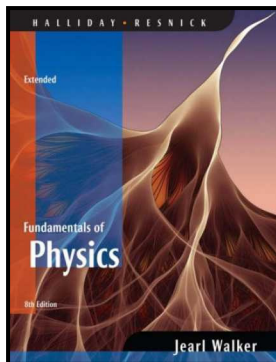


Workshop Physics

1017 - 311

University Physics I

Week 4 : Day 2

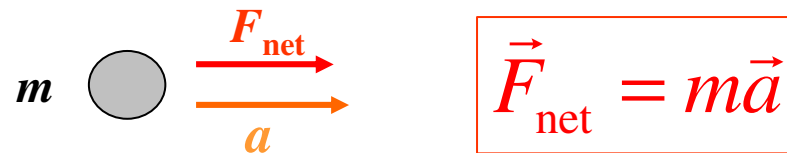


Newton's Second Law

The results of the discussions on the relations between the net force F_{net} applied on an object of mass m and the resulting acceleration a can be summarized in the following statement known as “**Newton's second law.**”

The net force on a body is equal to the product of the body's mass and its acceleration.

In equation form Newton's second law can be written as:



The diagram shows a grey circle representing mass m . To its right, two parallel arrows point to the right: the top one is red and labeled F_{net} , and the bottom one is orange and labeled a . To the right of these arrows is a red-bordered box containing the vector equation $\vec{F}_{\text{net}} = m\vec{a}$.

The above equation is a compact way of summarizing three separate equations, one for each coordinate axis:

$$F_{\text{net},x} = ma_x$$

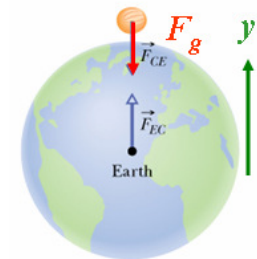
$$F_{\text{net},y} = ma_y$$

$$F_{\text{net},z} = ma_z$$

Gravity and Weight

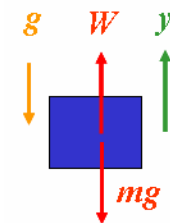
The Gravitational Force: It is the force that the Earth exerts on any object (in the picture a cantaloupe). It is directed toward the center of the Earth. Its magnitude is given by Newton's second law.

$$\vec{F}_g = m\vec{a} = -mg\hat{j} \qquad \left| \vec{F}_g \right| = mg$$



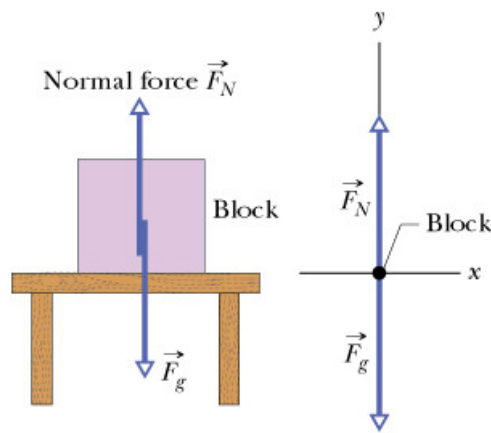
Weight: The weight of a body is defined as the magnitude of the force required to prevent the body from falling freely.

$$F_{\text{net},y} = ma_y = W - mg = 0 \rightarrow W = mg$$



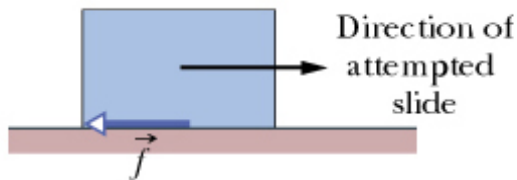
Note: The weight of an object is not its mass. If the object is moved to a location where the acceleration of gravity is different (e.g., the moon, where $g_m = 1.7 \text{ m/s}^2$), the mass does not change but the weight does.

Contact Forces



Normal Force: When a body presses against a surface, the surface deforms and pushes on the body with a normal force perpendicular to the contact surface. An example is shown in the picture to the left. A block of mass m rests on a table. (Note: In this case $F_N = mg$. This is not always the case.)

$$F_{\text{net},y} = ma_y = F_N - mg = 0 \rightarrow F_N = mg$$



Friction: If we slide or attempt to slide an object over a surface, the motion is resisted by a bonding between the object and the surface. This force is known as “friction.” (More in Chapter 6.)

