PHYS 1441 – Section 002
Lecture #10

Monday, Oct. 11, 2010

Dr. Jaehoon Yu

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

Today's homework is homework #6, due 10pm, Tuesday, Oct. 19!!

Announcements

- Quiz #2 Results
  - Class average: 17/30
    - Equivalent to: 57/100
  - Top score: 30/30
- Evaluation policy
  - Homework: 30%
  - Comprehensive final exam: 25%
  - One better of the two non-comprehensive term exam: 20%
  - Lab: 15%
  - Quiz:10%
  - Extra credit: 10%
- Colloquium this week

Physics Department
The University of Texas at Arlington
COLLOQUIUM

Modeling and Simulations of Materials

Dr. Qiming Zhang

Department of Physics
The University of Texas at Arlington
4:00 pm Wednesday October13, 2010 room 101 SH

Abstract:

First-principles computational studies are widely used in modeling and simulations of the electronic and magnetic properties of materials. In this talk, I will briefly review the theoretical methodology and present several applications conducted recently in our group. They include searching for low-cost solar-cell materials, studying on the exchanged-coupled nanocomposite permanent magnet materials, and fundamental study on carbon adsorption on transition metal surfaces.

Refreshments will be served in the Physics Lounge at 3:30 p.m.

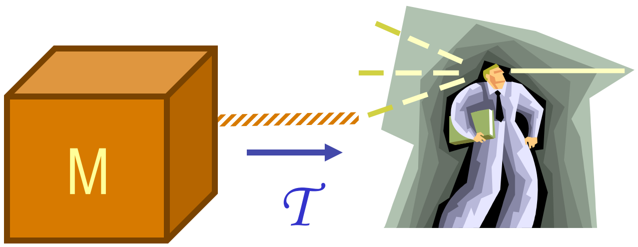
Reminder: Special Project for Extra Credit

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 and by how much? b) Who moves farther in the same elapsed time?

- Derive fomulae for the two problems above in much more detail than what is shown in this lecture note.
- Be sure to clearly define each variables used in your derivation.
- Each problem is 10 points each.
- Due is this Wednesday, Oct. 13.

Applications of Newton's Laws

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



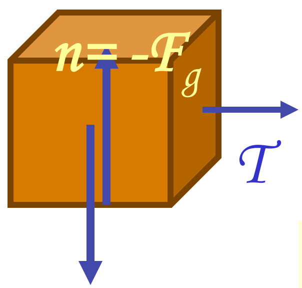
What are the forces being exerted on the box?

