PHYS 1441 – Section 002
Lecture #8

Wednesday, Feb. 25, 2009

Dr. Jaehoon Yu

- Newton's Second Law and Third Law
- Free Body Diagram
- Categories of forces
- Application of Newton's Laws
  - Motion without friction
- Forces of Friction
  - Motion with friction

Announcements

- Quiz Monday, Mar.2
  - Beginning of the class
  - Covers Ch4. or what we finish this Wednesday
- Change of Exam Dates
  - Mid-term exam scheduled on Mar. 11 now moved to Wed. Mar. 27
  - Second non-comprehensive exam scheduled on Apr. 13 now moved to Wed. Apr. 22
  - Final comprehensive exam stays on the same date, May 11
- Colloquium today

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.
- Each problem is 10 points each.
- Due is Wednesday, Mar. 4.
- Please be sure to clearly define each variables used in your derivation.

Physics Department

The University of Texas at Arlington

COLLOQUIUM

Integrated Optical Chem-Bio Sensors and Microacoustic Cytometry

Dr. Igal Brener

Sandia National Laboratories and Center for Integrated Nanotechnologies

Albuquerque, New Mexico

4:00 pm Wednesday February 25, 2009 Room 101 SH

Abstract

A large fraction of existing and proposed sensors rely on microresonators (i.e., acoustical, mechanical, etc). Each resonator modality has its unique properties, and optical microresonators in particular are sensitive to the dielectric constant of adsorbed layers, which in turn depends on electronic and vibronic excitations. Furthermore, these optical microresonators can cover a large frequency range in the electromagnetic spectrum, from UV to terahertz frequencies. In this talk I will present our work on integrated microring waveguide sensors, (which probe adsorbed molecules in the near-IR) and show our progress in plasmonic and metamaterial sensors working from visible to far-IR wavelengths. Finally I will describe our work on miniature flow cytometry based on microfluidics, microacustics and optical detection.

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

Vector Nature of the Force

The direction of force and acceleration vectors can be taken into account by using x and y components.

