PHYS 1443 – Section 001
Lecture #7

Monday, February 21, 2011

Dr. Jaehoon Yu

- Categories of Forces
- Free Body Diagram
- Force of Friction
- Application of Newton's Laws
  - Motion without friction
  - Motion with friction
- Uniform Circular Motion

Today's homework is homework #5, due 10pm, Tuesday, Mar. 1!!

Announcements

- 1st Term exam results
  - Class average: 71.2/102
    - Equivalent to 69.8/100
    - Excellent!
  - Top score: 102/102
- Evaluation policy
  - Homework: 25%
  - Comprehensive mid-term exam: 19%
  - Comprehensive final exam: 19%
  - Lab: 15%
  - One better of the two non-comprehensive term exams: 12%
  - Quizzes: 10%
  - Extra credit: 10%

Extra credit

- 10% addition to the total
  - Could boost a B to A, C to B or D to C
- What constitute for extra credit?
  - Random attendances
  - Physics department colloquium participation
    - Some will be double or triple credit (
  - Strong participation in the class discussions
  - Special projects
  - Watch the valid planetarium shows
  - Many other opportunities

Valid Planetarium Shows

- Regular running shows
  - Magnificent Sun
  - Violent Universe
  - Wonders of the Universe
- Shows that need special arrangements
  - Stars of the Pharaohs
  - Black Holes
  - Two small pieces of glass
  - SOPHIA
- How to submit for extra credit?
  - Obtain the ticket stub that is signed and dated by the planetarium star lecturer of the day
  - Collect the ticket stubs
  - Tape all of them on a sheet of paper with your name and ID written on it
  - Submit the sheet at the end of the semester when asked

Announcements

- Quiz #2
  - Early in the class this Wednesday, Feb. 24
  - Covers CH3.6 through what we finish today
- Mid-term comprehensive exam
  - 1 – 2:20pm, Monday, Mar. 7, SH103
  - Covers: CH.1.1 through what we complete next Wednesday, Mar. 2 plus Appendix
- Colloquium this week: Our own Dr. C. Jackson on "Race to God Particle"

Physics Department
The University of Texas at Arlington

COLLOQUIUM

"The Race for the 'God Particle'"

Dr. Chris Jackson

UT Arlington, Dept of Physics

4:00 p.m Wednesday February 23, 2011
At SH Rm 101

Abstract:

Despite years of searching, the origin of mass has remained a mystery. Now, however, with the turn on of the Large Hadron Collider at CERN and the continuing efforts of the Tevatron at Fermilab, this mystery appears to be close to being solved. In the Standard Model of particle physics, mass generation occurs through a process called spontaneous symmetry breaking. The lone remnant of this process is a spinless particle called the Higgs boson. Detection of a Higgs boson (which has been called the 'holy grail' of particle physics) is one of the major goals of particle physics experiments, since this would provide direct evidence for the process of spontaneous symmetry breaking. In this talk, I will review the physics of the mechanism that produces mass in the Standard Model as well as discuss alternatives to the Standard Model. I will also give an update of where we stand (both theoretically and experimentally) in the search for the Higgs boson both in the Standard Model as well as in more exotic scenarios.

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

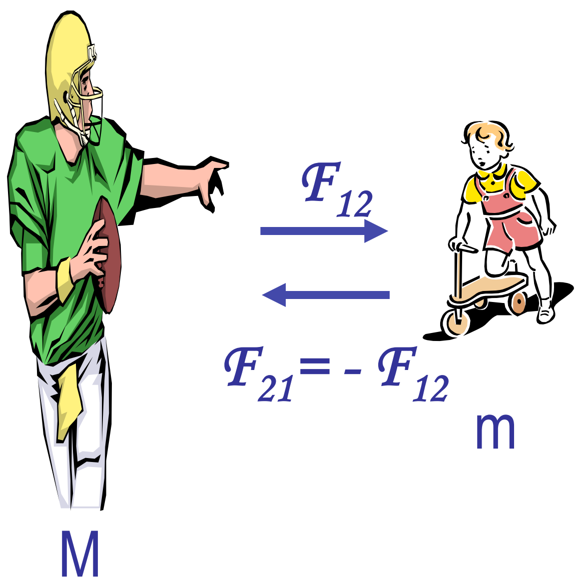
Special Project for Extra Credit

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, 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 this lecture note.
- Be sure to clearly define each variables used in your derivation.
- Each problem is 10 points.
- Due is Wednesday, Mar. 2.

