Introduction to Mechanics
Dynamics
Forces
Newton's Laws

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Last time

- another example
- relative motion and projectiles

Overview

- forces
- net force
- equilibrium
- free body diagrams
- Newton's first law
- inertia

Forces

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We did not consider what the causes of this motion might be. We now will think about that.

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We will understand **forces** as the cause of changes in the motion of objects.

Forces are a "push" or "pull" that an object experiences because of an interaction.

Forces are **vectors**.

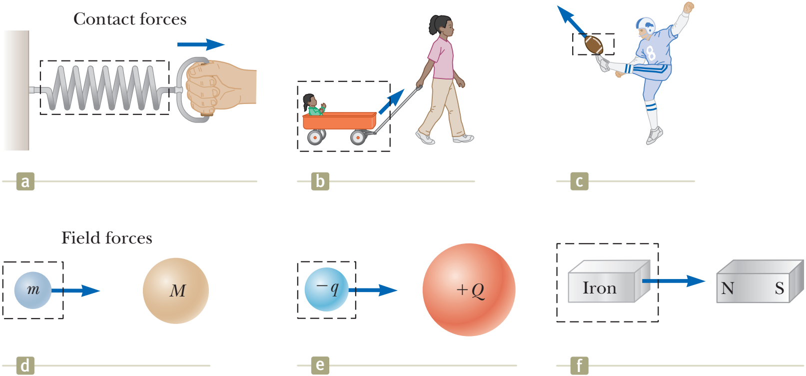
Forces

Two types of forces

- contact forces
  another object came into contact with the object
- field forces
  a kind of interaction between objects without them touching each other

Forces

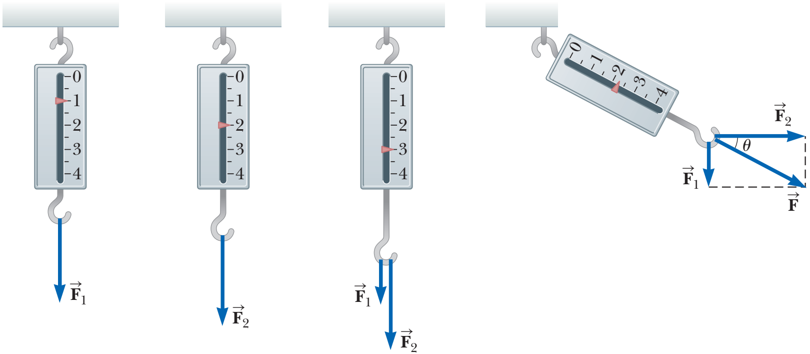
Force type examples:



[1]Serway & Jewett, “Physics for Scientists and Engineers”.

Forces are Vectors

We typically draw forces as vector arrows like this:



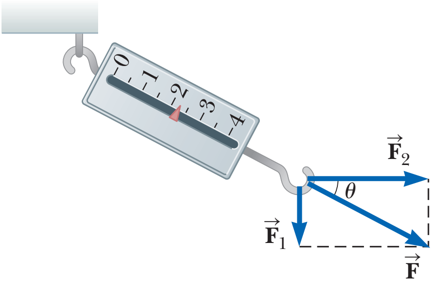
[1]Figure from Serway & Jewett.

Net Force

Net Force

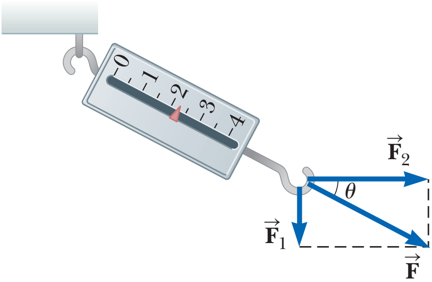
the vector sum of all forces acting on an object.

$$\vec{F}_{\text{net}} = \sum_i \vec{F}_i$$



In the diagram $\vec{F} = \vec{F}_1 + \vec{F}_2$.

Net Force



In the diagram $\vec{\mathbf{F}} = \vec{\mathbf{F}}_1 + \vec{\mathbf{F}}_2$.

The magnitude of $\vec{\mathbf{F}}$ is

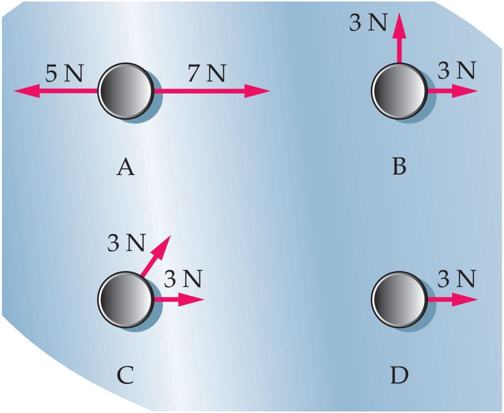
$$F = \sqrt{F_1^2 + F_2^2} = \sqrt{1^2 + 2^2} = 2.23 \text{ N}$$

The direction of $\vec{\mathbf{F}}$ is

$$\theta = \tan^{-1}(F_1/F_2) = 26.6^\circ$$

Net Force Question

A hockey puck is acted on by one or more forces, as shown. What is the net force on each puck?



