PHYS 1443 – Section 003
Lecture #9

Monday, March 1, 2021

Dr. Jaehoon Yu

- CH4: Newton's Laws of Motion
  - Newton's third law of motion
  - Categories of Forces
  - Gravitational Force and Weight
  - Application of Newton's Laws
  - Force of Friction

Today's homework is homework #5, due 11pm, Tuesday, March 23!!

Announcements

- Quiz #2 beginning of the class this Wednesday, March 3
  - Covers CH3.4 to what we finish today, Monday, March 1
  - BYOF: You may bring a one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants for the test
  - No derivations, word definitions, setups or solutions of any problems, figures, pictures, diagrams or arrows, etc!
  - Must email me the photos of front and back of the formula sheet, including the blank at jaehoonyu@uta.edu no later than **12:00pm the day of the test**
    - The subject of the email should be the same as your file name
    - File name must be FS-Q2-LastName-FirstName-SP21.pdf
    - Once submitted, you cannot change, unless I ask you to delete part of the sheet!
- Mid-term comprehensive online exam in class on Wed. March 10
  - Covers CH1.1 through what we learn on Monday, March 8 + Math refresher
- Reminder: Extra credit special COVID seminar at 4pm Saturday, March 20
  - Extra credit for participation and for asking the relevant questions
  - Dr. Linda Lee, a practicing physician from Wisconsin

Reminder: SP #3 – Statistical Analysis : COVID19

- Make comparisons of COVID-19 statistics between the U.S., South Korea, Italy and Texas from https://coronaboard.com on spreadsheet
  - Total 44 points: 1 point for each of the top 20 cells and 2 points for each of the 8 cells for vaccination
- Fill the US Historic event analysis table at the bottom 12 cells of the sheet (2 points per cell, 24 points total) and make a >3 sentence statement on COVID19 with respect to other events (6 points)
- What are the 3 fundamental quantitative requirements for opening up (2 points each, 6 points total)?
  - **Must be quantitative! (e.g. number of tests per capita per day, positivity rate, etc)**
- Assess the readiness of the three fundamental requirements U.S. (Do NOT just take politician's words!). Must provide the independent scientific entity's reference you took the information from. (2 point each, total 6 points)
- Evaluate **quantitatively** the success/failure of the US responses to COVID-19 in 2020 in 5 sentences and that in 2021 in 5 sentences. **Must provide quantitative reasons behind your conclusion!** (2 points each sentence, 20 points total)
- Assess **quantitatively** the effectiveness of wearing masks (4 points) and at least 4 reasons for it being effective (1 point each, 0.5 point extra after the first 4).
- **Possible maximum: 122 points total**
- **Due: 11pm, Friday, March 19**
  - Submit one pdf file SP3-YourLastName-YourFirstName.pdf, including the spreadsheet
  - Spreadsheet will be posted on canvas. Download ASAP.

PHYS1443-003, Spring 21, Special Project #3, Statistical Analysis - COVID19

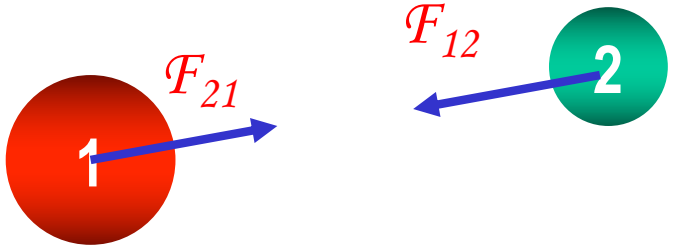
Name:			Date & time of your COVID-19 Data:		
Items		**U.S.A**	**South Korea**	**Italy**	**Texas**
Total Population					
COVID-19 Confirmed cases	Total				
	Cases per 1M people				
COVID-19 Deaths	Total				
	Death per 1M people				
COVID-19 Testing	Total				
	Testing per 1M people				
	Poditivity Rate				
COVID-19 Vaccination to date	Total				
	Per 1M people				
		COVID-19	**US H1N1**	**US Vietnam War**	**US World War II**
US Historic Event Analysis	Time period (mm/dd/yy - MM/DD/YY)				
	Duration in Months				
	Total deaths				
	Death per month				