Example of Newton's 3rd Law

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?



$$\vec{F}_{12} = -\vec{F}_{21} \quad \Rightarrow \quad \left|\vec{F}_{12}\right| = \left|\vec{F}_{21}\right| = F$$

$$\vec{F}_{12} = m\vec{a}_b \quad \Rightarrow \quad F_{12x} = ma_{bx}, \quad F_{12y} = ma_{by} = 0$$

$$\vec{F}_{21} = M\vec{a}_M \quad \Rightarrow \quad F_{21x} = Ma_{Mx}, \quad F_{21y} = Ma_{My} = 0$$

Since $\vec{F}_{12} = -\vec{F}_{21}$ and $\left|\vec{F}_{12}\right| = \left|-\vec{F}_{21}\right| = F$

Establish the equation $\Rightarrow$ $ma_{bx} = F = Ma_{Mx}$ Divide by m $\Rightarrow$ $a_{bx} = \dfrac{F}{m} = \dfrac{M}{m} a_{Mx}$

Example of Newton's 3rd Law, cnt'd

Man's velocity

$$v_{Mxf} = v_{Mxi} + a_{Mx}t = a_{Mx}t$$

Boy's velocity

$$v_{bxf} = v_{bxi} + a_{bx}t = a_{bx}t = \frac{M}{m} a_{Mx}t = \frac{M}{m} v_{Mxf}$$

So boy's velocity is higher than man's, if M>m, by the ratio of the masses.

b) Who moves farther while their hands are in contact?

Boy's displacement

$$x_b = v_{bxi}t + \frac{1}{2} a_{bx}t^2 = \frac{M}{2m} a_{Mx}t^2$$

$$x_b = \frac{M}{m}\left(\frac{1}{2} a_{Mx}t^2\right) = \frac{M}{m} x_M$$

Man's displacement

Given in the same time interval, since the boy has higher acceleration and thereby higher speed, he moves farther than the man.

Categories of Forces

- Fundamental Forces: Truly unique forces that cannot be derived from any other forces
  - Total of three fundamental forces
    - Gravitational Force
    - Electro-Weak Force
    - Strong Nuclear Force
- Non-fundamental forces: Forces that can be derived from fundamental forces
  - Friction
  - Tension in a rope
  - Normal or support forces

Gravitational Force and Weight

Gravitational Force, F_g

The attractive force exerted on an object by the Earth

$$\vec{F}_G = m\vec{a} = m\vec{g}$$

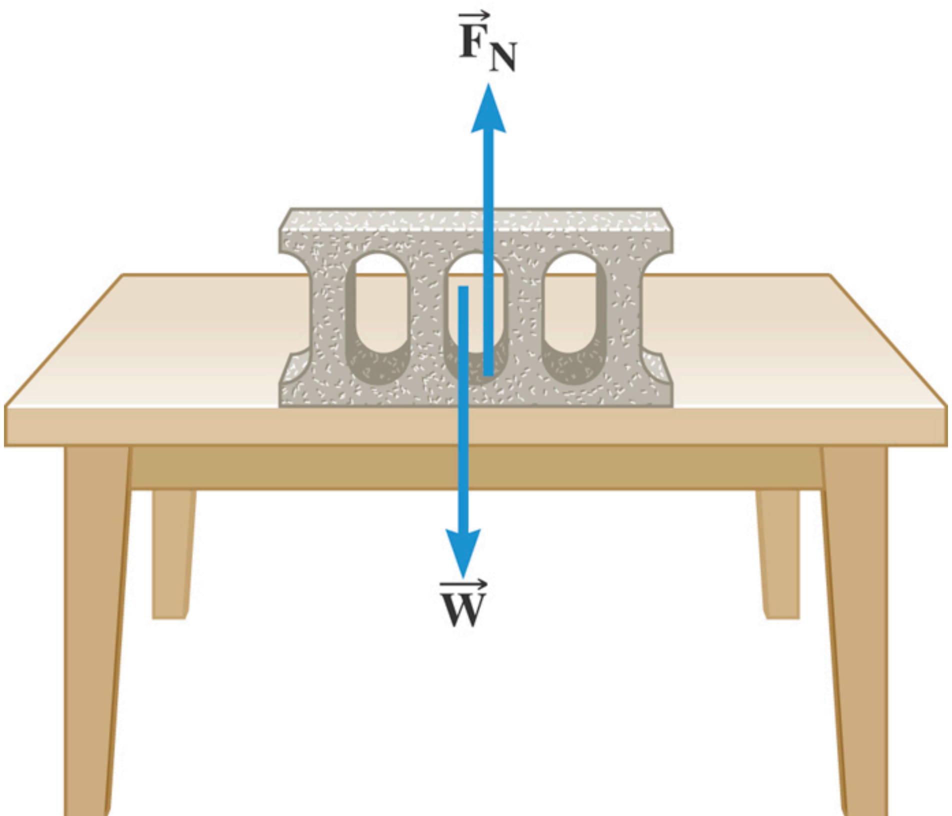
Weight of an object with mass M is $W = \left|\vec{F}_G\right| = M\left|\vec{g}\right| = Mg$