In case C, assume that the forces make an angle of 60° to each other.

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[1]Figure from Walker, "Physics", page .

Net Force

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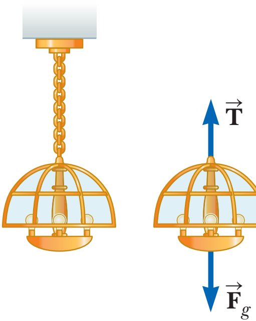
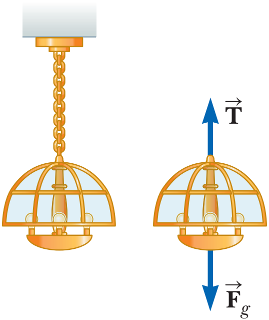
Net Force and Equilibrium

What is the net force on this lamp?



Net Force and Equilibrium

What is the net force on this lamp?



When the net force on an object is zero, we say that the object is in **equilibrium**.

Equilibrium

$$\vec{F}_{\text{net}} = \sum_i \vec{F}_i = 0$$

Diagrams of Forces

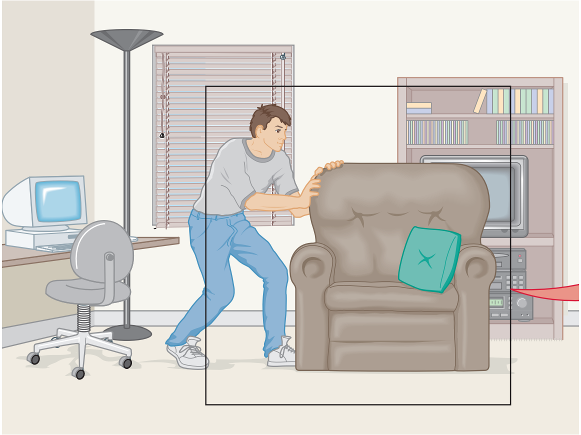
We can draw pictures to aid our reasoning. This is always a good idea.

The process will be to identify a **system** of interest. Something we want to study. We will make a mathematical model of it.

Everything that is not part of the system, but interacts with it, is part of the **environment**. We do not describe the environment mathematically.

Diagrams of Forces

This is a physical picture.

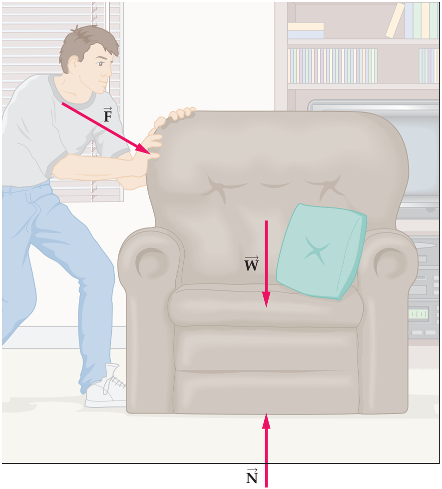


We need to identify the system we want to study. Here: the chair.

[1]Diagrams from Walker, "Physics".

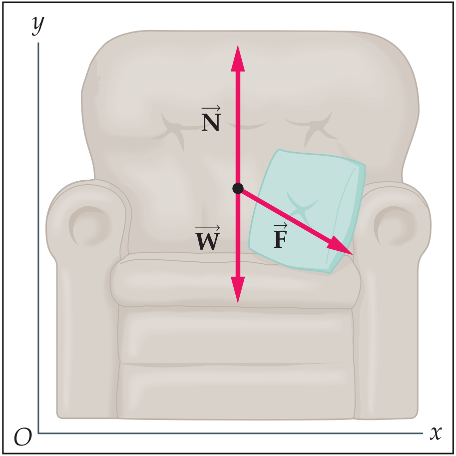
Diagrams of Forces

This is a physical picture, but now we consider the forces that act on the system (chair) from the environment (everything else).