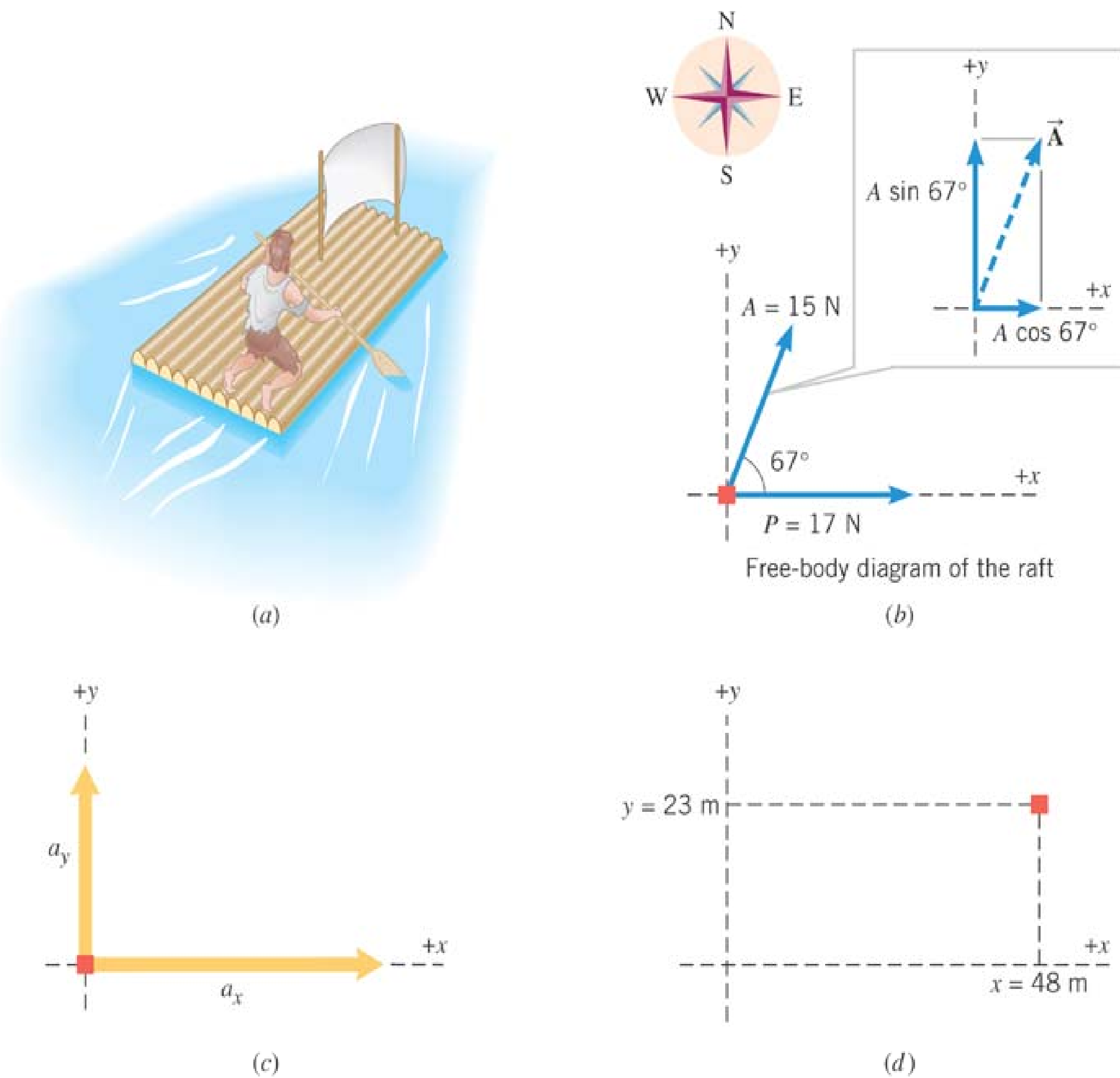
$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

is equivalent to

$$\sum F_y = ma_y \qquad \sum F_x = ma_x$$

Ex. Stranded man on a raft

A man is stranded on a raft (mass of man and raft = 1300kg)m as shown in the figure. By paddling, he causes an average force P of 17N to be applied to the raft in a direction due east (the +x direction). The wind also exerts a force A on the raft. This force has a magnitude of 15N and points 67^o north of east. Ignoring any resistance from the water, find the x and y components of the rafts acceleration.



First, let's compute the net force on the raft as follows:

Force	*x* component	*y* component
$\vec{\mathbf{P}}$ $\vec{\mathbf{A}}$	+17 N +(15N)cos67°	0 N +(15N)sin67°
$\vec{F} = \vec{P} + \vec{A}$	+17+15cos67°= +23(N)	+17+15sin67°= +14(N)

Now compute the acceleration components in x and y directions!!

$$a_x = \frac{\sum F_x}{m} = \frac{+23\ \mathrm{N}}{1300\ \mathrm{kg}} = +0.018\ \mathrm{m/s^2}$$

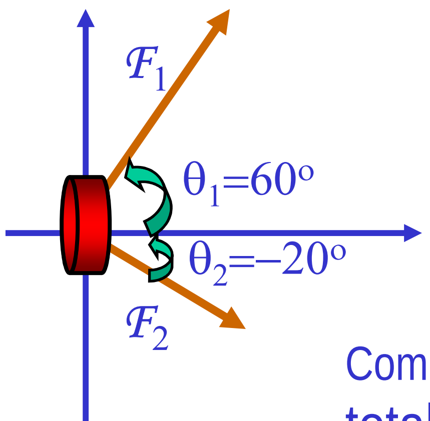
$$a_y = \frac{\sum F_y}{m} = \frac{+14\ \mathrm{N}}{1300\ \mathrm{kg}} = +0.011\ \mathrm{m/s^2}$$

The overall acceleration is

$$\vec{a} = a_x \vec{i} + a_y \vec{j} = \left(0.018\vec{i} + 0.011\vec{j}\right) m/s^2$$

Example for Newton's 2nd Law of Motion

Determine the magnitude and direction of the acceleration of the puck whose mass is 0.30kg and is being pulled by two forces, **F1** and **F2**, as shown in the picture, whose magnitudes of the forces are 8.0 N and 5.0 N, respectively.



