Newton’s Laws of Motion

Examining what *causes* objects to accelerate.

Newton's 1st Law of Motion

An object at rest will remain at rest and an object in motion will continue to move at constant velocity unless acted upon by an unbalanced *force*.

"Things tend to keep on doing
what they are already doing."

Restatement of Galileo's Principle of Inertia

What is *Inertia*?

Inertia is the property of an object to resist changes in it state of motion.

In other words,

"Everything in the universe is lazy."

Mass:

A quantitative measure of an object's inertia.

Standard for mass: "1.0 kilogram"

How to Define *Force*?

- Put the standard 1.0 kg mass on a spring.
- Pull it until (by trial and error) an acceleration of 1.0 m/s^2.
- We then define the force exerted on the mass by the spring to be “1.0 Newton.”
- Define 2.0 N as the amount of force needed to accelerate the standard kilogram at 2.0 m/s^2.
- Use experiment to prove that force is a vector.

Types of forces

Forces arise because of some interaction between two objects.

Four fundamental forces:

- Gravity: Responsible for what we feel as weight.
- E&M: Responsible for Tension, Normal, Friction
- Nuclear Weak: Governs radioactive decay.
- Nuclear Strong: Binds quarks and atomic nuclei.

Newton's 2nd Law of Motion

The acceleration of an object is directly proportional to the net force acting on the object and inversely proportional to the mass of the object.

$$\vec{a} = \frac{\sum \vec{F}}{m} \quad \text{or} \quad \sum \vec{F} = m\vec{a}$$

Note: There are 3 independent equations here:

$$\sum \vec{F}_x = m\vec{a}_x, \quad \sum \vec{F}_y = m\vec{a}_y, \quad \sum \vec{F}_z = m\vec{a}_z.$$

Newton's 3rd Law of Motion

When an object exerts a force on another object, the other object exerts an equal and opposite force back on the first object.

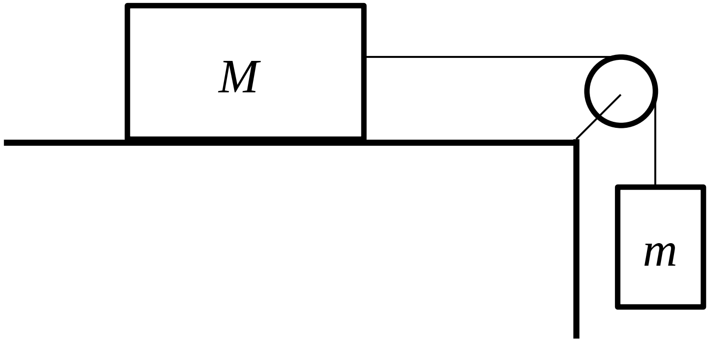
For every "action" there is an equal and opposite "reaction."

$$\vec{F}_{AB} = -\vec{F}_{BA}$$

The 3rd law tells us about the forces, not about the motion. (We need to 2nd law to get that information.)

Example #1

Consider the system shown below. The pulley and the surfaces are frictionless. The string is of negligible mass.

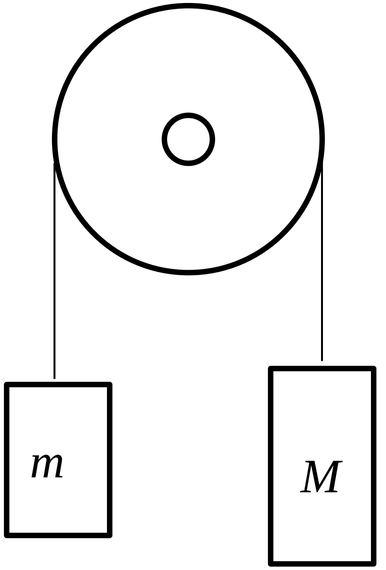


- What is the acceleration of this system?
- What is the tension in the string?

Example #2

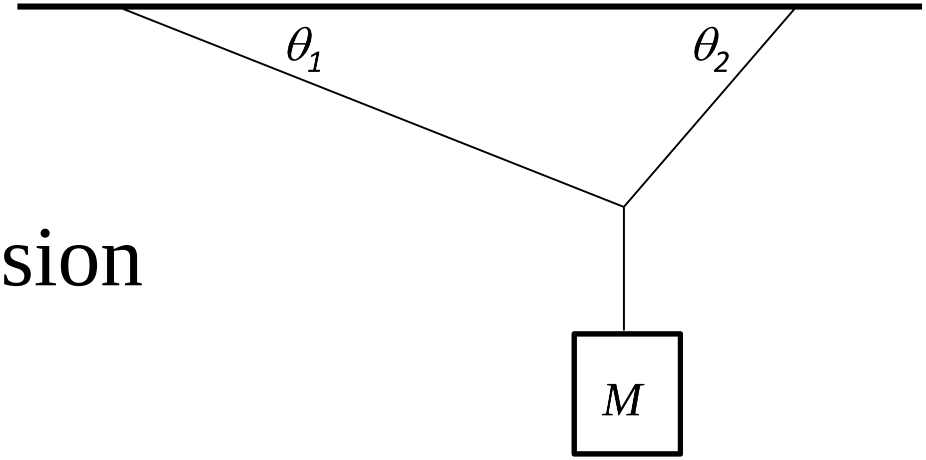
"Atwood's machine" consists of two masses connected by a cord of negligible mass draped over a pulley (assumed frictionless).

- Determine the acceleration of the system.
- Determine the tension in the cord.



Example #3

The mass (M = 15 kg) is being supported by the three cords as shown below. The angles are θ_1 = 28^o and θ_2 = 47^o.



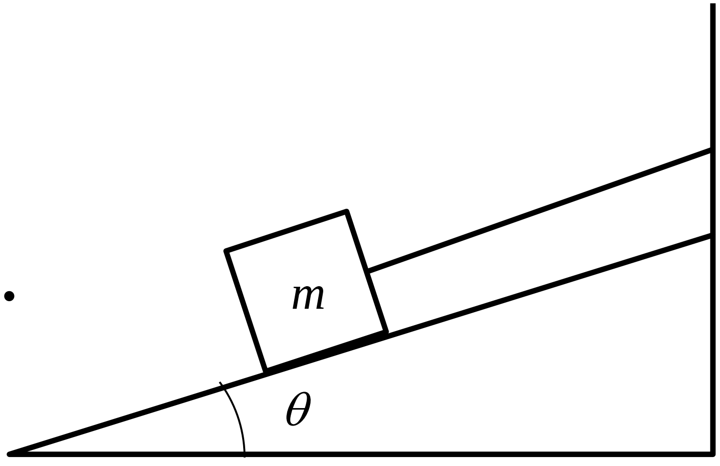
- Calculate the tension in each cord.

Example #4

A block having a mass of 15 kg is held in place on a ramp that makes an angle of 27° with the horizontal by a cord that is parallel to the incline.

There is no friction.

- Find the tension in the cord.
- Find the force exerted on the block by the ramp.



Example #5

A block of (M = 33 kg) is being pushed by someone with a horizontal stick of (m = 3.2 kg). The block slides a distance (d = 0.77 m) in a time (t = 1.7 s). There is no friction between the block and the tabletop.

- Identify “action-reaction” pairs of forces.
- What force must the person apply to the stick?
- What force does the stick apply to the block?
- Calculate the net force on the stick.