Course announcement

- Homework set 1 has been posted on eLearn. It will be due on next Friday(10/7) at 5PM. No late homework will be accepted.
- There are 5 points in Homework set 1. The homework points will directly be added to final grades.

GENERAL PHYSICS B 1
NEWTON'S LAW

Newton's First and Second Law II

2022/09/30

Newton’s first and second law

- **Newton’s first law of motion:** A body in uniform motion remains in uniform motion, and a body at rest remains at rest, unless acted on by a nonzero net force ($\overrightarrow{F_{net}} \neq 0$) .
- **Newton’s second law**: The net force on a body is

$$\overrightarrow{F_{net}} = \frac{d\vec{p}}{dt}$$

When mass is constant, Newton’s second law becomes:

$$\overrightarrow{F_{net}} = m\vec{a}$$

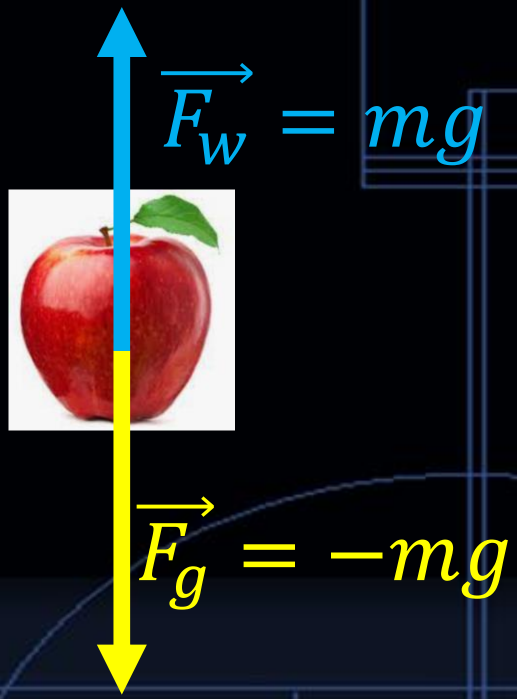
Topics

- Some particular forces
- Application of Newton’s second law
- Equation of motion
- Newton’s third law

Gravitational force and weight

- Suppose a body of mass m is in free fall with the free-fall acceleration of magnitude g. Then, if we neglect the effects of the air, the only force acting on the body is the gravitational force $\overrightarrow{F_g}$. SI Unit: Newton.

- The weight W of a body is the magnitude of the net force required to prevent the body from falling freely, as measured by someone on the ground. SI Unit: Newton.



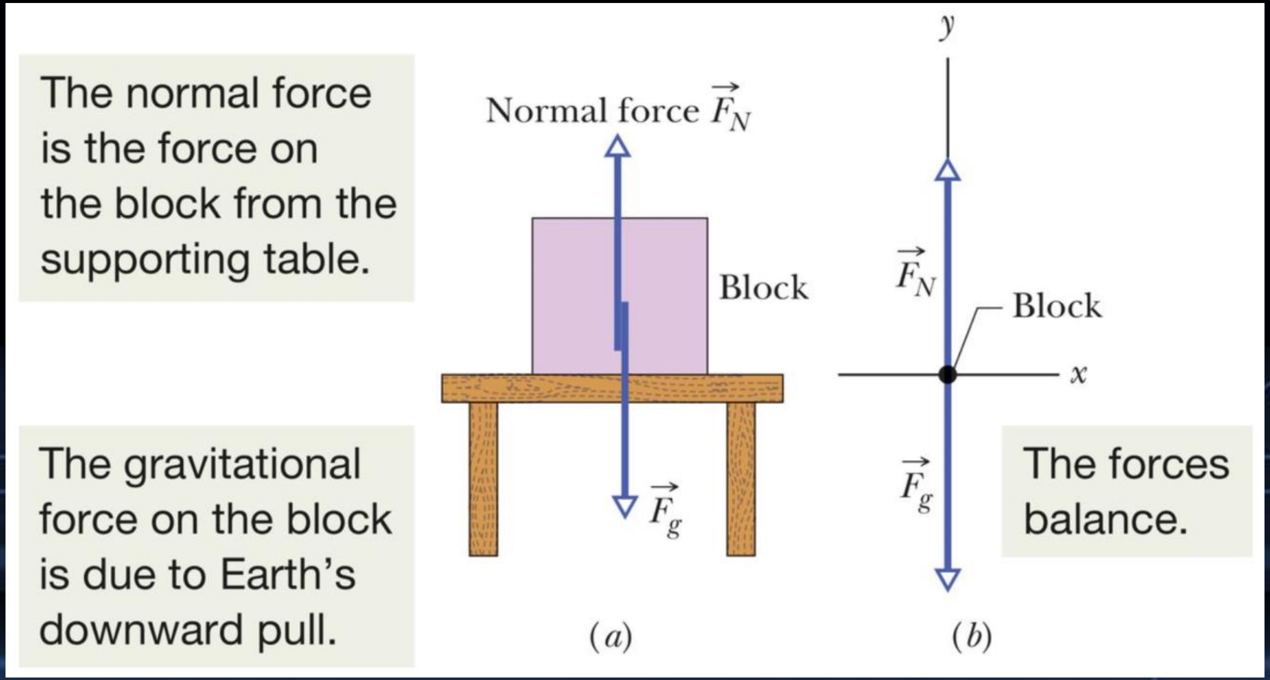
The Force of Gravity: Mass and Weight

- **Weight** is the force of gravity on an object. Since all objects in free fall, fall with a downward acceleration $\vec{g}$ we can infer the weight of a mass *m* using Newton's second law: $\overrightarrow{W} = m\vec{g}$
- Weight depends on gravity so varies with location:
  - Weight is different on different planets.
  - Near Earth's surface, $\vec{g} = 9.8m/s^2$ and is downward.