*Since weight depends on the magnitude of gravitational acceleration, **g**, it varies depending on geographical location.*

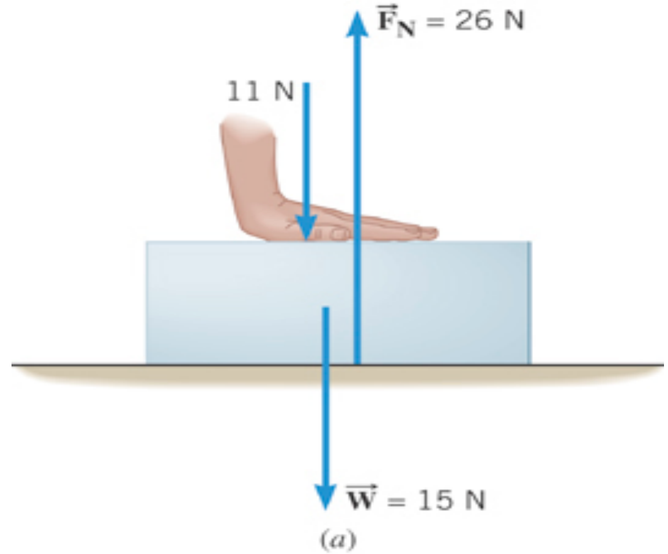
By measuring the force one can determine the mass. This is why you can measure mass using the spring scale.

The Normal Force

The normal force is one component of the force that a surface exerts on an object with which it is in contact – namely, the component that is **perpendicular to the surface**.



Some normal force exercises



Case 1: Hand pushing down on the book

$$F_N - 11\text{ N} - 15\text{ N} = 0$$

$$F_N = 26\text{ N}$$

Case 2: Hand pulling up the book

$$F_N + 11\text{ N} - 15\text{ N} = 0$$

$$F_N = 4\text{ N}$$

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***: *The force that reacts to action forces on the surface due to the surface structure of an object. Its direction is ALWAYS perpendicular to the surface.*

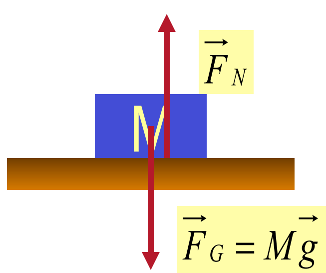
Tension, ***T***: *The reactionary force by a stringy object against an external force exerting on it.*

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 to solve a problem using forces or using dynamics

1. Select a point on a movable object in the problem, each FBD gives you different info on the motion.
2. Identify all the forces acting only on the selected object
3. Define a consistent 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 equation
6. Write down the forces in components to solve the problem

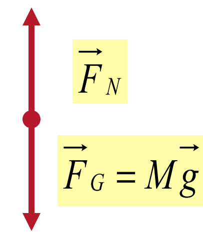


Which one should you select to draw FBD?

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

Gravitational force

the force supporting the object exerted by the floor

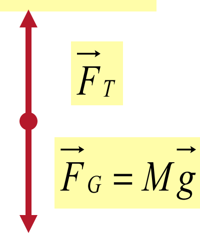


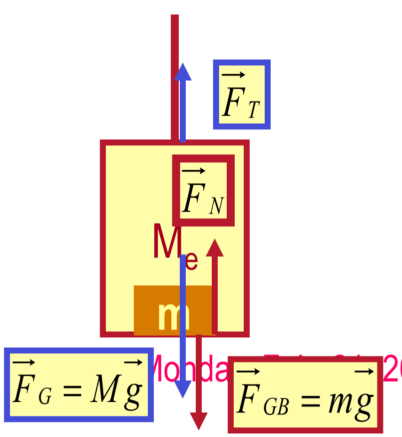
What is the FBD for the elevator?

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

Gravitational force

The force pulling the elevator (Tension)

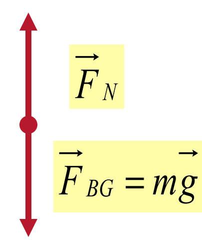




What about the box in the elevator?