SP#4: Newton's 3rd Law

- The mass of the spacecraft is 11,000 kg and the mass of the astronaut is 92 kg. What is the velocity of the space craft and the astronaut 10 sec into the motion if they were in contact for 50cm during with the astronaut is applying the force of 36N?
- Maximum score: 20 points
- Please be sure to show details of your OWN work!
- Must be handwritten!
- Due 2:30pm, Monday, March 8
- Submit one pdf file SP4-YourLastName-YourFirstName.pdf on canvas assignment #4

Newton's Third Law (Law of Action and Reaction)

When two objects interact, the force F_{12} that object 1 exerts on object 2 is equal in magnitude and opposite in direction to the force F_{21} object 2 exerts on object 1.



$$\vec{F}_{12} = -\vec{F}_{21}$$

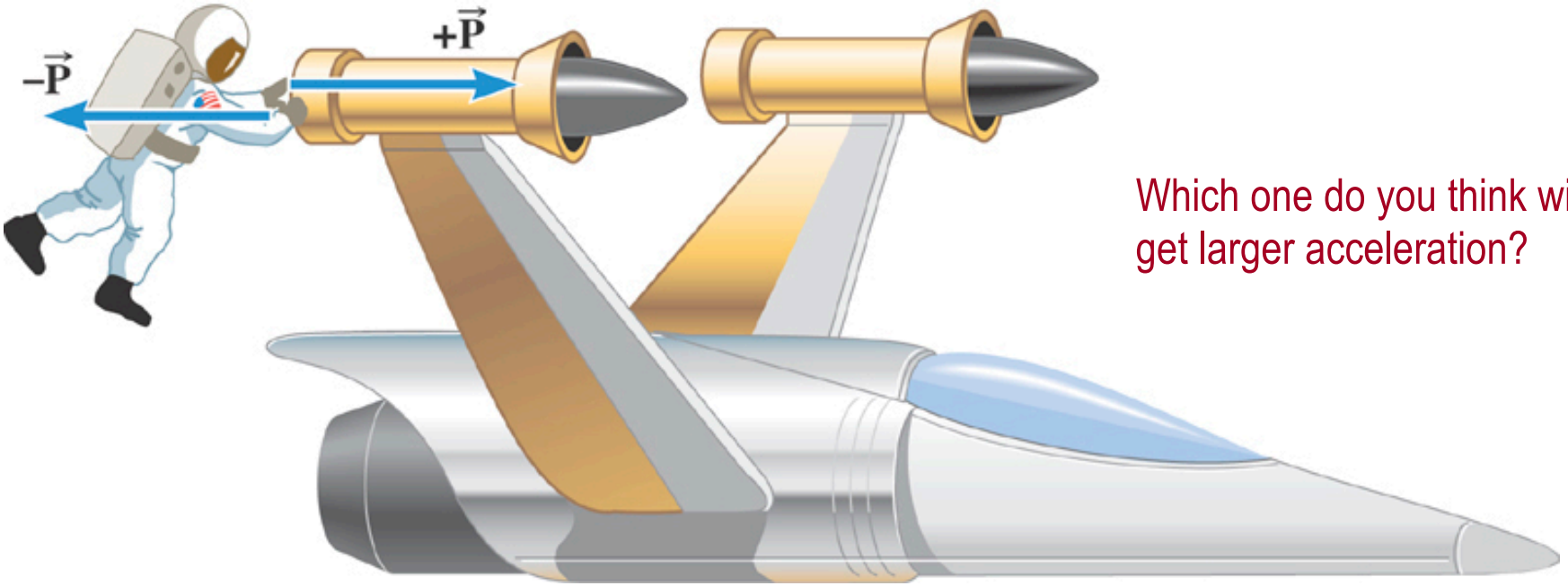
The reaction force is equal in magnitude to the action force but in opposite direction. These two forces always act ***on different objects***.

