Mechanics
Newton's Laws

Lana Sheridan

De Anza College

Oct 15, 2018

Last time

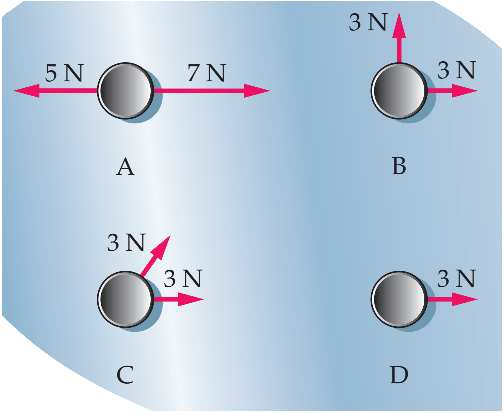
- circular motion
- force
- net force

Overview

- net force example
- Newton's first law
- Newton's second law
- mass vs weight
- force diagrams

Net Force Question

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

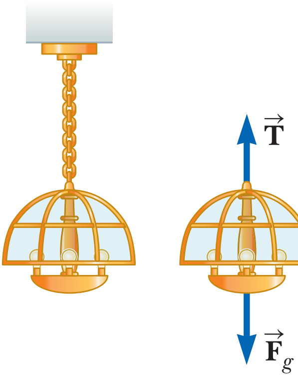


In case C, assume that the forces make an angle of 60° to each other.

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

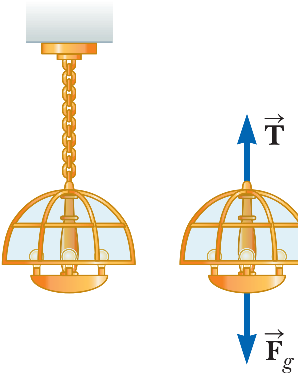
Net Force and Equilibrium

What is the net force on this lamp?



Net Force and Equilibrium

What is the net force on this lamp?



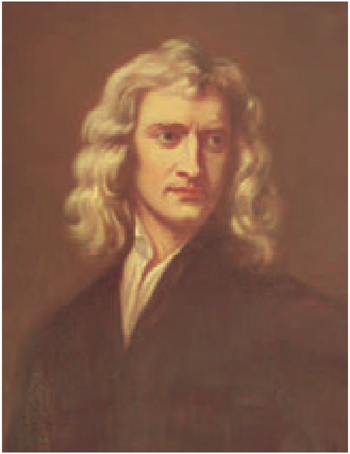
When the net force on an object is zero:

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

we say that the object is in **equilibrium**.

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.

An "object" for these purposes is something with mass.

Velocity and Newton's First Law

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

Velocity and Newton's First Law

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

Both are constant!

Neither the speed or the direction of motion can change.

Galileo and Inertia

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

Galileo and Inertia

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

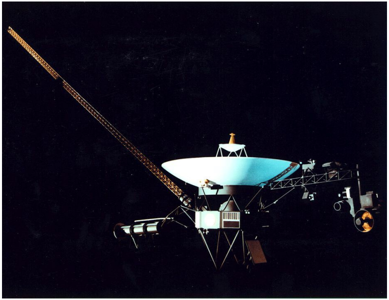
This was a really radical idea in the 1600s. In our everyday environment, everything seems to naturally slow to a stop.

[1] Figure from JPL.

Newton's First Law

This was a really radical idea in the 1600s. 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.

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

[1]The situation is different in the theory of general relativity.

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.

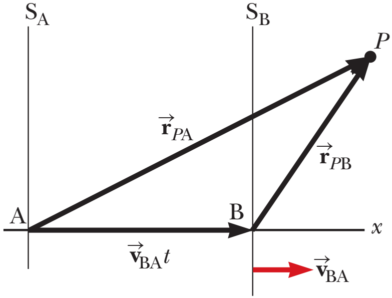
A zero-acceleration reference frame is called an *inertial reference frame*.

All frames that move with constant velocity relative to an inertial frame, are also inertial frames.[1]

[1] The situation is different in the theory of general relativity.

Different Observers

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



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

Newton's laws hold in inertial frames.