https://giphy.com/explore/walking-on-the-moon

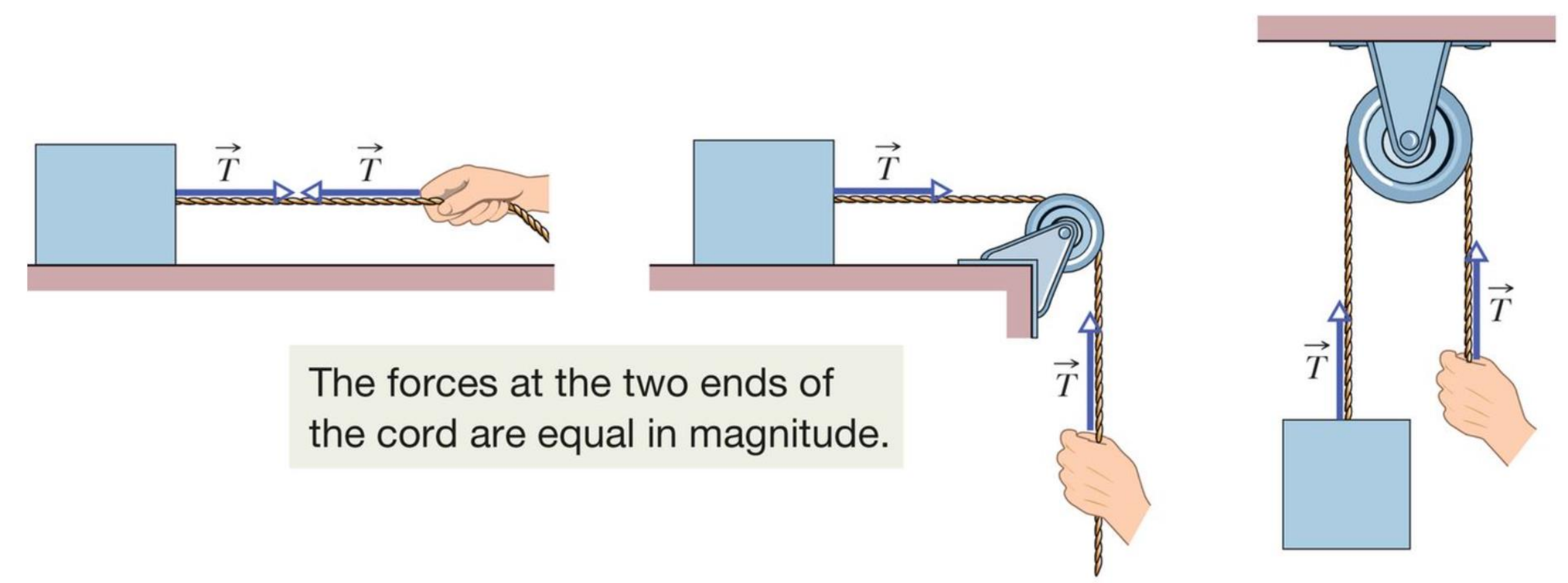
Normal force

- When a body presses against a surface, the surface (even a seemingly rigid one) deforms and pushes on the body with a normal force $\overrightarrow{F_N}$ that is perpendicular to the surface.



Tension

- When a cord (or a rope, cable, or other such object) is attached to a body and pulled taut, the cord pulls on the body with a tension force $\vec{T}$ directed away from the body and along the cord.