Gravitational force: $\boldsymbol{F_g}$

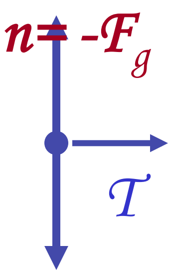
Normal force: $\boldsymbol{n}$

Tension force: $\boldsymbol{T}$

Free-body diagram



$F_g = Mg$



$F_g = Mg$

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

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

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

If T *is a constant force,* a_x*, is constant*

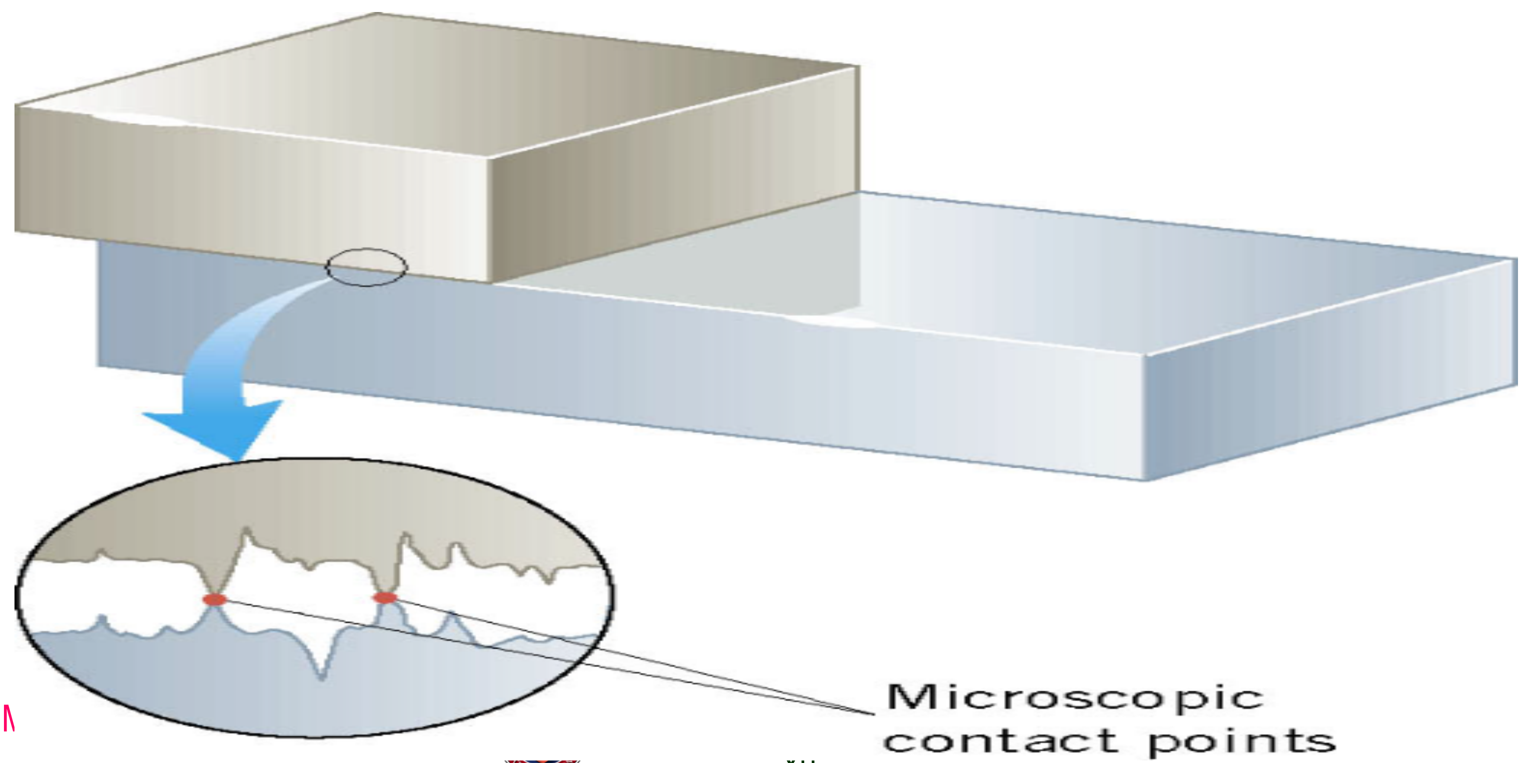
$$v_{xf} = v_{xi} + a_x t = v_{xi} + \left(\frac{T}{M}\right)t$$

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

What happened to the motion in y-direction?