What is the reaction force to the force of a free falling object?

The gravitational force exerted by the object to the Earth!

Stationary objects on top of a table has a reaction force (called the normal force) from the table to balance the action force, the gravitational force.

Ex. The Accelerations Produced by Action and Reaction Forces



Which one do you think will get larger acceleration?

Suppose that the magnitude of the force P is 36 N. If the mass of the spacecraft is 11,000 kg and the mass of the astronaut is 92 kg, what are the accelerations?

Ex. continued

Force exerted on the space craft by the astronaut $\sum \vec{\mathbf{F}}_{AS} = \vec{\mathbf{P}}$

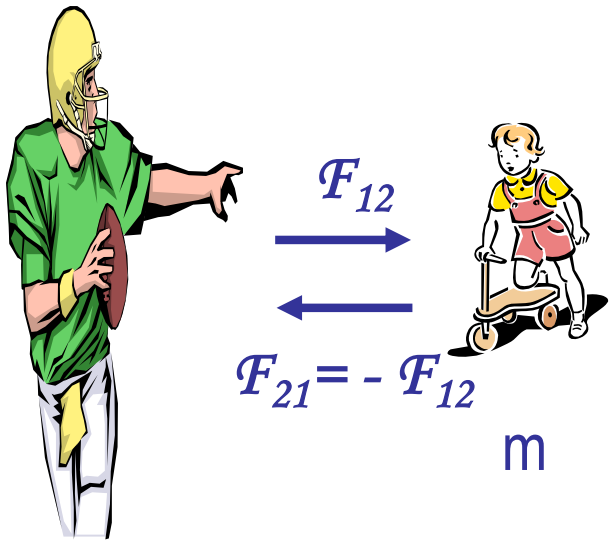
Force exerted on the astronaut by the space craft $\sum \vec{\mathbf{F}}_{SA} = -\vec{\mathbf{P}}$

space craft's acceleration $\vec{\mathbf{a}}_s = \frac{\vec{\mathbf{P}}}{m_s} = \frac{+36\,\vec{i}\ \text{N}}{11{,}000\ \text{kg}} = +0.0033\vec{i}\left(\text{m/s}^2\right)$

astronaut's acceleration $\vec{\mathbf{a}}_A = \frac{-\vec{\mathbf{P}}}{m_A} = \frac{-36\,\vec{i}\ \text{N}}{92\ \text{kg}} = -0.39\vec{i}\left(\text{m/s}^2\right)$

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?



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

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

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

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** $\Rightarrow a_{bx} = \frac{F}{m} = \frac{M}{m}a_{Mx}$

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

Man's speed

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

Boy's speed

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

So boy's speed 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 (poll 2)
  - Total of three fundamental forces
    - Gravitational Force
    - Electro-Weak Force (the unified force of EM and Weak)
    - 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, $\vec{F}_g$

The attractive force exerted on an object by the Earth (Polls 3, 6, 12)

