PHYS 1443 – Section 002
Lecture #9

Monday, Oct. 1, 2007
Dr. Jaehoon Yu

- Free Body Diagram
- Application of Newton's Laws
  – Motion without friction
- Forces of Friction
  – Motion with friction
- Uniform and Non-uniform Circular Motions

Today's homework is homework #6, due 7pm, Monday, Oct. 8!!

Announcements

- Quiz results
  - Average: 2.9/6
    - Equivalent to 48/100
  - Top score: 6
- Term exam being graded. Will give this back to you Wednesday.
- E-mail distribution list: 71 of you subscribed to the list so far

Some Basic Information

When Newton's laws are applied, *external forces* are only of interest!!

Why?

Because, as described in Newton's first law, an object will keep its current motion unless non-zero net external force is applied.

Normal Force, ***n***:

Reaction force to the net force on a surface due to the surface structure of an object. Its direction is always perpendicular to the surface.

Tension, ***T***:

The reactionary force by a stringy object against an external force exerted on it.

Free-body diagram

A graphical tool which is a ***diagram of external forces on an object*** *and is extremely useful analyzing forces and motion!! Drawn only on an object.*

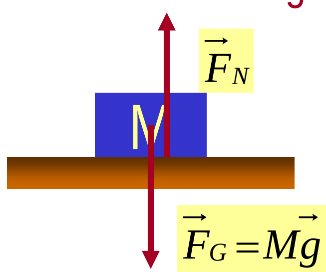
Free Body Diagrams and Solving Problems

- Free-body diagram: A diagram of vector forces acting on an object

⇒ A great tool in solving a problem using forces or using dynamics

1. Select a point on an object in the problem
2. Identify all the forces acting only on the selected object
3. Define a reference frame with positive and negative axes specified
4. Draw arrows to represent the force vectors on the selected point
5. Write down net force vector equations
6. Write down the forces in components to solve the problems

⇒ No matter which one we choose to draw the diagram on, the results should be the same, as long as they are from the same motion

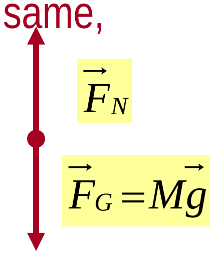


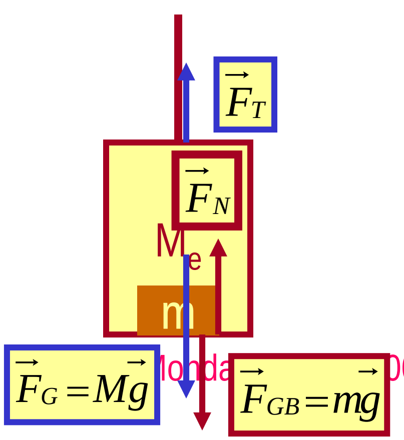
Which one would you like to select to draw FBD?

What do you think are the forces acting on this object?

Gravitational force

A force supporting the object exerted by the floor



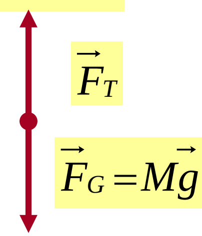


Which one would you like to select to draw FBD?

What do you think are the forces acting on this elevator?

Gravitational force

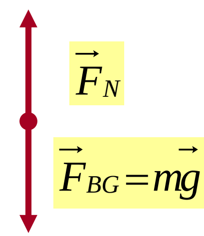
The force pulling the elevator (Tension)



What about for the box in the elevator?

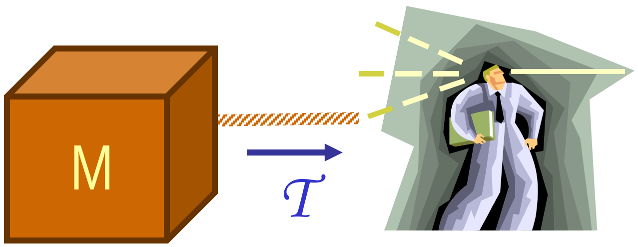
Gravitational force

Normal force



Applications of Newton's Laws

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



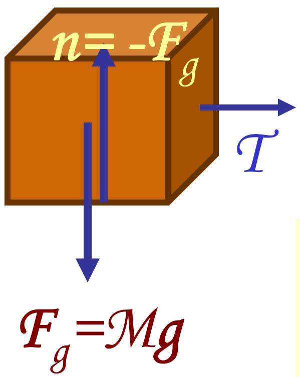
What are the forces being exerted on the box?