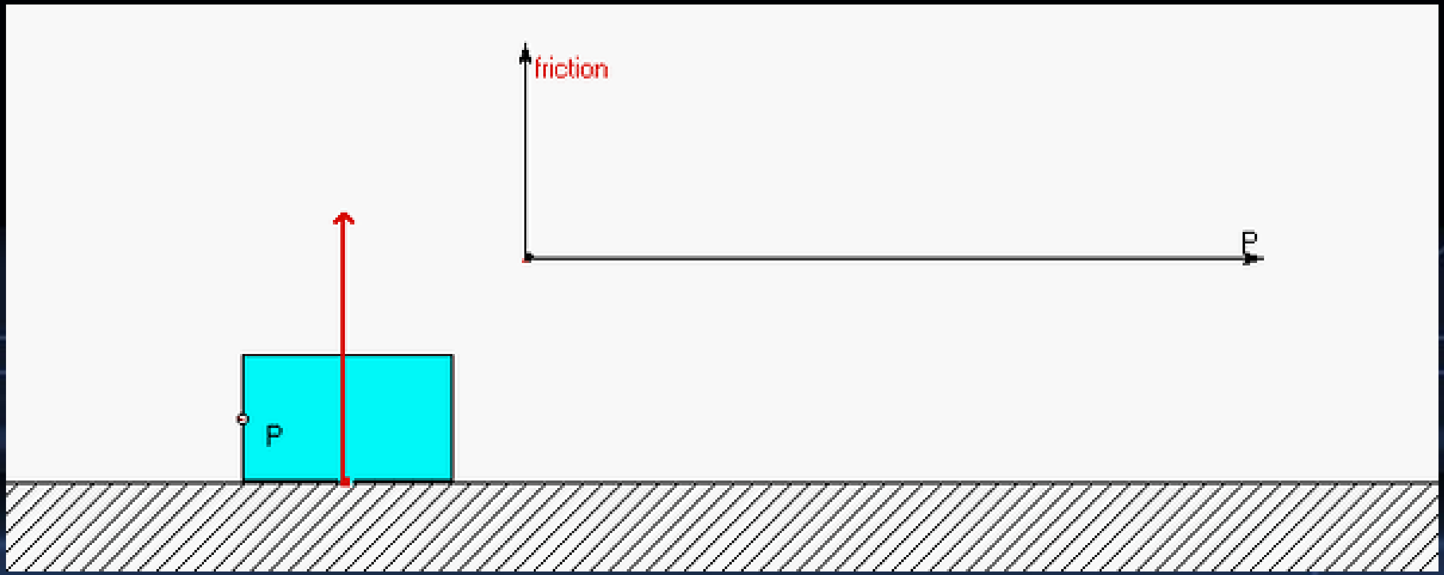


Frictional force

- If we either slide or attempt to slide a body over a surface, the motion is resisted by a bonding between the body and the surface. (We discuss this bonding more in the next chapter.) The resistance is considered to be a single force $\vec{f}$ called either the frictional force or simply friction.

Two types of frictions: static and kinetic

- Static friction: If the body does not move, then the static frictional force $\overrightarrow{f_s}$ and the component of $\vec{F}$ that is parallel to the surface balance each other. They are equal in magnitude, and $\overrightarrow{f_s}$ is directed opposite that component of $\vec{F}$.



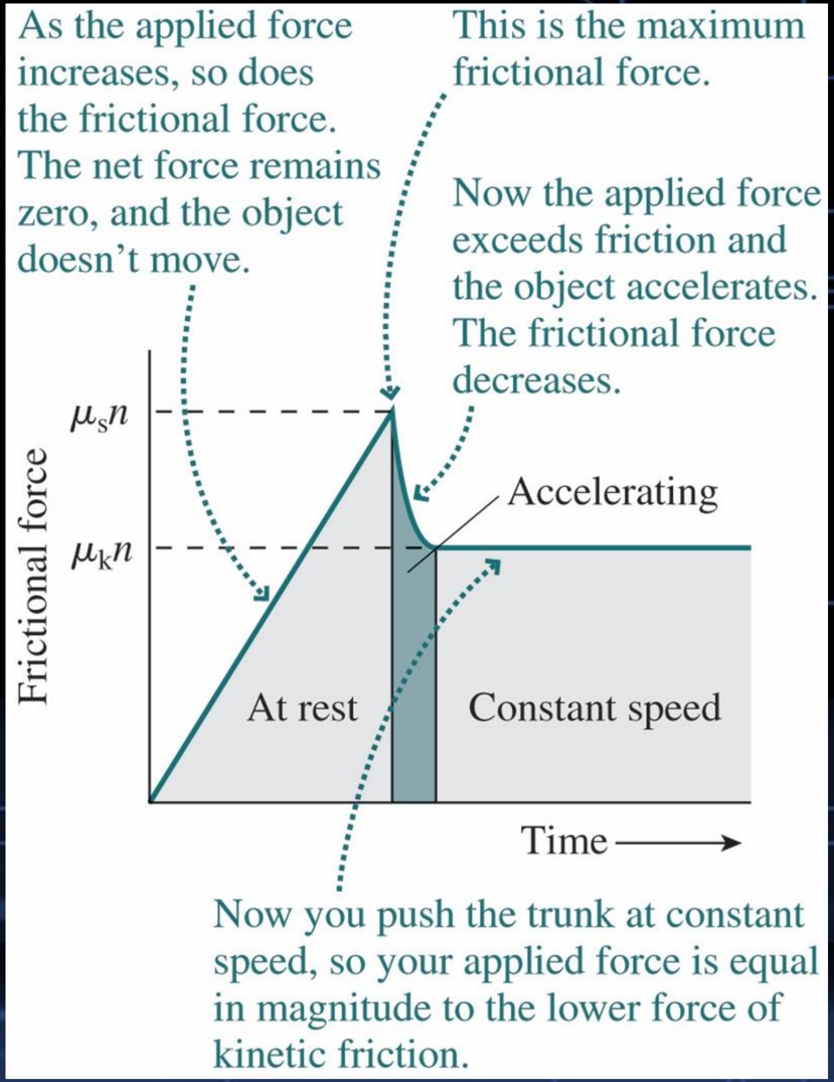
https://www.purdue.edu/freeform/statics/friction-on-sliding-block/

Two types of frictions: static and kinetic

- The magnitude of $\vec{f_s}$ has a maximum value $f_{s,max}$ that is given by

$$f_{s,max} = \mu_s \cdot n$$

where μ_s is the coefficient of static friction and n is the magnitude of the normal force on the body from the surface.

