Dynamics
Laws of Motion

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Overview

- uniform and nonuniform circular motion

Overview

- introduce forces
- Newton's Laws! (1st & 2nd)
- mass and weight

Forces!

Dynamics: why do objects change their motion?

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Dynamics: why do objects change their motion?
A force is a “push” or a “pull” that an object experiences.

Forces are connected to acceleration of an object that has mass.
Unbalanced forces cause an acceleration.

Forces are **vectors**.

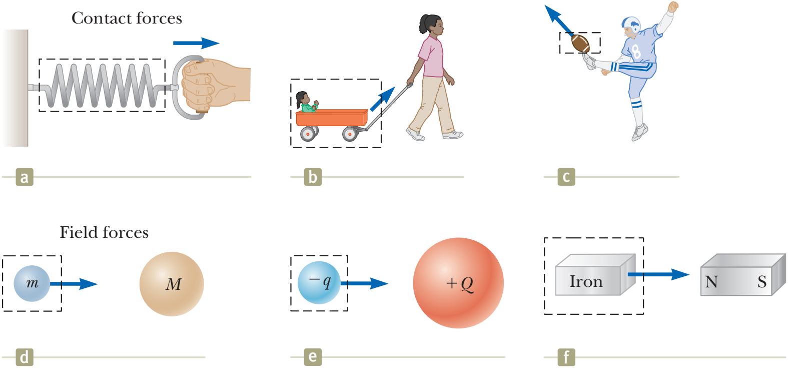
Forces

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

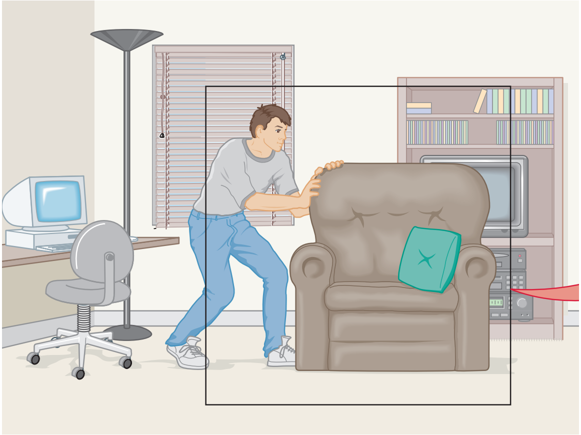
Force type examples:



[1]Serway & Jewett

Diagrams of Forces

This is a physical picture.

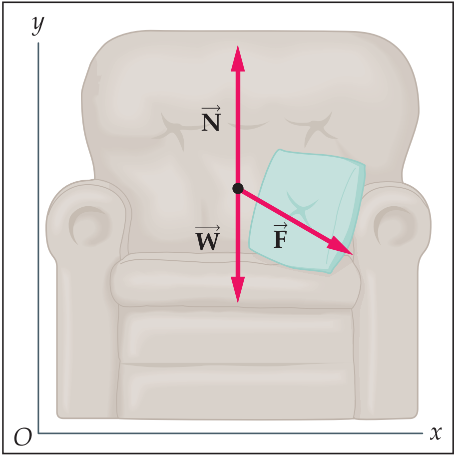


We need to identify the system we want to study. Here: the chair.

[1] Diagrams from Walker, "Physics".

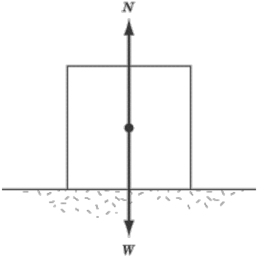
Diagrams of Forces: Free-Body Diagram

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).

Forces are Vectors



$\uparrow +y$

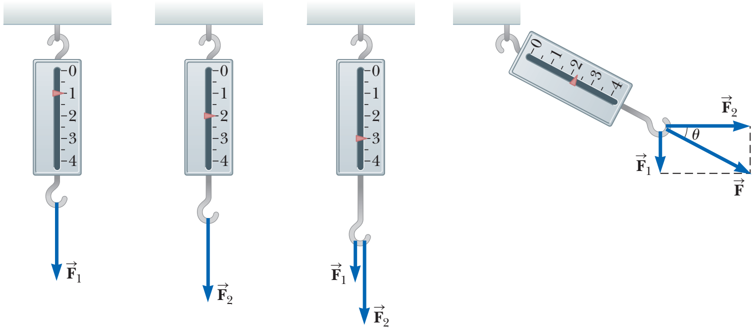
$$\vec{\mathbf{N}} + \vec{\mathbf{W}} = (N - W)\,\hat{\mathbf{j}} = 0$$

or sometimes written

$$\vec{\mathbf{F}}_n + \vec{\mathbf{F}}_g = (F_n - F_g)\,\hat{\mathbf{j}} = 0$$

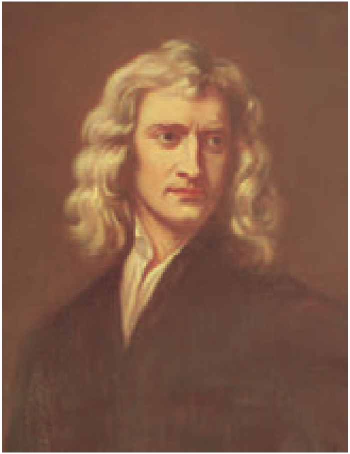
[1]Figure from www.sparknotes.com

Forces are Vectors



Newton's Laws

The simple rules that govern the way in which forces act and effect motion.