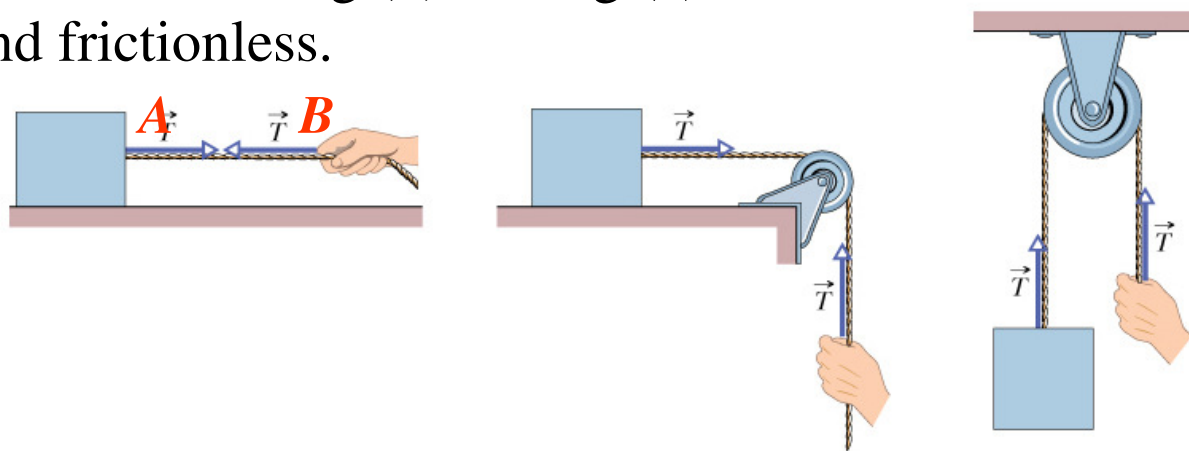
TENSION

Tension: This is the force exerted by a rope or a cable attached to an object. Tension has the following characteristics:

1. It is always directed along the rope.
2. It is always pulling the object.
3. It has the same value along the rope (e.g., between points A and B).

The following assumptions are made: a) The rope has negligible mass compared to the mass of the object it pulls; b) The rope does not stretch.

If a pulley is used as in fig.(b) and fig.(c), we assume that the pulley is massless and frictionless.



Force Summary

- ❑ **Pushing forces**
 - external pushing or pulling forces provided by people, motors, etc. as specified by problem
- ❑ **Weight or Force of Gravity (near the earth)**
 - magnitude is mg
 - direction is straight down
- ❑ **Normal Force**
 - contact force between two objects
 - you must solve for the magnitude – not just equal to the weight !!!
 - direction is always perpendicular (“normal”) to the surface between the objects
- ❑ **Tension**
 - tension exists in a cord or string or rope
 - tension always pulls, never pushes
 - tension at one end of a string is often in the opposite direction than in the other end: remember, the tension must pull on the object its attached to
- ❑ **Ideal strings or cords or ropes and Ideal pulleys:**
 - an ideal string is both “inextensible” (no-stretch) and massless
 - if a cord goes around an ideal pulley, which is massless and frictionless, there is only a change the direction, not the magnitude, of the tension
- ❑ **Non-ideal strings**
 - tensions are not the same on both sides of the rope
- ❑ **Friction**
 - always in the direction opposite the motion that would have happened without friction