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

Weight of an object with mass M is

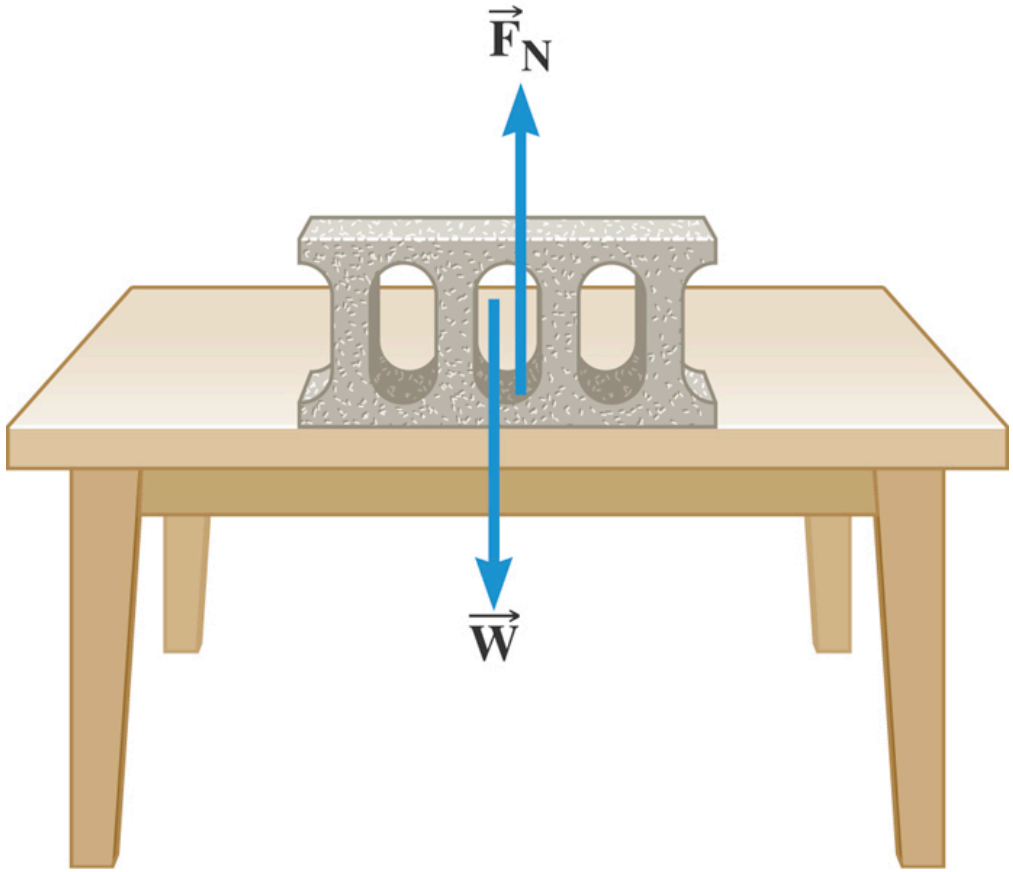
$$\left|\vec{W}\right| = \left|\vec{F}_G\right| = M\left|\vec{g}\right| = Mg$$

*Since weight depends on the magnitude of gravitational acceleration, **g**, it varies depending on geographical location. (poll 7)*

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

The Normal Force

The normal force is one component of the reactionary force that a surface exerts on an object with which it is in contact – namely, the component that is **perpendicular to the surface**. (polls 6, 3)