Components of $\mathcal{F}_1$

$$F_{1x} = \left|\vec{F}_1\right| \cos\theta_1 = 8.0\times\cos\left(60^\circ\right) = 4.0N$$

$$F_{1y} = \left|\vec{F}_1\right| \sin\theta_1 = 8.0\times\sin\left(60^\circ\right) = 6.9N$$

Components of $\mathcal{F}_2$

$$F_{2x} = \left|\vec{F}_2\right| \cos\theta_2 = 5.0\times\cos\left(-20^\circ\right) = 4.7N$$

$$F_{2y} = \left|\vec{F}_2\right| \sin\theta_2 = 5.0\times\sin\left(-20^\circ\right) = -1.7N$$

Components of total force $\mathcal{F}$

$$F_x = F_{1x} + F_{2x} = 4.0 + 4.7 = 8.7N = ma_x$$

$$F_y = F_{1y} + F_{2y} = 6.9 - 1.7 = 5.2N = ma_y$$

Magnitude and direction of acceleration a

$$a_x = \frac{F_x}{m} = \frac{8.7}{0.3} = 29m/s^2 \quad a_y = \frac{F_y}{m} = \frac{5.2}{0.3} = 17m/s^2 \quad \left|\vec{a}\right| = \sqrt{\left(a_x\right)^2 + \left(a_y\right)^2} = \sqrt{\left(29\right)^2 + \left(17\right)^2} = 34m/s^2$$

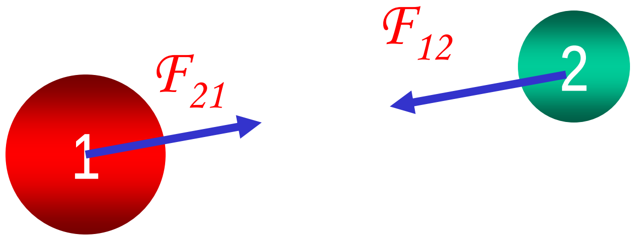
$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{17}{29}\right) = 30^\circ$$