Newton's First Law

Newton I (as commonly stated)

In an inertial reference frame, an object in motion tends to stay in motion (with constant velocity) and an object at rest tends to stay at rest, unless acted upon by a nonzero net force.

Newton I (textbook version)

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

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

Newton's First Law

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

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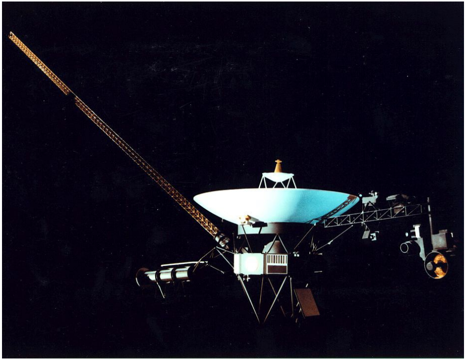
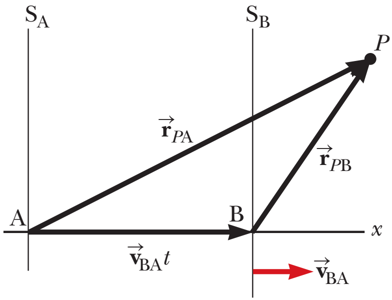
But we now know of other environments where we see this behavior.



[1]Figure from JPL.

Different Observers

Observer A is at rest and observer B is moving with constant relative velocity $\vec{\mathbf{v}}_{BA}$. 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!

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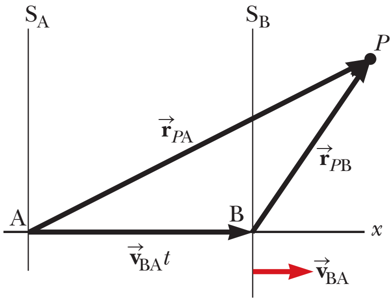

Both agree that Newton's first law holds for P!

(But if B is in an accelerated frame, what does he see?)

Newton's First Law Implications

Quick Quiz 5.1[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.

[1] S&J page 114

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[1] S&J page 114

Newton's Second Law

The really important one.

Newton II

In an inertial reference frame, the sum of the forces (net force) on an object is equal to the mass of the object times its acceleration:

$$\vec{\mathbf{F}}_{\text{net}} = m\,\vec{\mathbf{a}}$$

$\vec{\mathbf{F}}_{\text{net}} = \sum_i \vec{\mathbf{F}}_i$ where $\vec{\mathbf{F}}_i$ are individual separate forces that we sum to get the net force.

(This expression assumes the mass of the object is constant!)

Newton's Second Law

$$\vec{\mathbf{F}}_{\text{net}} = m\,\vec{\mathbf{a}}$$

Acceleration is directly proportional to the net force and in the same direction. The constant of proportionality is the mass, m.

$$\vec{\mathbf{F}}_{\text{net}} \propto \vec{\mathbf{a}}$$

Alternatively, given a net force, the magnitude of the acceleration is inversely proportional to the mass of the object.

$$a \propto \frac{1}{m}$$

Units of Force

Newton's second law gives us units for force.

$$\begin{aligned} F_{\text{net}} &= ma \\ \text{Newtons, N} &= (\text{kg})\ (\text{ms}^{-2}) \end{aligned}$$

$1\text{N} = 1$ kg m s^{-2}: on Earth's surface there are roughly 10 N of weight per kg of mass. Why?

Newton's Second Law Implications

Question. If an object is not accelerating, can there be forces acting on it?

A Yes.

B No.

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Newton's Second Law Implications

Question. If an object with mass 16 kg is acted upon by two forces, $\vec{\mathbf{F}}_1 = -(10\text{N})\hat{\mathbf{i}}$ and $\vec{\mathbf{F}}_2 = (2\text{N})\hat{\mathbf{i}}$, what is the object's acceleration?

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B $+\frac{3}{4}\ \text{ms}^{-2}\,\hat{\mathbf{i}}$.

C $-\frac{3}{4}\ \text{ms}^{-2}\,\hat{\mathbf{i}}$.

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Quick Quiz 5.3.[2] You push an object, initially at rest, across a frictionless floor with a constant force for a time interval Δt, resulting in a final speed of v for the object. You then repeat the experiment, but with a force that is twice as large. What time interval is now required to reach the same final speed v?

A $4\Delta t$

B $2\Delta t$

C $\frac{\Delta t}{2}$

D $\frac{\Delta t}{4}$

[2] S&J page 116.

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It happens to be equal to *gravitational mass*, because the strength of gravitational interactions depends on mass. (More on this later...)

The Difference between Mass and Weight

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Mass is a measure of inertia. Weight is a force an object experience due to a gravitational interaction.

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A measure of the amount of matter in an object. Also, a measure of the inertia of an object, that is, its resistance to changes in its motion.

weight

The force due to gravity on an object.

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Weight F_g,

$$F_g = mg$$

Units: Newtons.

Summary

- Newton's 1st & 2nd laws
- mass and weight

Quiz tomorrow, relative and/or circular motion.

(Uncollected) Homework Serway & Jewett,

- Ch 5, onward from page 136. Obj Ques: 1; Problems 3, 5, 7, 9, 11, 15, 17, 19