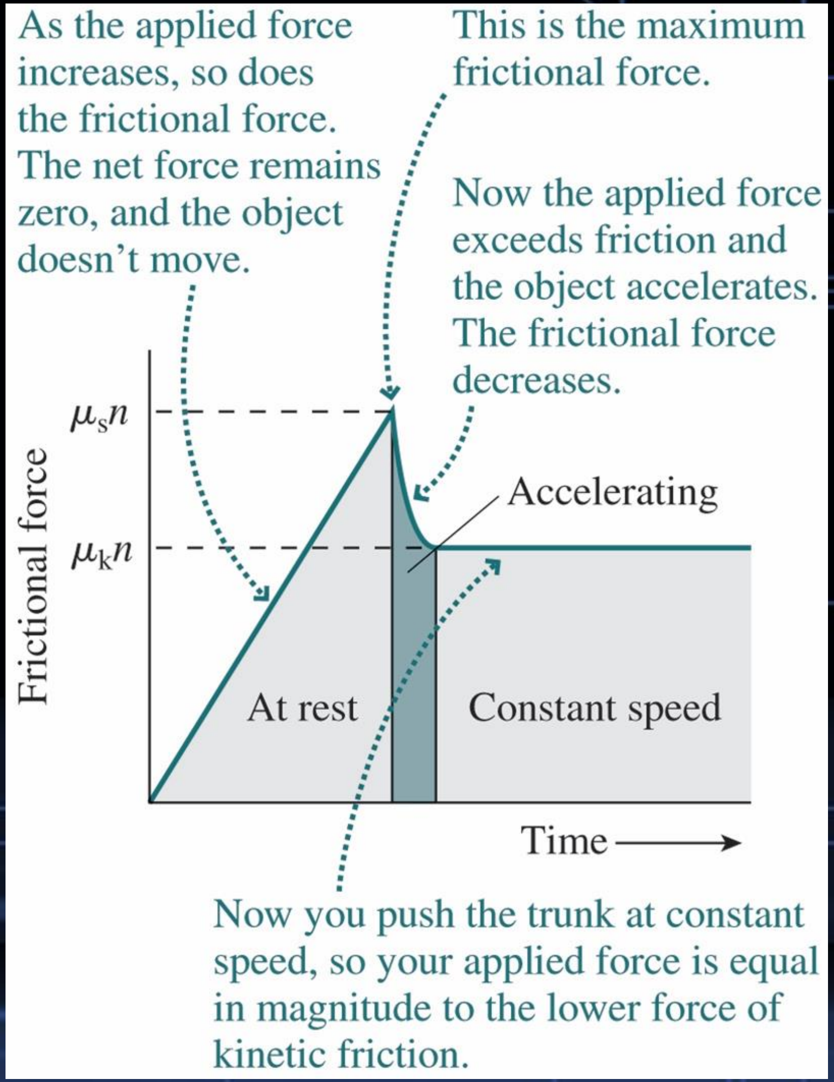


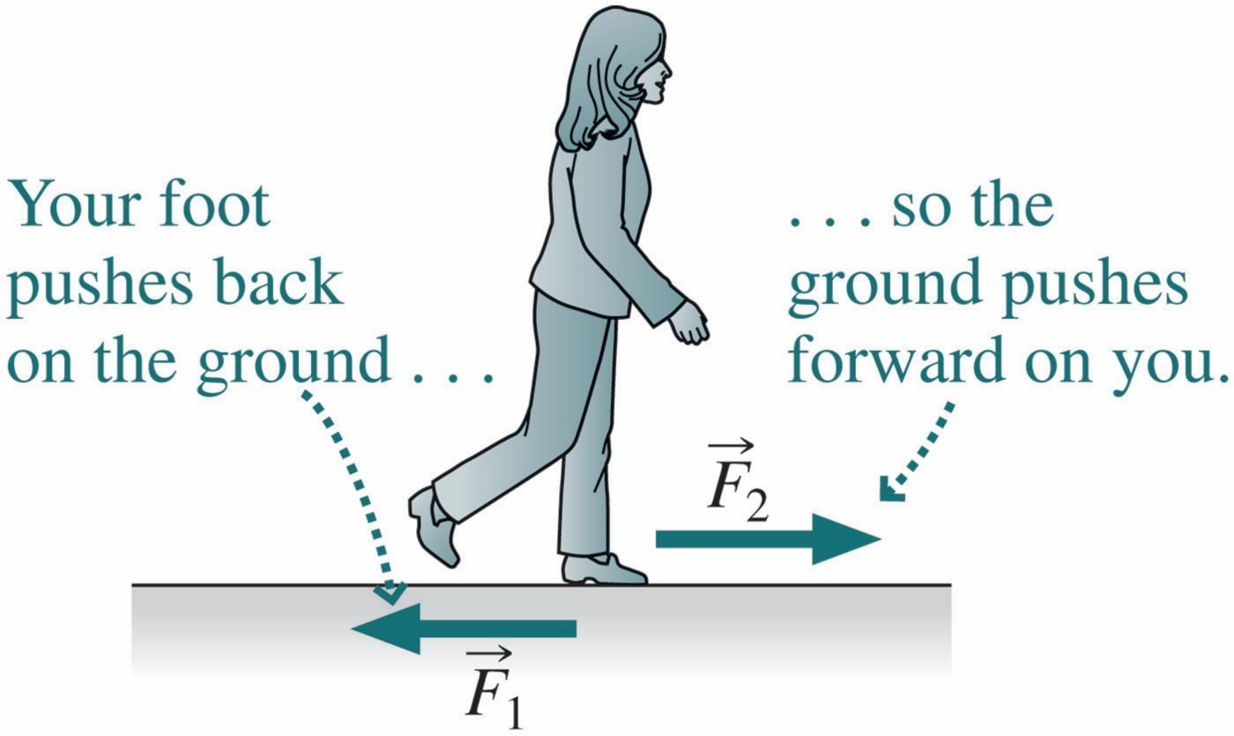
Two types of frictions: static and kinetic

- Kinetic friction: If the body begins to slide along the surface, the magnitude of the frictional force rapidly decreases to a value f_k given by

$$f_k = \mu_k \cdot n$$

where μ_k is the coefficient of kinetic friction.