Acceleration Vector a

$$\vec{a} = a_x\hat{i} + a_y\hat{j} = \left(29\hat{i} + 17\hat{j}\right)m/s^2$$

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

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



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

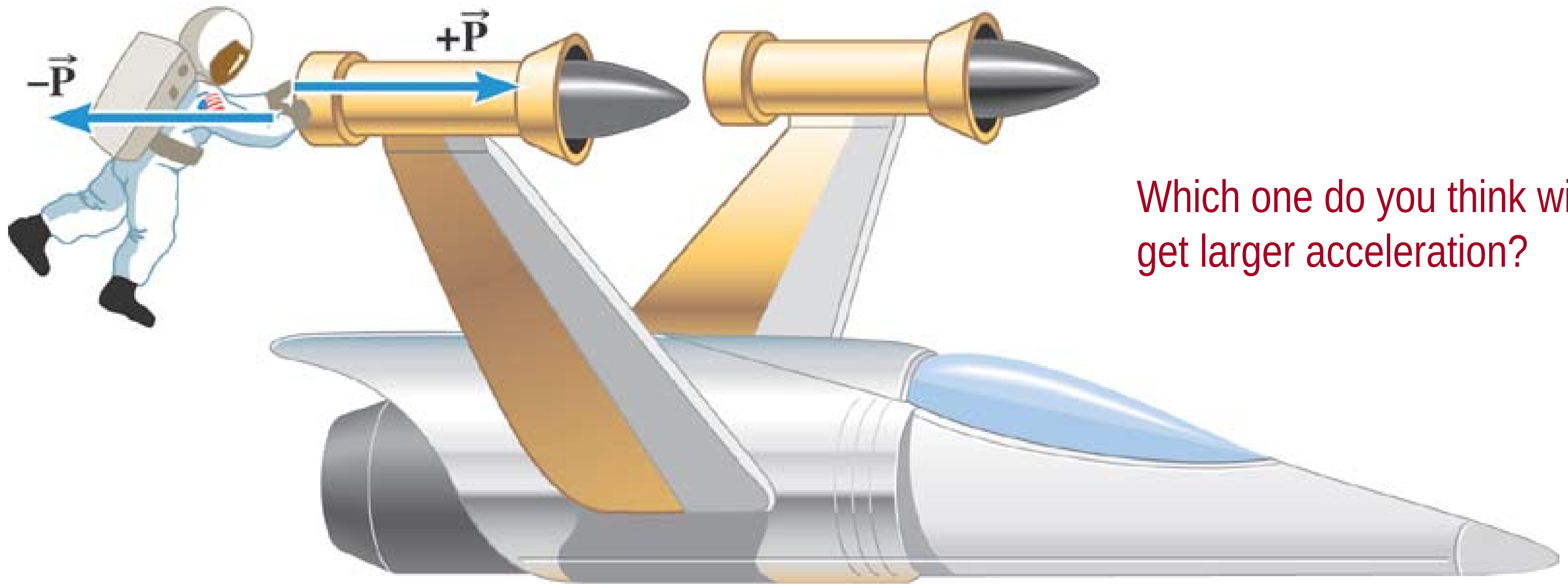
The action force is equal in magnitude to the reaction force but in opposite direction. These two forces always act <u>on different objects</u>.

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 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 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 $\sum \vec{\mathbf{F}} = \vec{\mathbf{P}}.$

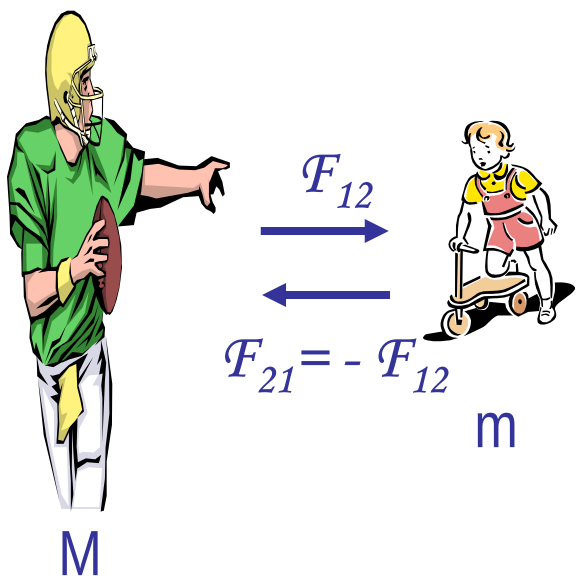
Force exerted on the astronaut by the space craft $\sum \vec{\mathbf{F}} = -\vec{\mathbf{P}}.$

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

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

Example of Newton's 3[rd] 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 $\Rightarrow$ $a_{bx} = \dfrac{F}{m} = \dfrac{M}{m}a_{Mx}$

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.

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 action forces due to the surface structure of an object. Its direction is 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 <u>diagram of external forces on an object</u> and is extremely useful analyzing forces and motion!! Drawn only on an object.

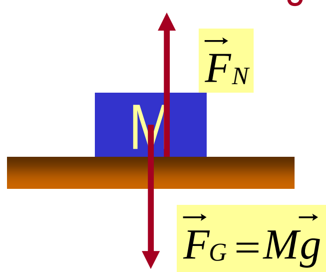
Free Body Diagrams and Solving Problems

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

$\Rightarrow$ 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
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 problems