Problem Solving Strategies

□ Problem Solving Steps

- It makes things a lot easier if you follow the same approach every time

□ Example: Pulling a Sled

Example Problem – One body

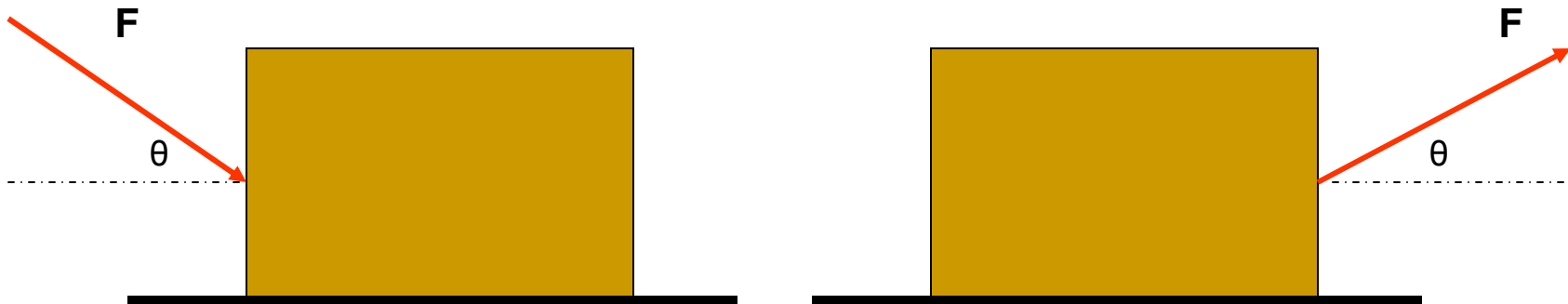
Dad pulls his 20 kg child in a 10 kg sled, at constant speed, using a rope that makes an angle of 30° above the horizontal. If he pulls with a constant force of 100 N, what is the frictional force acting on the sled, and what is the normal force?

Force Problems: Steps to Solution – Problems with ONE body

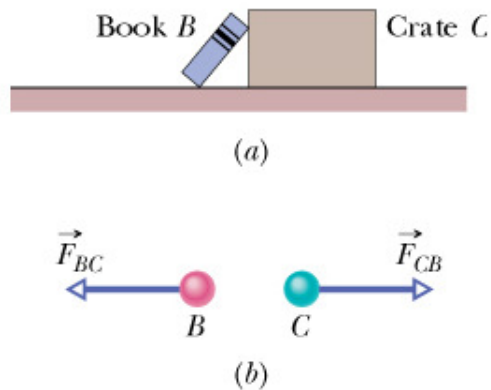
- 1) Sketch
- 2) Draw a free body diagram
 - decide what “the body” is, and isolate it. Depict it as a simple dot
 - draw vectors for each force acting on the body, with each vector’s tail on the body
 - name each force with a symbolic name, W, T, etc on the diagram
 - don’t put anything else on the free body diagram ... just the forces and the axes
- 3) Decide on an axis system and add it to your free body diagram
 - pick axis system so that the final motion of the object is along one of the axes!
 - label any angles you know
- 4) Construct a table of the forces and their components
 - Use symbols, don’t evaluate just yet
- 5) Check your signs, in the table.
 - use the axis system on the free body diagram and see if each vector points along the axis (+) or against it (-).
- 6) Set up the equations for $\sum F_x = ma_x$ and $\sum F_y = ma_y$
- 7) Solve
- 8) Sanity checks: think about your answer in limiting cases ... does it make sense?

Pushing Vs. Pulling

- ❑ Consider the task of moving a box by pushing or pulling...
 - Which one should be easier and why?



Newton's Third Law



When two bodies interact by exerting forces on each other, the forces are equal in magnitude and opposite in direction.

For example, consider a book leaning against a bookcase. We label \vec{F}_{BC} , the force exerted on the book by the case. Using the same convention we label \vec{F}_{CB} , the force exerted on the case by the book. Newton's third law can be written as $\vec{F}_{BC} = -\vec{F}_{CB}$. The book together with the bookcase are known as a "third-law force pair."

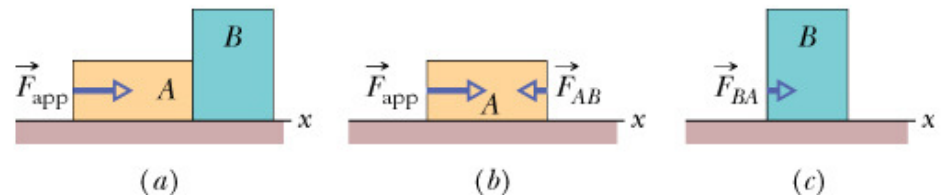
Free-Body Diagrams

Part of the procedure of solving a mechanics problem using Newton's laws is drawing a free-body diagram. This means that among the many parts of a given problem we choose one that we call the "system." Then we choose axes and enter **all** the forces that are acting on the system and omit those acting on objects that were not included in the system.