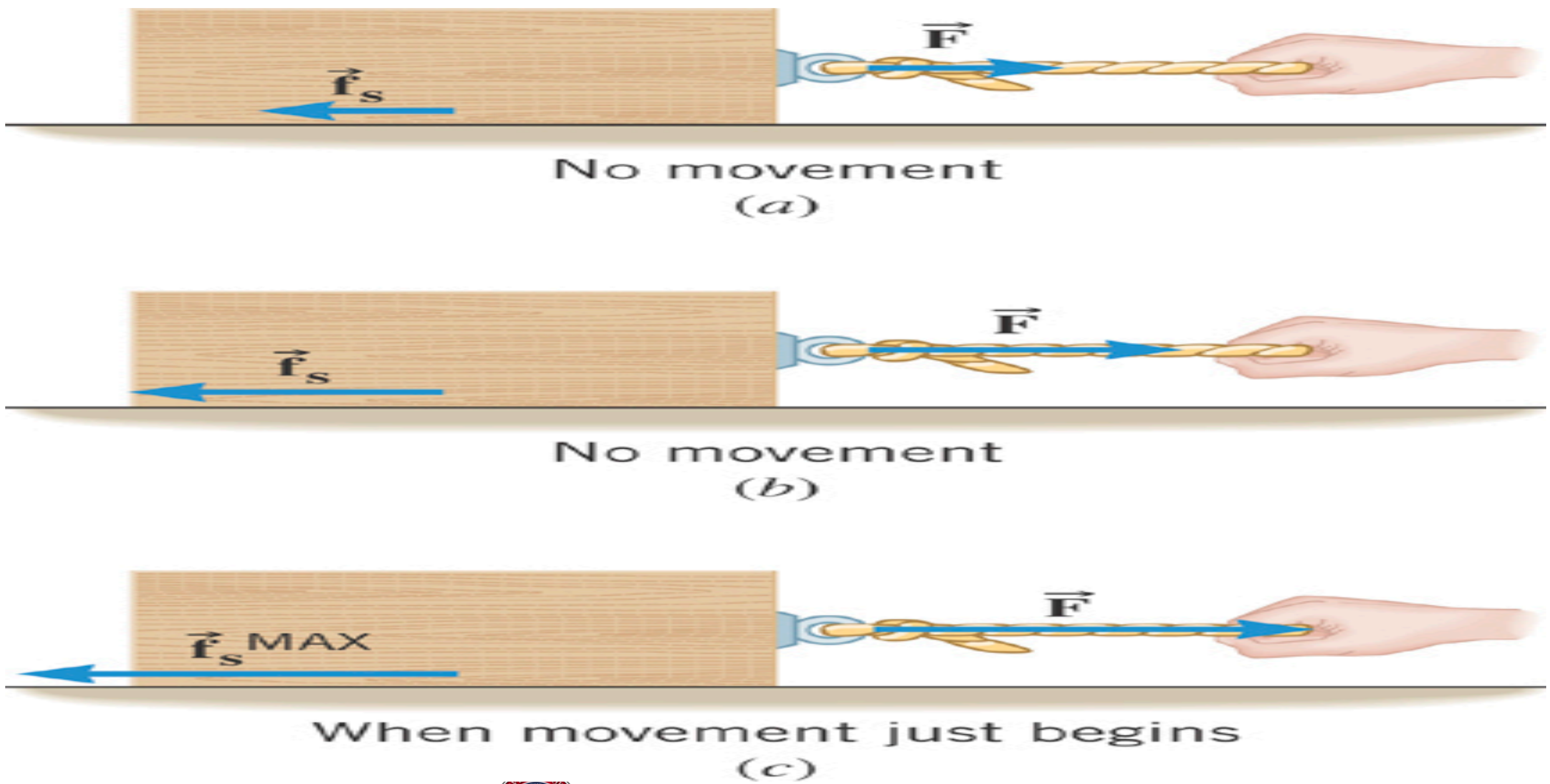
Friction Force

When an object is in contact with a surface there is a force acting on that object. The component of this force that is parallel to the surface is called the ***friction force***. *This resistive force is exerted on a moving object due to viscosity or other types of frictional property of the medium in or surface on which the object moves.* *Always opposite to the movement!!*



Static Friction

When the two surfaces are not sliding across one another the friction is called ***static friction***. *The resistive force exerted on the object up to the time just before the object starts moving.*