$\Rightarrow$ 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

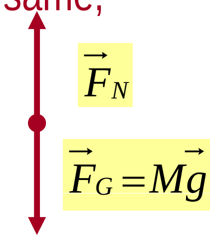


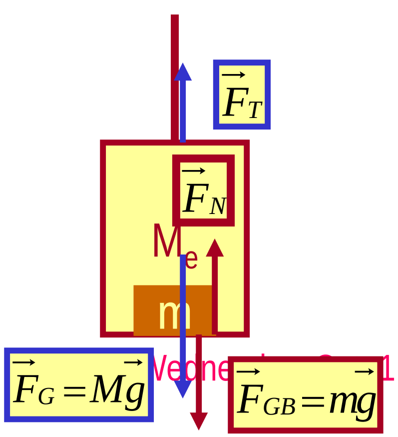
Which one would you like to select to draw FBD?

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

Gravitational force

the force supporting the object exerted by the floor



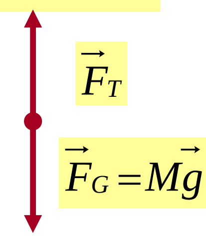


Which one would you like to select to draw FBD?

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

Gravitational force

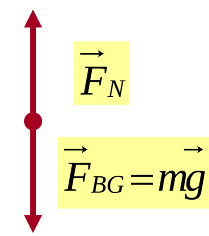
The force pulling the elevator (Tension)



What about the box in the elevator?

Gravitational force

Normal force

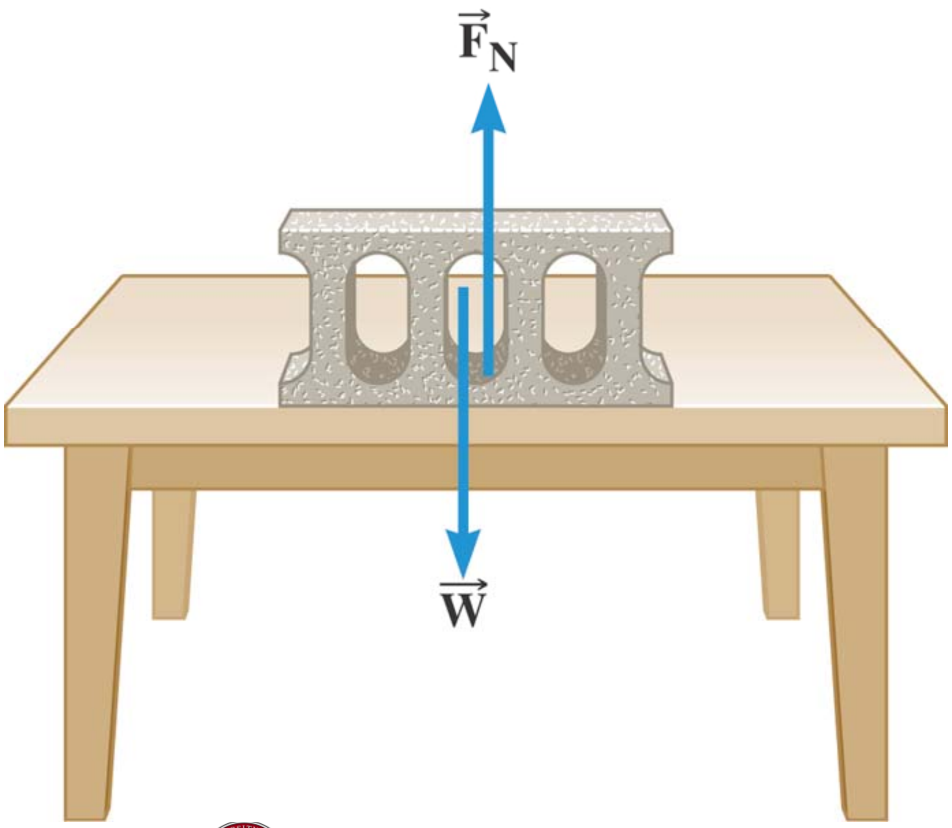


Categories of Forces

- 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

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.