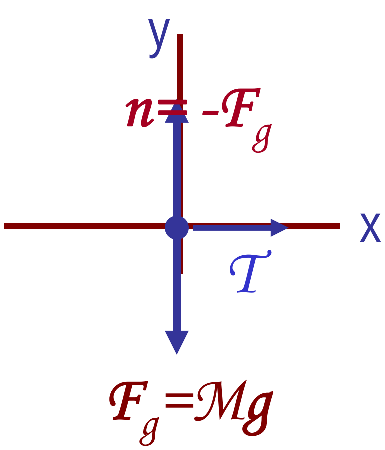
Gravitational force: $\mathbf{F}_g$

Normal force: $\mathbf{n}$

Tension force: $\mathbf{T}$

Free-body diagram





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

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

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

If T is a constant force, a_x, is constant

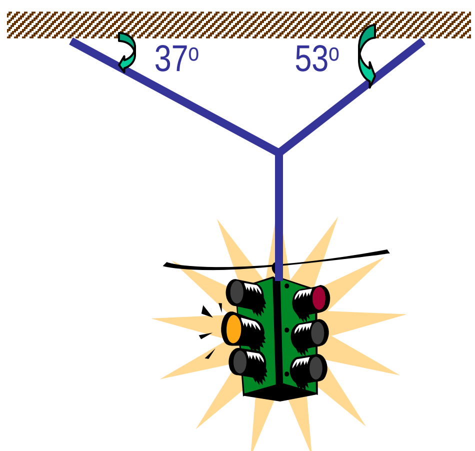
$$v_{xf} = v_{xi} + a_x t = v_{xi} + \left(\frac{T}{M}\right)t$$

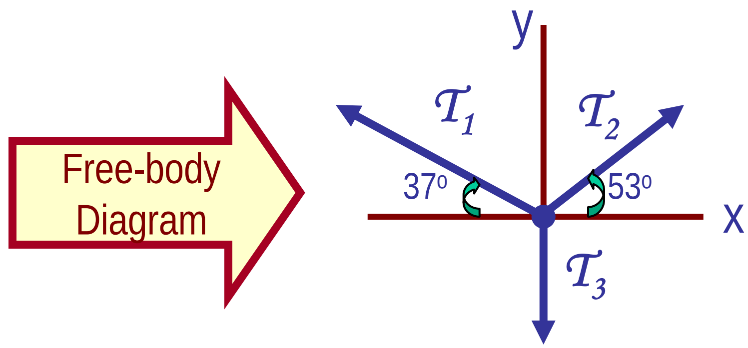
$$\Delta x = x_f - x_i = v_{xi}t + \frac{1}{2}\left(\frac{T}{M}\right)t^2$$

What happened to the motion in y-direction?

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

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

y-comp. of net force

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

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

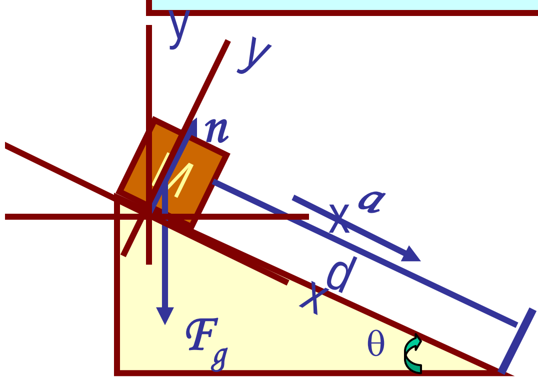
$$T_2\left[\sin(53^\circ) + 0.754\times\sin(37^\circ)\right] = 1.25T_2 = 125N$$

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

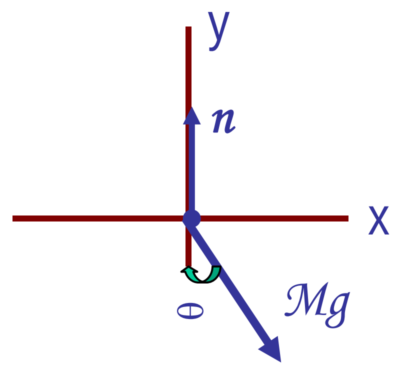
Example w/o Friction

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.



Free-body Diagram



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

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

$$a_x = g\sin\theta$$

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

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?

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

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

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

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

Forces 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

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

What does this formula tell you?

Frictional force increases till it reaches the limit!!

Beyond the limit, the object starts moving, and there is NO MORE static friction but kinetic friction takes over from this point.

Force of kinetic friction, f_k

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

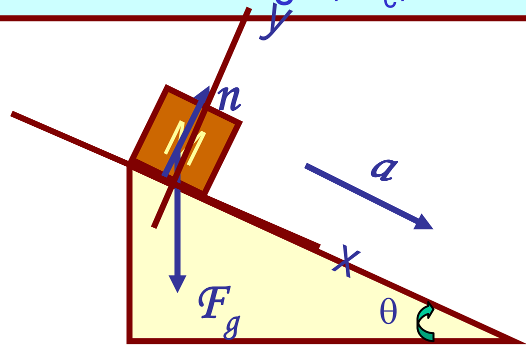
The resistive force exerted on the object during its movement

Which direction does kinetic friction apply?

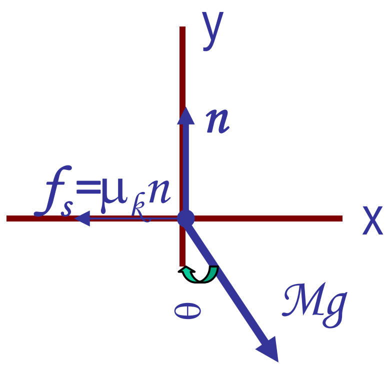
Opposite to the motion!

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, μ_s.



Free-body Diagram



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

x comp. $F_x = F_{gx} - f_s = Mg\sin\theta - f_s = 0 \quad f_s = \mu_s n = Mg\sin\theta_c$

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

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