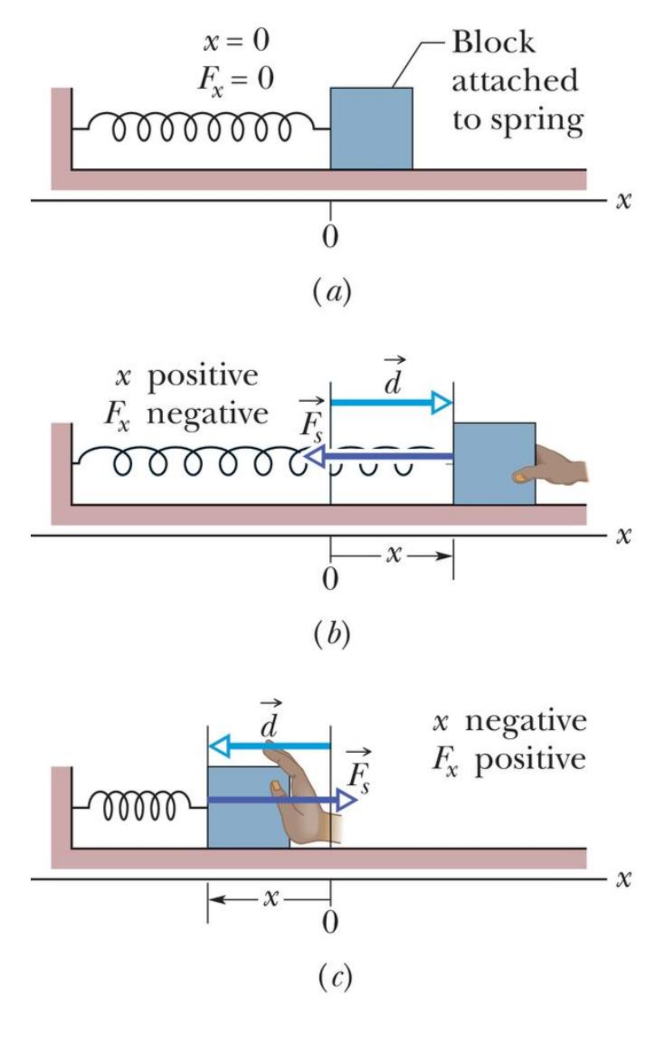


https://media.giphy.com/media/BvBEozfsXWWHe/giphy.gif

Walking would be impossible without friction!

Spring force

- **Spring force:** To a good approximation for many springs, the force $\vec{F_s}$ from a spring is proportional to the displacement $\vec{d}$ of the free end from its position when the spring is in the relaxed state. The spring force is given by $\vec{F_s} = -k\vec{d}$, which is known as Hooke's law.



Application of Newton's second law

Recipe of applying Newton's second law to analyze motion of an object:

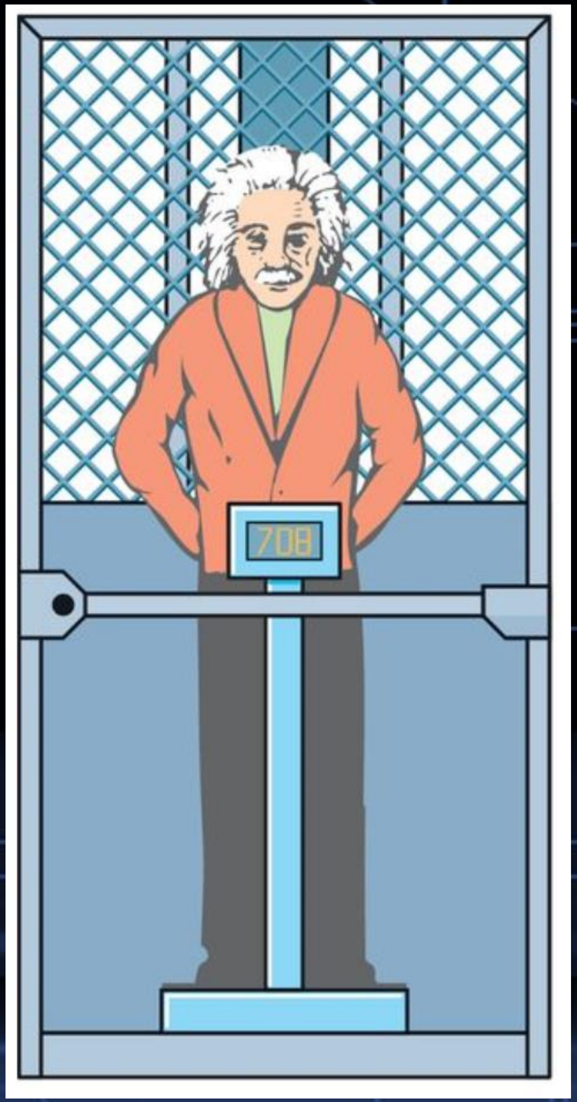
- Draw free body diagram of the object and plot out all the forces.
- Analyzing the net force applying on the object.
- Applying Newton's law to link the net force to acceleration and thus other quantities of kinetics.