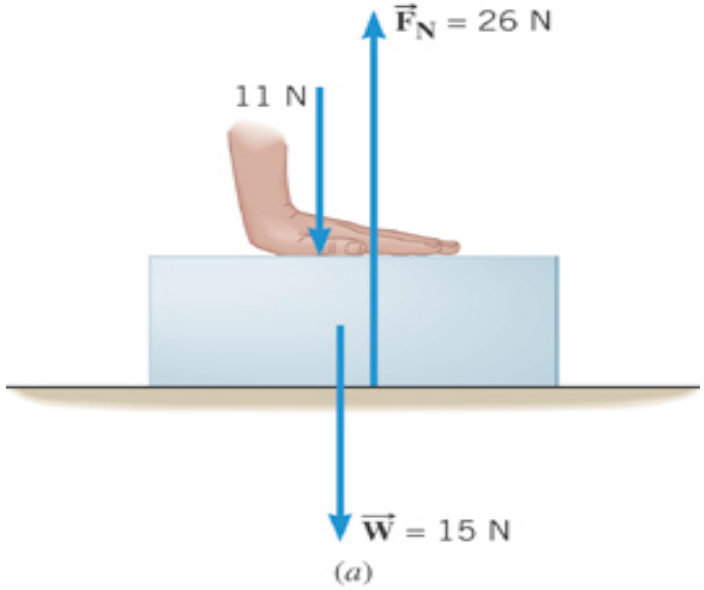


Some normal force exercises

Case 1: Hand pushing down the book

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

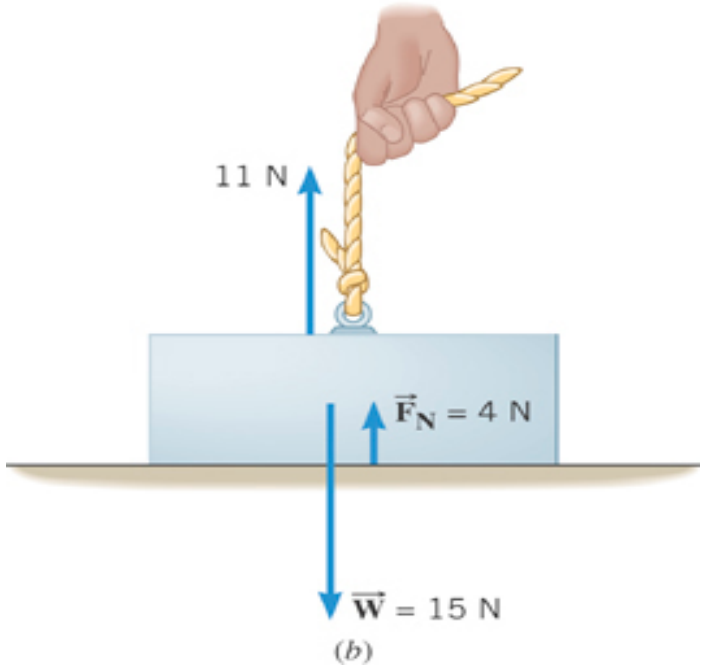
$$F_N = 26\ \text{N}$$



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***:

Reaction force that reacts to the action force due to the surface structure of an object. Its direction is perpendicular to the surface.

Tension, $\mathcal{T}$:

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

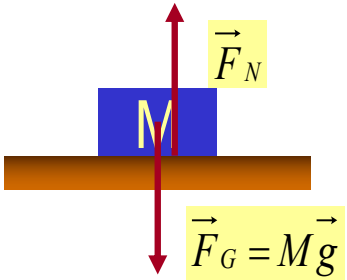
Free-body diagram

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 to solve 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 (easier if one of the axes is aligned with the anticipated direction of motion!)
4. Draw arrows to represent the force vectors on the selected point
5. Write down the net force vector equation
6. Write down the force components to solve the problem for the motion of an object

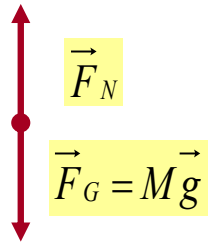


Draw the FBD on the box of mass M.

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

Gravitational force

the force supporting the object exerted by the floor

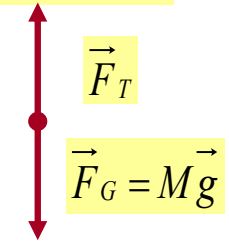


Draw FBD on the elevator!

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

Gravitational forces

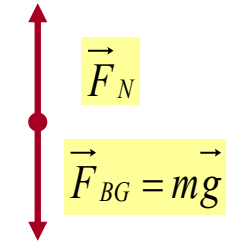
The force pulling the elevator (Tension)

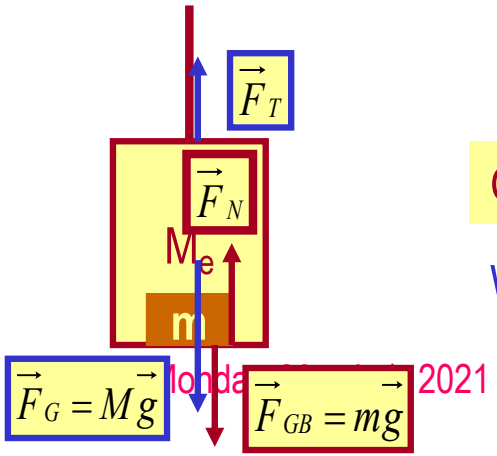


What about the box in the elevator?