Newton's First Law Implications

Question[2] 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.

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

Newton's First Law Implications

Question[2] 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. $\leftarrow$

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

Newton's Second Law

Galileo also proposed the concept of acceleration, but Newton realized:

$$\text{acceleration} \propto \text{net Force}$$

(Remember net force is the sum of all the forces on an object)

If the net force on an object is doubled, the acceleration is twice as big also.

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:

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

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

(We are assuming the mass of the object is constant.)

Newton's Second Law

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

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

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

Units of Force

Newton's second law gives us units for force.

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

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

Mass vs. Weight

mass, m

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.

Weight is a force. It is measured in Newtons (N) as are all forces.

$$\text{weight} = mg$$

Weight depends on mass, m. The mass that appears in the equation above is sometimes called the "gravitational mass".

Mass is an amount of "stuff", measured in kilograms (kg).

Mass and Inertia

Mass is also a measure of resistance to acceleration.

For a constant net applied force:

$$\text{acceleration} \propto \frac{1}{\text{mass}}$$

The mass, m, in the equation $\mathbf{F}_{\text{net}} = m\mathbf{a}$ is sometimes called "inertial mass".

Weight and acceleration

Let the weight of an object be written F_g.

$$F_g = mg$$

Mass in this equation is sometimes called “gravitional mass”.

Weight and acceleration

Let the weight of an object be written F_g.

$$F_g = mg$$

Mass in this equation is sometimes called "gravitional mass".

We can find the acceleration of an object when the only force on it is due to gravity:

$$a = \frac{F_g}{m} = \frac{mg}{m} = g$$

Weight and acceleration

Let the weight of an object be written F_g.

$$F_g = mg$$

Mass in this equation is sometimes called "gravitional mass".

We can find the acceleration of an object when the only force on it is due to gravity:

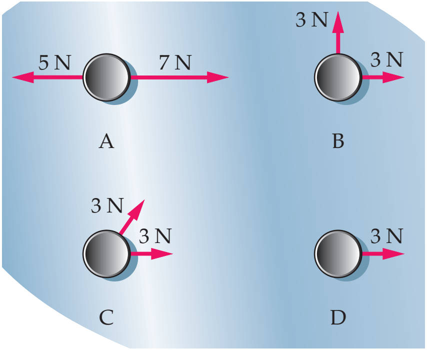
$$a = \frac{F_g}{m} = \frac{mg}{m} = g$$

As we would expect! This is because the inertial mass is the same as the gravitational mass.

That is why all objects, no matter their mass, fall at the same rate (with the same acceleration).

Question

A hockey puck is acted on by one or more forces, as shown. Rank the four cases, A, B, C, and D, in order of the magnitude of the puck's acceleration, starting with the smallest. Ties are shown in brackets.



A A, B, C, D

B D, C, B, A

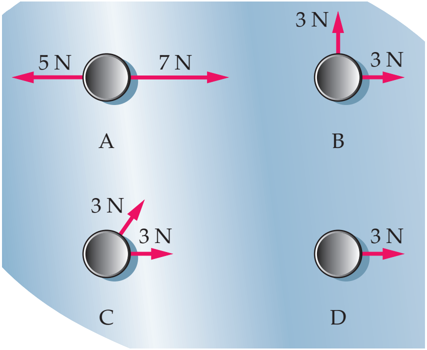
C A, D, B, C

D D, (B and C), A

[1] Walker, "Physics", page .

Question

A hockey puck is acted on by one or more forces, as shown. Rank the four cases, A, B, C, and D, in order of the magnitude of the puck's acceleration, starting with the smallest. Ties are shown in brackets.



A A, B, C, D

B D, C, B, A

C A, D, B, C ←

D D, (B and C), A

[1]Walker, "Physics", page .