Example: weight in an elevator

https://youtu.be/_Fay3_mRpzc

Example: weight in an elevator

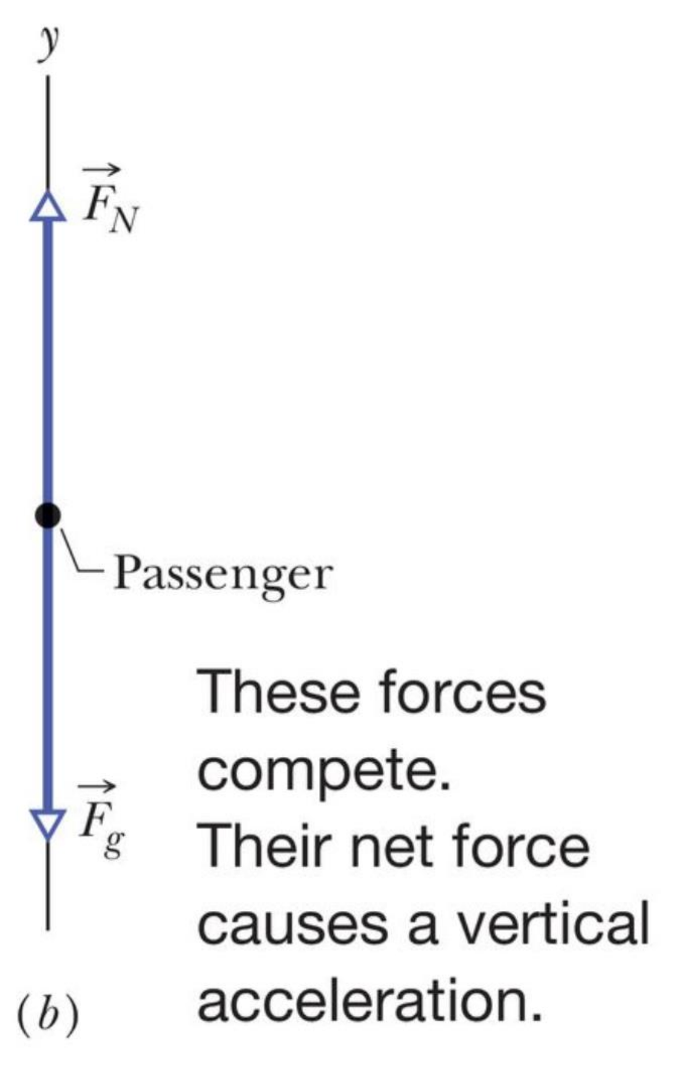
- a passenger of mass m stands on a platform scale in an elevator cab. We are concerned with the scale readings when the cab is stationary and when it is moving up or down. Find a general solution for the scale reading, whatever the vertical motion of the cab.



Example: weight in an elevator

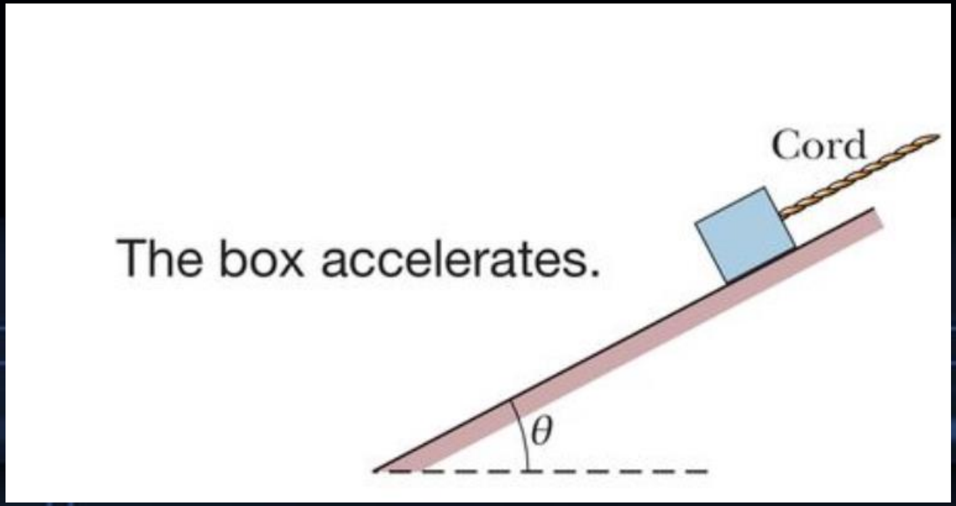
- The free-body diagram for the passenger, showing the normal force on him from the scale and the gravitational force: $F_N - F_g = ma$
- The scale reading is equal to normal force magnitude F_N, depends on the vertical acceleration. Substituting mg for F_g, we got:

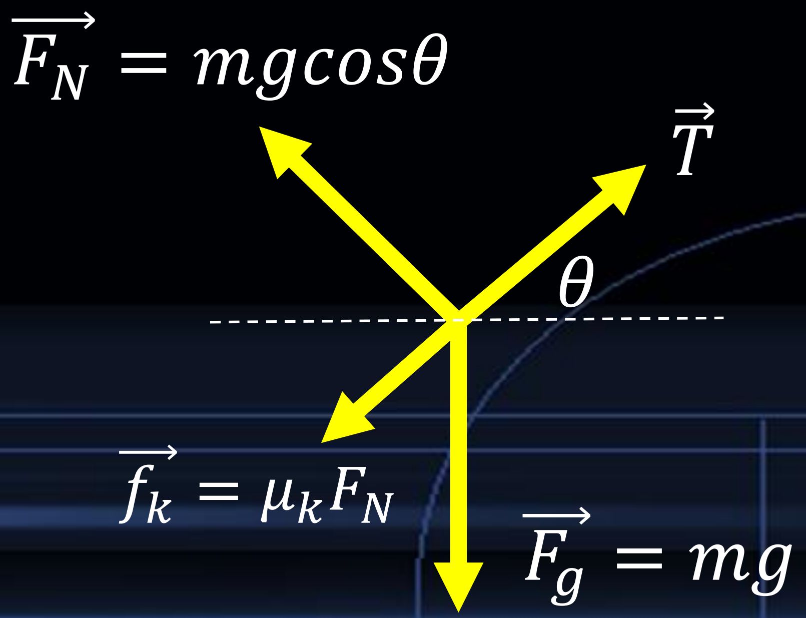
$$F_N = m(g + a)$$



Example 2: motion on a slope

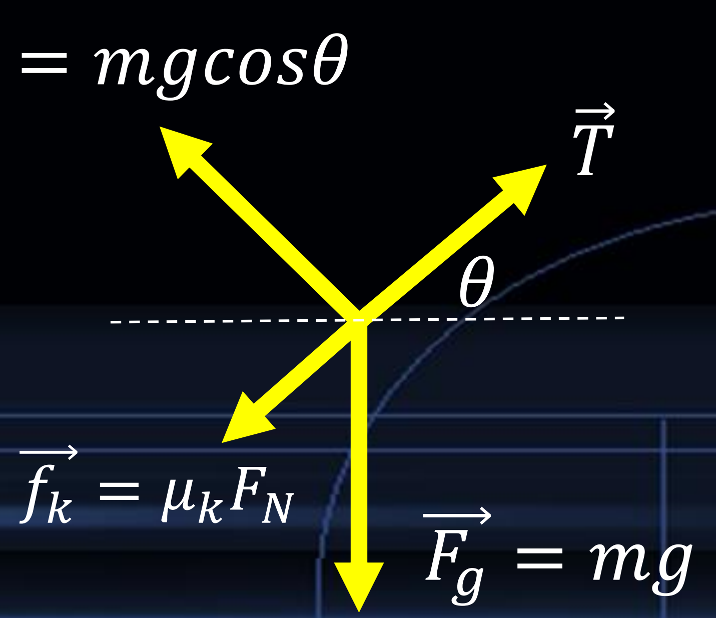
- a cord pulls a box up along a plane (with kinetic friction coefficient $\mu_k = 0.01$) inclined at angle θ = 30.0°. The box has mass m = 5.00 kg, and the force from the cord has magnitude T = 25.0 N. What is the box's acceleration a along the inclined plane?





Example 2: motion on a slope

- a cord pulls a box up along a plane (with kinetic friction coefficient $\mu_k = 0.01$) inclined at angle θ = 30.0°. The box has mass m = 5.00 kg, and the force from the cord has magnitude T = 25.0 N. What is the box's acceleration a along the inclined plane?



The net force magnitude along the plane:

$$F_{Net,plane} = T - mgsin\theta - \mu_k F_N$$

$$= T - mgsin\theta - \mu_k mgcos\theta = 0.076N$$

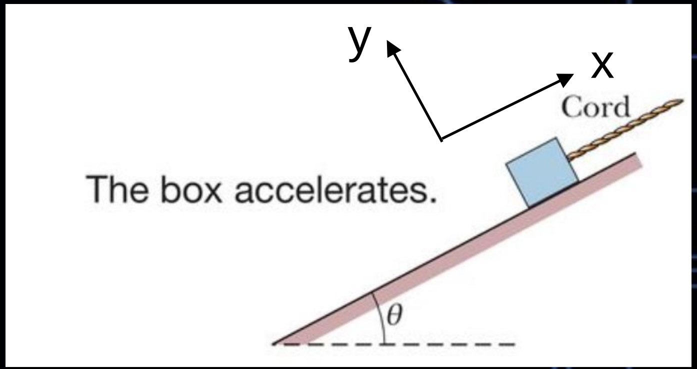
$$a = \frac{F_{Net,plane}}{m} = 0.015m/s^2$$

Equation of motion

- Newton’s second law provide link between force and acceleration, which is the second derivative of position respect to time. Therefore, one can obtain an equation to describe the behavior of a physical system in terms of its motion as a function of time, which is called equation of motion.

Example of equation of motion

- In our example of motion on slope, we found $F_{NET} = 0.076N$.



With Newton's second law:

$$F_{NET} = m\frac{d^2x}{dt^2}$$

This is the equation of motion for the box.

The solution of this equation: $x(t) = \frac{1}{2}(\frac{F_{NET}}{m})t^2$

Think about it…

- Assuming we are in a META world such that the Newton's second law is $\overrightarrow{F_{net}} = m\frac{d}{dt}\vec{a}$, what is the position versus time $y(t)$ of a free-falling motion in this META world? (assuming $v_0=0$ $y_0=0$)

Think about it…

- Assuming we are in a META world such that the Newton's second law is $\overrightarrow{F_{net}} = m\frac{d}{dt}\vec{a}$, what is the position versus time $\mathrm{y}(t)$ of a free-falling motion in this META world?