An example is given in the figure below. This is a problem that involves two blocks labeled A and B on which an external force \vec{F}_{app} is exerted.

We have the following "system" choices:

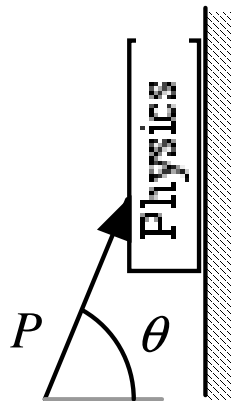
- System = block A + block B . The only horizontal force is \vec{F}_{app} .
- System = block A . There are now two horizontal forces: \vec{F}_{app} and \vec{F}_{AB} .
- System = block B . The only horizontal force is \vec{F}_{BA} .



Activity – Force Problems w/Table

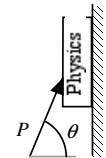
□ Example Problem

- A book of mass m is pushed against a smooth frictionless wall by a force P that makes an angle θ with the horizontal. Find (a) the normal force on the book and (b) its acceleration in terms of P , m , θ , and constants. (c) Look at limiting cases (large and small angles) to see if it makes sense.



Two Force Problems With Table

1. A book of mass m is pushed against a smooth frictionless wall by a force P that makes an angle θ with the horizontal. Find (a) the normal force on the book and (b) its acceleration in terms of P , m , θ , and constants. (c) Look at limiting cases (large and small angles) to see if it makes sense.



Free Body Diagram:

Force	x-component	y-component

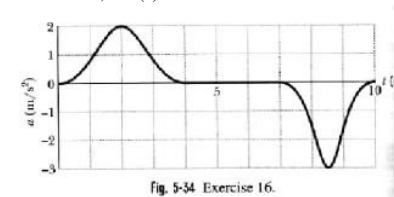
Activity – 1D Force Problems

□ Set-up and try problems 1, 3, and 5.

- Work individually
- Compare answers with group

1-D Force Problems

1. A 50 kg passenger rides in an elevator that starts from rest on the ground floor of a building at $t = 0$ and rises to the top floor during a 10 sec interval. The acceleration of the elevator as a function of the time is shown in the figure, where positive values of the acceleration mean that it is directed upward. Give the magnitude and direction of the following forces: (a) the maximum force on the passenger from the floor, (b) the minimum force on the passenger from the floor, and (c) the maximum force on the floor from the passenger.



2. A 29.0 kg child, with a 4.50 kg backpack on his back, first stands on a sidewalk and then jumps up into the air. Find the magnitude and direction of the force on the sidewalk from the child when the child is (a) standing still and (b) in the air. Now find the magnitude and direction of the net force on Earth due to the child when the child is (c) standing still and (d) in the air.
3. Boxes A and B, with masses m_A and m_B can move on a horizontal frictionless surface. You push horizontally with a push P on block A. (a) Find the acceleration of the boxes. (b) Find the force between the boxes. Answers may contain symbols already given plus any constants like g . (c) Suppose $m_A = 10$ kg and $m_B = 40$ kg, and $P = 100$ N. What are the numerical answers? (d) Suppose $m_A = 40$ kg and $m_B = 10$ kg, and $P = 100$ N. What are the numerical answers?
4. You have been hired to design the interior of a special executive express elevator for a new office building. This elevator has all the latest safety features and will stop with an acceleration of $g/3$ in case of any emergency. The management would like a decorative lamp hanging from the unusually high ceiling of the elevator. You design a lamp which has three sections which hang one directly below the other. Each section is attached to the previous one by a single thin wire which also carries the electric current. The lamp is also attached to the ceiling by a single wire. Each section of the lamp weighs 7.0 N. Because the idea is to make each section appear that it is floating on air without support, you want to use the thinnest wire possible. Unfortunately the thinner the wire, the weaker it is. To determine the thinnest wire that can be used for each stage of the lamp, calculate the force on each wire in case of an emergency stop.
5. Two blocks, masses m_1 and m_2 , are connected by an ideal string passing over an ideal pulley. One block is on a horizontal frictionless surface and the other can move vertically and only touches the string. Find the acceleration of each block and the tension in the string in terms of the masses and constants.