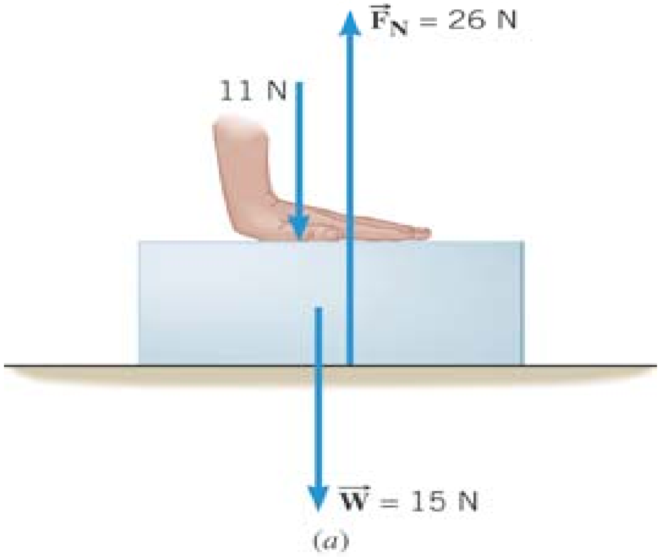


Some normal force exercises

Case 1: Hand pushing down on the book

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

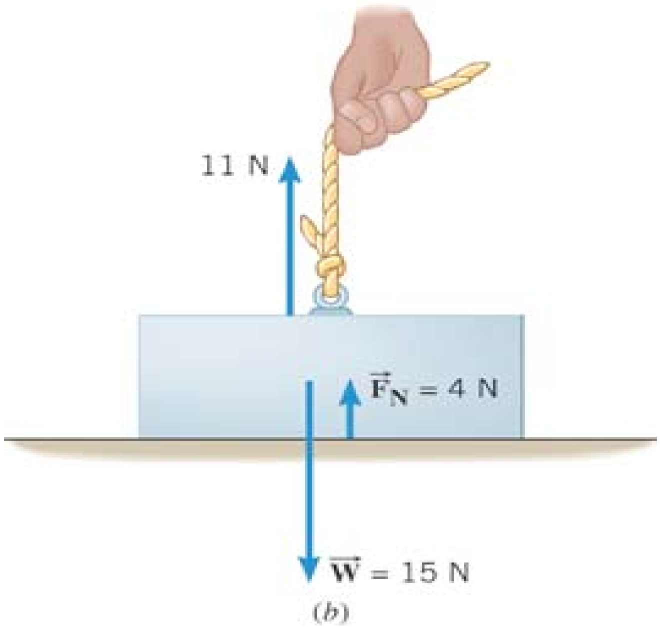
$$F_N = 26\text{ N}$$



Case 2: Hand pulling up the book

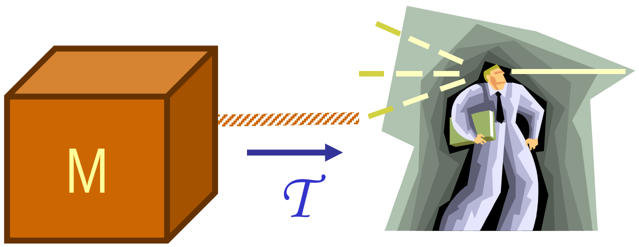
$$F_N + 11\text{ N} - 15\text{ N} = 0$$

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



Applications of Newton's Laws

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



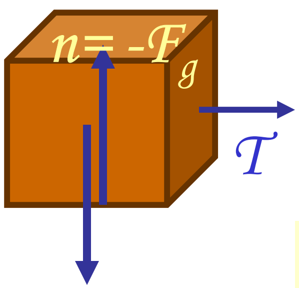
What are the forces being exerted on the box?

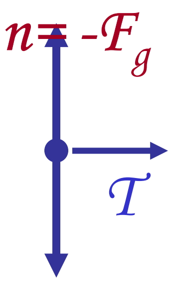
Gravitational force: F_g

Normal force: n

Tension force: T

Free-body diagram





Total force:
$F = F_g + n + T = T$

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

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

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?