Magnitude of the Static Friction

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

$$f_s \le f_s^{MAX}$$

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

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

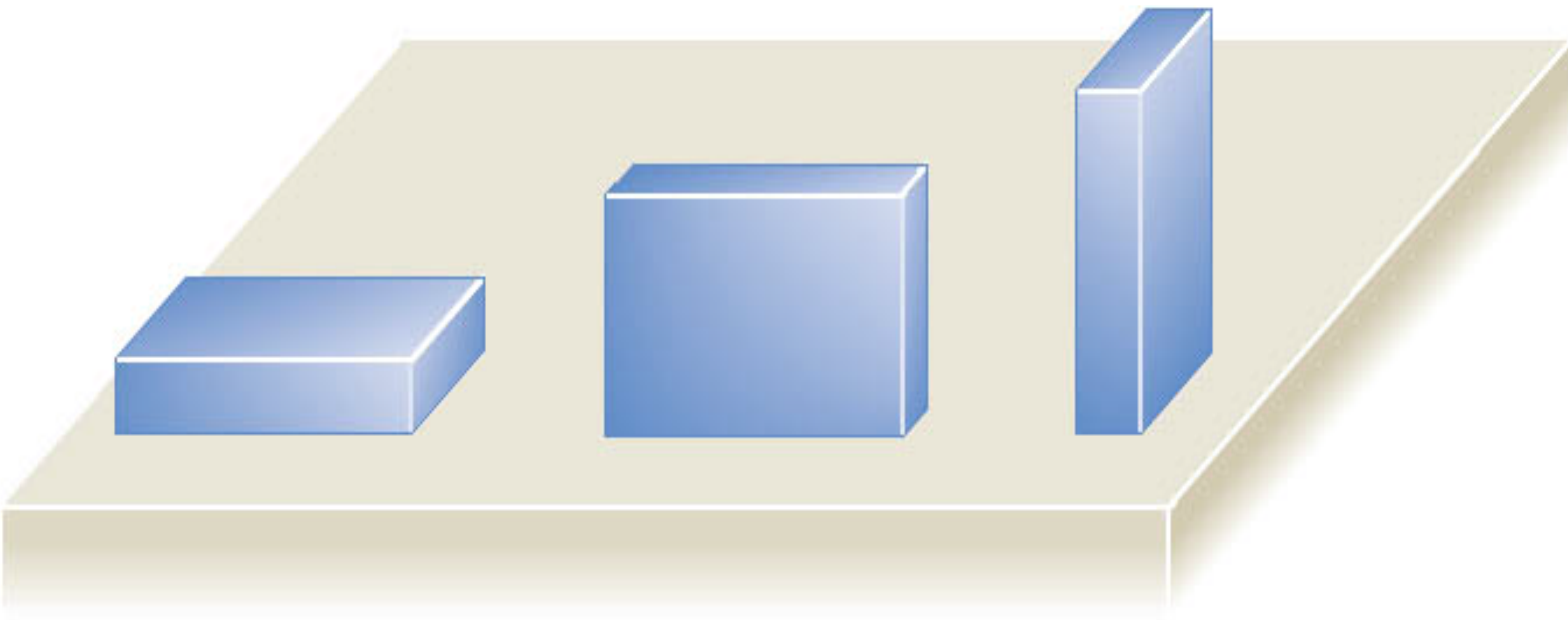
What is the unit? None

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

Kinetic friction applies during the move!!

Note that the magnitude of the frictional force **does not depend on the contact area of the surfaces**.

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



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

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

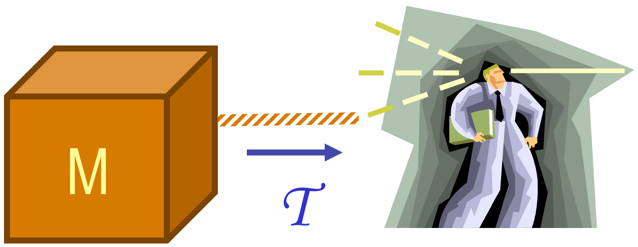
The resistive force exerted on the object during its movement

Which direction does kinetic friction apply?

Opposite to the motion!

Look at this problem again…

Suppose you are pulling a box on a rough surfice, using a rope.



What are the forces being exerted on the box?

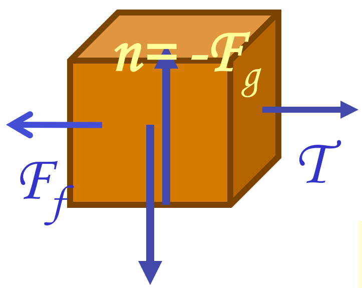
Gravitational force: $\mathbf{F_g}$

Normal force: $\mathbf{n}$

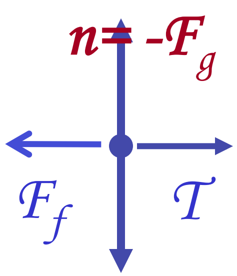
Tension force: $\mathbf{T}$

Friction force: $\mathbf{F_f}$

Free-body diagram



$F_g = Mg$



$F_g = Mg$

Total force:
$\mathbf{F = F_g + n + T + F_f}$

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

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

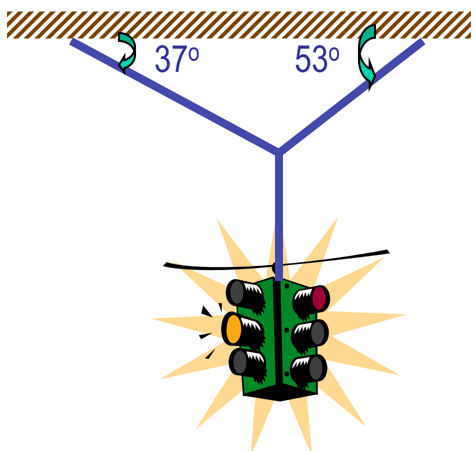
If T is a constant force, a_x, is constant

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

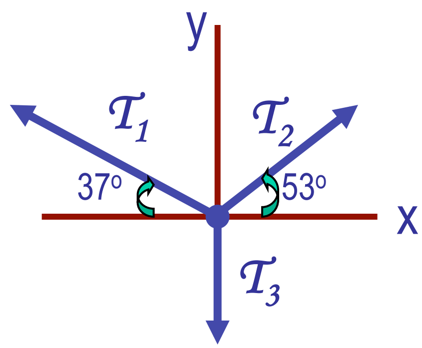
$$\Delta x = x_f - x_i = v_{xi}t + \frac{1}{2}\left(\frac{T - F_f}{M}\right)t^2$$

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 37.0º and 53.0º with the horizontal plane. Find the magnitudes of the tensions in the three cables.