Gravitational force on the box

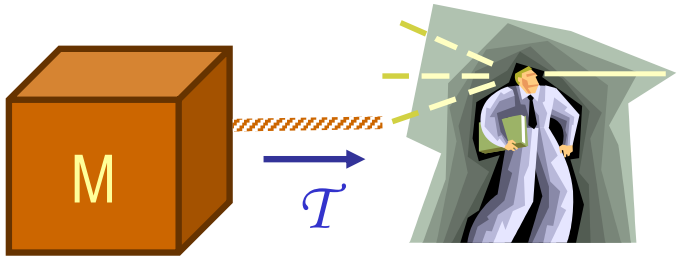
Normal force





Applications of Newton's Laws

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



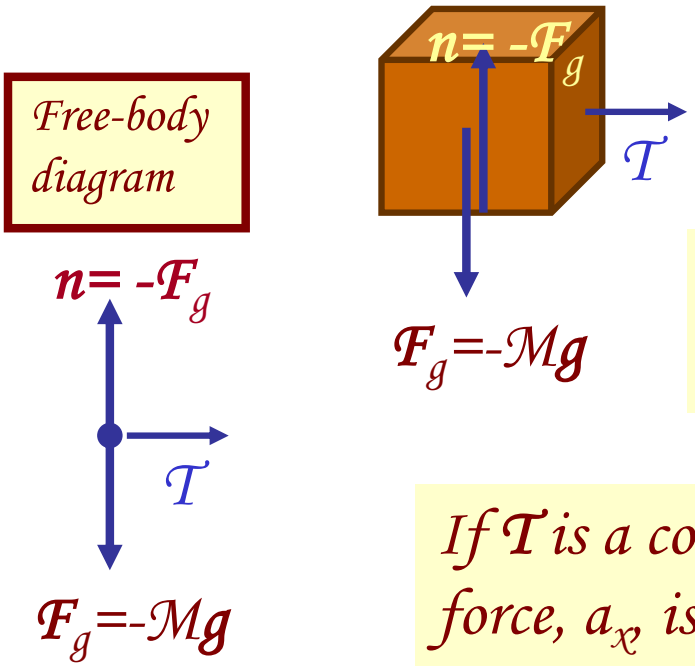
What are the forces being exerted on the box?

Gravitational force: $\boldsymbol{F_g}$

Normal force: $\boldsymbol{n}$

Tension force: $\boldsymbol{\mathcal{T}}$

Free-body diagram



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

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

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

If $\mathcal{T}$ *is a constant force,* a_x *is constant*

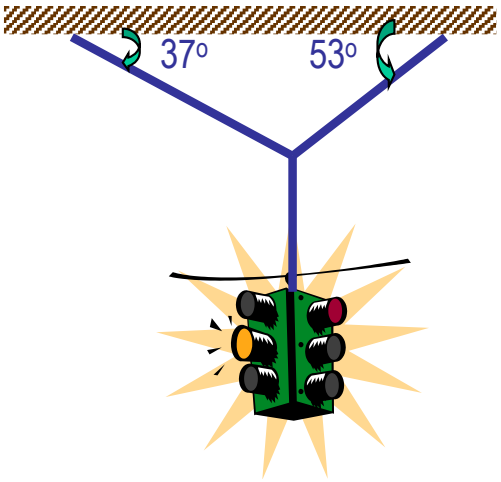
$$v_{xf} = v_{xi} + a_x t = v_{xi} + \left(\frac{T}{M}\right)t$$

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

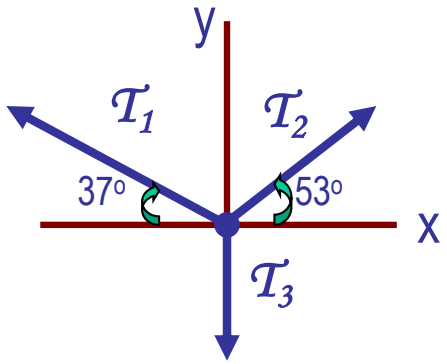
What happened to the motion in y-direction?

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 37.0° 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

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

y-comp. of net force

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

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

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

$$T_1 = 0.754T_2 = 75.4N$$