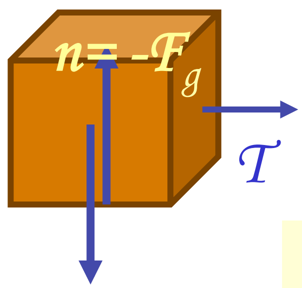
What are the forces being exerted on the box?

Gravitational force: $\boldsymbol{F}_g$

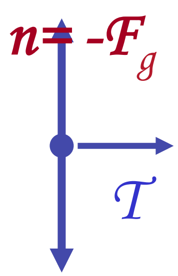
Normal force: $\boldsymbol{n}$

Tension force: $\boldsymbol{T}$

Free-body diagram



$\boldsymbol{F}_g = -M\boldsymbol{g}$



$\boldsymbol{F}_g = -M\boldsymbol{g}$

Total vector force:
$\boldsymbol{F}=\boldsymbol{F}_g+\boldsymbol{n}+\boldsymbol{T}=\boldsymbol{T}$

$$\sum F_x = T = Ma_x \qquad \boxed{a_x = \frac{T}{M}}$$

$$\sum F_y = -F_g + n = Ma_y = 0 \qquad \boxed{a_y = 0}$$

If T is a constant force, a_x, is constant

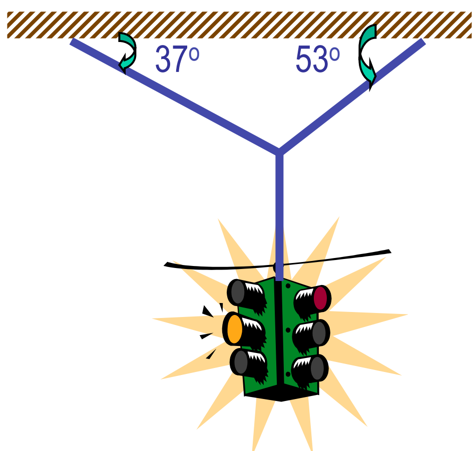
$$v_{xf} = v_{xi} + a_x t = v_{xi} + \left(\frac{T}{M}\right)t$$

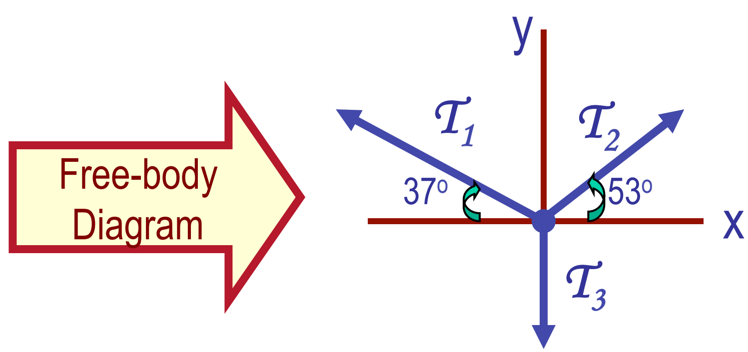
$$\Delta x = x_f - x_i = v_{xi}t + \frac{1}{2}\left(\frac{T}{M}\right)t^2$$

What happened to the motion in y-direction?

Example for Using Newton's Laws

A traffic light weighing 125 N hangs from a cable tied to two other cables fastened to a support. The upper cables make angles of 37.0º and 53.0º with the horizontal. Find the tension 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

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

y-comp. of net force

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

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

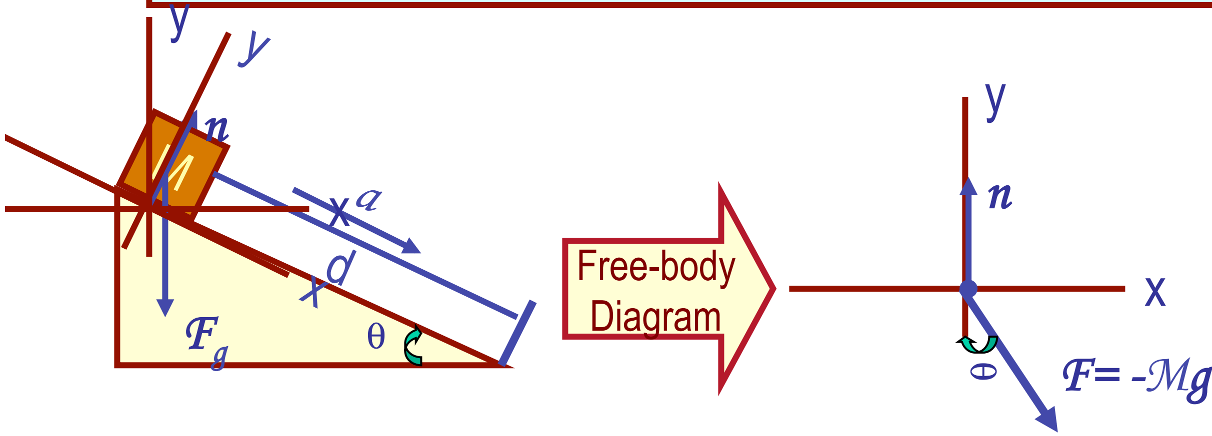
$$T_2\left[\sin\left(53^\circ\right) + 0.754\times\sin\left(37^\circ\right)\right] = 1.25T_2 = 125N$$

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

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.



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

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

$$\boxed{a_x = g\sin\theta}$$

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

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?

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

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

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

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

Force of Friction

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

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*

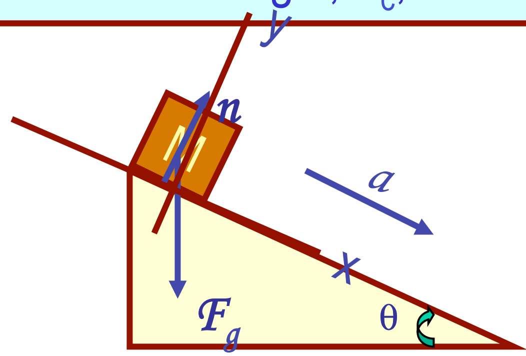
$$\left|\vec{f}_k\right| = \mu_k \left|\vec{n}\right|$$

Which direction does kinetic friction apply?

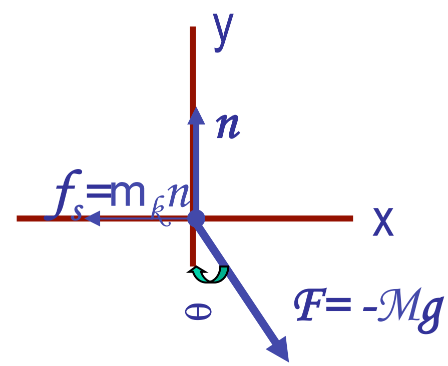
Opposite to the motion!

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, θ_c, one can determine coefficient of static friction, m_s.



Free-body Diagram



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

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