Diagrams of Forces

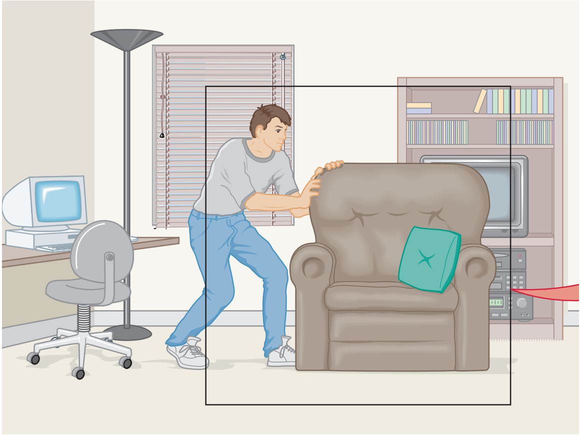
We can draw pictures to aid our reasoning. This is always a good idea.

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.

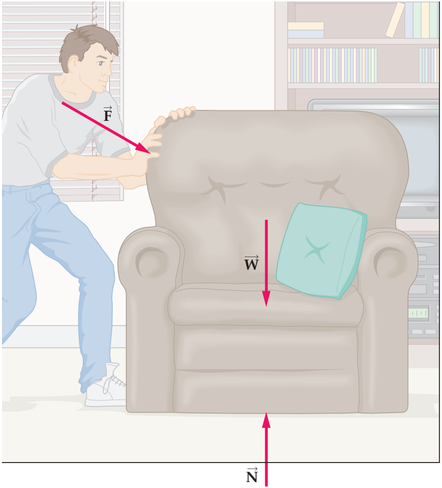


We need to identify the system we want to study. Here: the chair.

[1]Diagrams from Walker, "Physics".

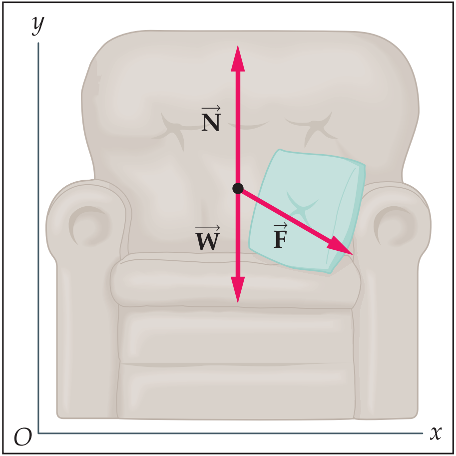
Diagrams of Forces

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

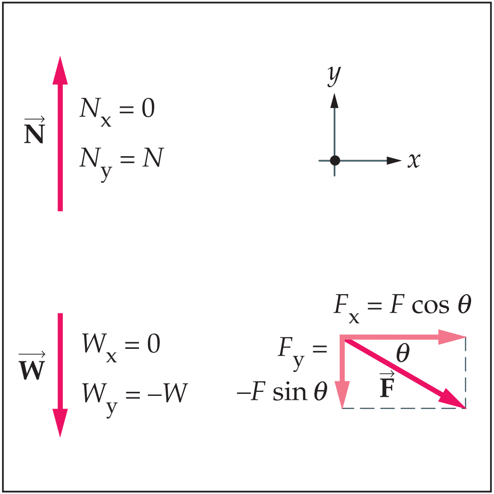
This is a free-body diagram. We represent the chair as a point-particle with force vectors pointing outward.



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

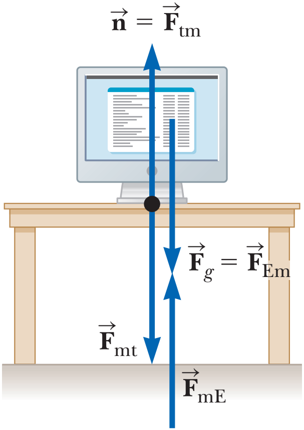
Diagrams of Forces: Free-Body Diagram

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



Diagrams of Forces

We can choose our system to be more than one object. This is three interacting objects, a monitor sitting on a table, on the Earth:



[1]Figure from Serway & Jewett.

Force Diagrams

We could later refine our system into pieces. Here is a depiction of the forces that act on a single object, the monitor.

Summary

- Newton's 1st and 2nd laws

Midterm on Thursday, Oct 18.

Homework

- Ch 5 Ques: 1, 5; Probs: 5, 7, 25, 27
- will be set this week: Ch 5 Ques: 9; Probs: 17, 29, 31, 33, 39, 45, 49, 53, 55, 87