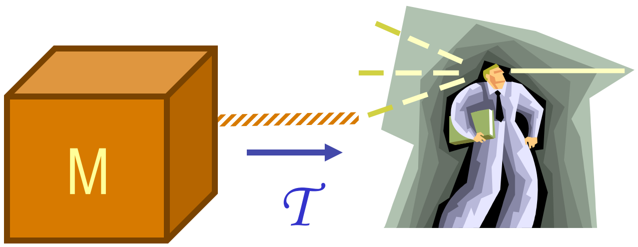
Gravitational force

Normal force



Applications of Newton's Laws

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



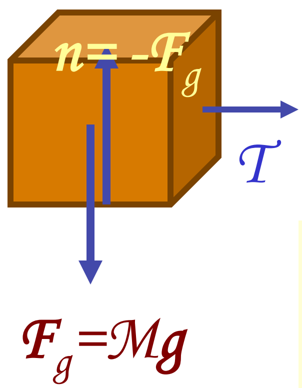
What are the forces being exerted on the box?

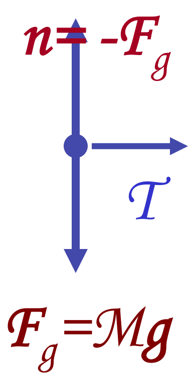
Gravitational force: $\boldsymbol{F_g}$

Normal force: $\boldsymbol{n}$

Tension force: $\boldsymbol{T}$

Free-body diagram





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

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

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

If T is a constant force, a_x, is constant

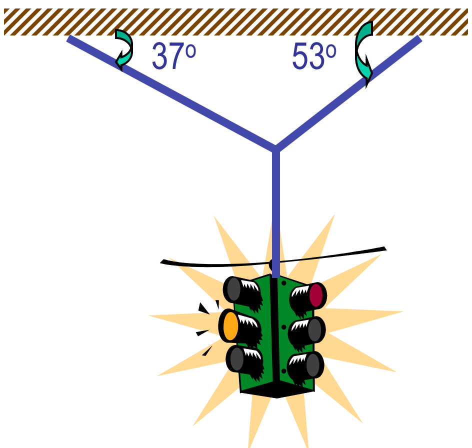
$$v_{xf} = v_{xi} + a_x t = v_{xi} + \left(\frac{T}{M}\right)t$$

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

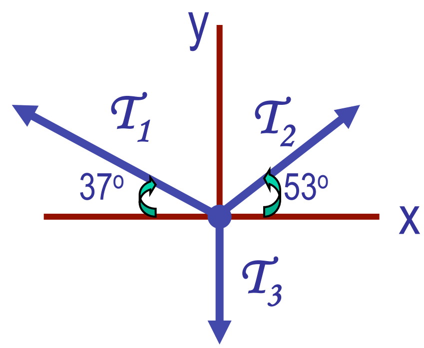
What happened to the motion in y-direction?

Example (~4.9) 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 37.0° and 53.0° with the horizontal. Find the tension 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

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

y-comp. of net force

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

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

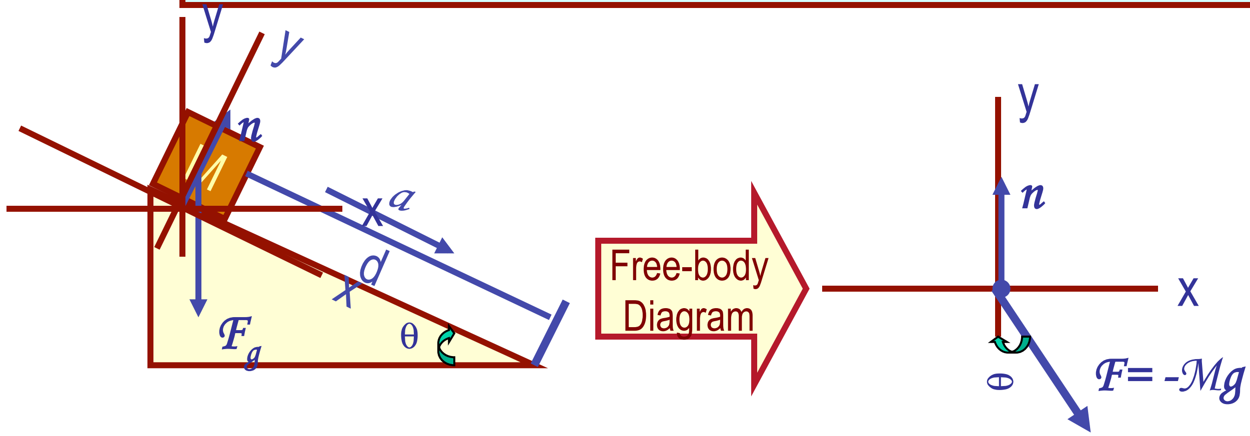
$$T_2\left[\sin\left(53^\circ\right) + 0.754\times\sin\left(37^\circ\right)\right] = 1.25T_2 = 125N$$

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

Example 4.16 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?

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

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

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

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