- $\overrightarrow{F_{net}} = m\frac{d}{dt}\vec{a} = -mg$

Think about it…

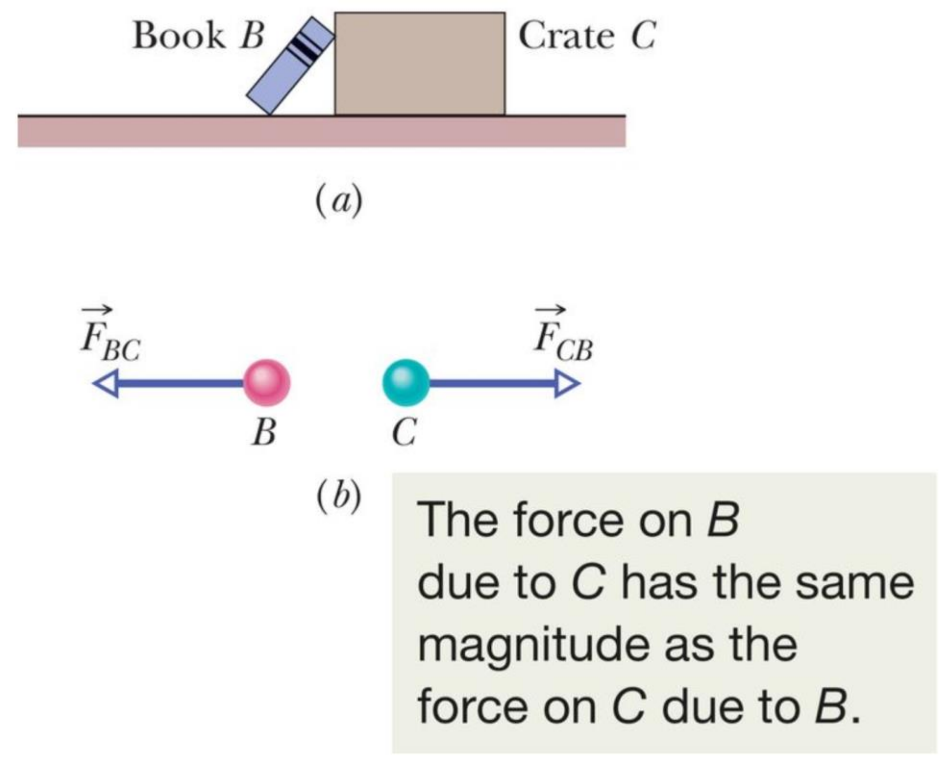
- Assuming we are in a META world such that the Newton's second law is $\overrightarrow{F_{net}} = m\frac{d}{dt}\vec{a}$, what is the position versus time $\mathrm{y}(t)$ of a free falling motion in this META world?

- $\overrightarrow{F_{net}} = m\frac{d}{dt}\vec{a} = -mg$
- $m\frac{d^3y}{dt^3} = -mg$ and assuming v_0=0 y_0=0

$$\mathrm{y}(t) = -\frac{1}{6}gt^3$$

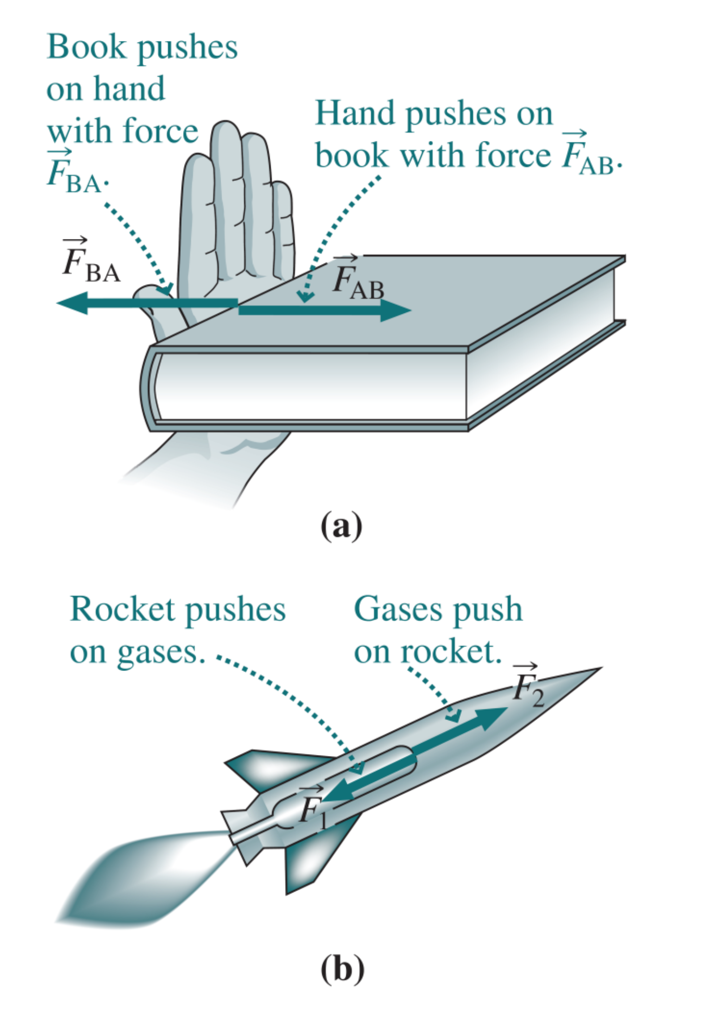
Newton's third law

- When two bodies interact, the forces on the bodies from each other are always equal in magnitude and opposite in direction.



Detail of Newton's third law

- The third law tells us forces come in pairs:
  - If object A exerts a force on object B, then object B exerts an oppositely directed force of equal magnitude on A.
  - Obsolete language: "For every action there is an equal but opposite reaction."
  - Important point: The two forces always act on **different** objects; therefore, they can't cancel each other.



- Example:
  - Hand pushes on a book with a force $\overrightarrow{F_{AB}}$
  - Third law states that the book must push on hand with a force $\overrightarrow{F_{BA}} = -\overrightarrow{F_{AB}}$

Summary

- **Weight** is the force of gravity on an object: $\vec{W} = m\vec{g}$
  Weight is different on different planets.
  Near Earth's surface, $\vec{g} = 9.8m/s^2$ and is downward
- Two types of frictions: static and kinetic.
- Spring force: To a good approximation for many springs, the spring force is given by $\vec{F_s} = -k\vec{d}$
- Equation of motion: An equation to describe the behavior of a physical system in terms of its motion as a function of time.
- Newton's third law: When two bodies interact, the forces on the bodies from each other are always equal in magnitude and opposite in direction.

Next

Using Newton's law

- Drag force and terminal speed
- Uniform circular motion
- Other examples of force and motion