Free-body Diagram



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

x-comp. of net force

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

y-comp. of net force

$$F_y = \sum_{i=1}^{i=3} T_{iy} = 0 \quad T_1 \sin\left(37^\circ\right) + T_2 \sin\left(53^\circ\right) - mg = 0$$

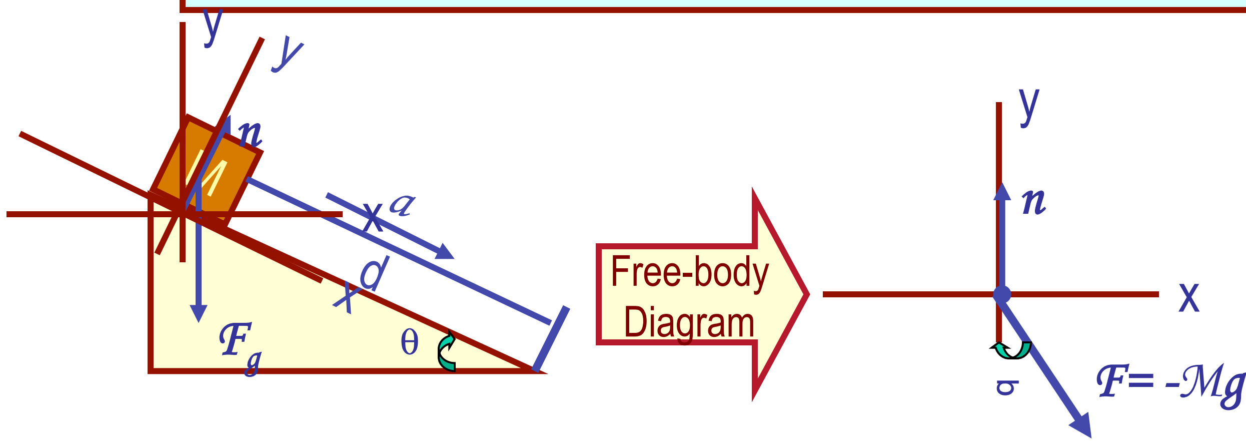
$$T_2\left[\sin\left(53^\circ\right) + 0.754 \times \sin\left(37^\circ\right)\right] = 1.25 T_2 = 125N$$

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

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.



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

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

$$a_x = g\sin\theta$$

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

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?

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

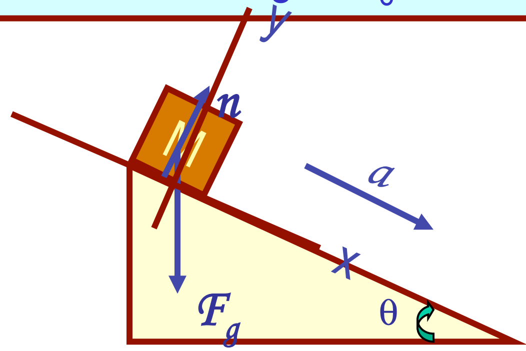
$$\therefore t = \sqrt{\frac{2d}{g\sin\theta}}$$

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

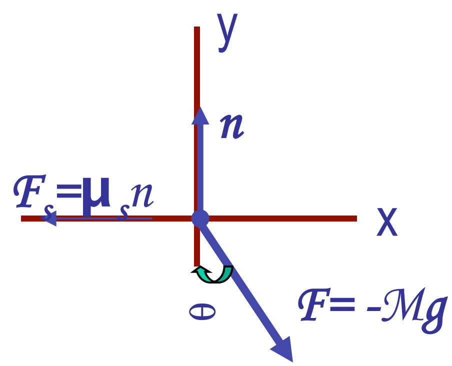
$$\therefore v_{xf} = \sqrt{2dg\sin\theta}$$

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, μ_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.

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

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