Diagrams of Forces: Free-Body Diagram

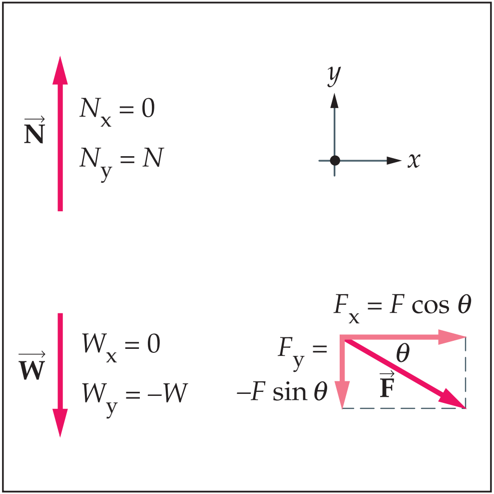
This is a free-body diagram. We represent the chair as a point-particle with force vectors pointing outward.



We also picked a coordinate system (x, y axes).

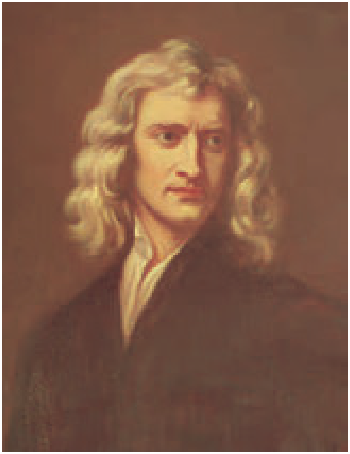
Diagrams of Forces: Free-Body Diagram

To analyze the forces, we must break them into components along our chosen axes.



Newton

Isaac Newton was able to articulate simple rules that govern the way in which forces act and effect motion.



Newton's First Law

Newton I (as commonly stated)

An object in motion will stay in motion with constant velocity and an object at rest will stay at rest, unless acted upon by a (non-zero) net force.

Velocity and Newton's First Law

If an object is in motion and there is zero net force on the object, does its speed have to be constant?

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Velocity and Newton's First Law

If an object is in motion and there is zero net force on the object, does its speed have to be constant?

Yes. What else?

The direction of motion.

Neither the speed or the direction of motion can change. The *velocity* is constant.

Galileo and Inertia

As we said earlier, Galileo had already proposed the idea of inertia when he considered balls rolling on inclined surfaces.

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As we said earlier, Galileo had already proposed the idea of inertia when he considered balls rolling on inclined surfaces.

Inertia (from the Latin word for *lazy*) is the tendency of objects to stay doing whatever they are already doing, unless they are interfered with.

Galileo's idea of inertia:

A body moving on a level surface will continue in the same direction at a constant speed unless disturbed.

Newton specifically understood the "disturbance" to be a net force.

Newton's First Law / Law of Inertia

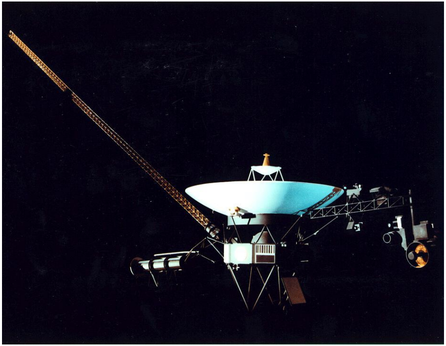
This does not really correspond with our expectation from daily life. In our everyday environment, everything seems to naturally slow to a stop.

[1] Figure from JPL.

Newton's First Law / Law of Inertia

This does not really correspond with our expectation from daily life. In our everyday environment, everything seems to naturally slow to a stop.

But we now know of other environments where there are very few resistive forces and we see this behavior.



[1]Figure from JPL.

Newton's First Law

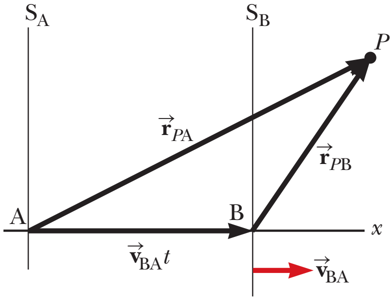
Newton I (another way to state it)

If an object does not interact with other objects, it is possible to identify a reference frame in which the object has zero acceleration. This is an inertial reference frame.

A zero-acceration reference frame is called an *inertial reference frame*.

Different Observers

Observer B is moving with velocity $\vec{\mathbf{v}}_{BA}$ relative to observer A. Suppose observer A sees the particle P at rest. Observer B sees it moving, with velocity $-\vec{\mathbf{v}}_{BA}$.



Both agree that Newton's first law holds for P!

Newton's First Law Implications

Question[1] Which of the following statements is correct?

I. It is possible for an object to have motion in the absence of forces on the object.
II. It is possible to have forces on an object in the absence of motion of the object.

A I. only

B II. only

C Neither I. or II.

D Both I. and II.

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[2]Serway & Jewett, Physics for Scientists and Engineers, p114.

Newton's First Law Implications

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Summary

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- net force
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Homework

Walker Physics:

- Read ahead in Ch 5.