Today's Topics

Monday, September 9, 2019 (Week 2, lecture 5) – Chapter 3.

0. Kepler's 3rd law

1. Galileo & Newton

2. Newton's laws

3. Conservation laws

5. Gravity

Participation Quiz

2 minutes

0 point – no answer
1 point – wrong answer
2 points – correct answer

Which of the following is equivalent to 930 km ? (only one answer is correct)

$0.930 \times 10^3 \text{ m}$

$93.0 \times 10^9 \text{ cm}$

$93.0 \times 10^4 \text{ m}$

Kepler’s 3rd Law

T = orbital period in units of Earth years

a = semimajor axis in AU

$$T^2 = a^3$$

<u>Examples</u>

1. Martian orbit.

2. Orbital speed vs orbital radius.

Galileo Galilei: Birth of Classical Mechanics

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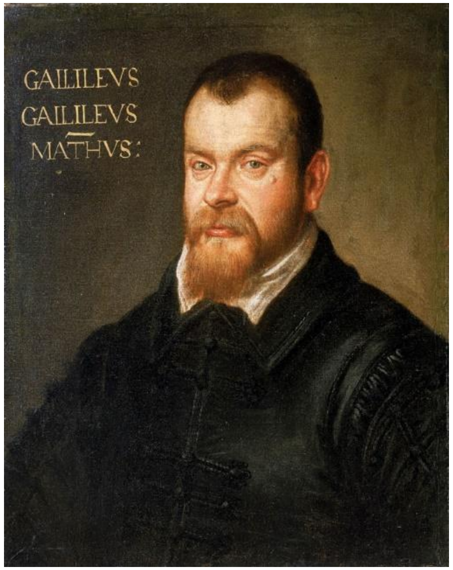
- Universities of Pisa, Florence, Padua.
- Contributed to physics, astronomy, optics, engineering.
- Confronted Catholic Inquisition over **heliocentrism**.



Galileo (1605-1607)
[by D. Tintoretto]

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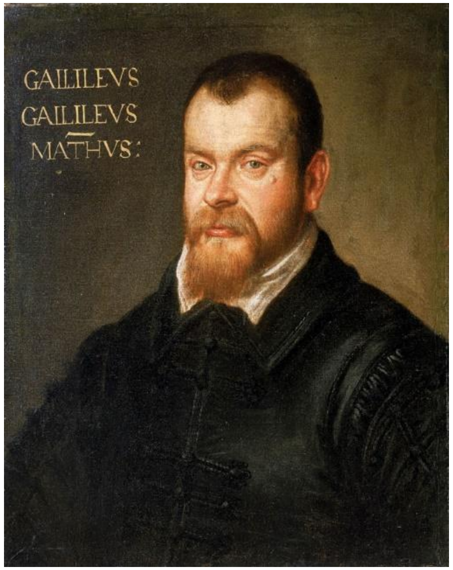
Physics contributions – classical mechanics

- Galilean Relativity
  → Objects in uniform motion tend to stay in motion.
- Objects fall with a **parabolic trajectory.**



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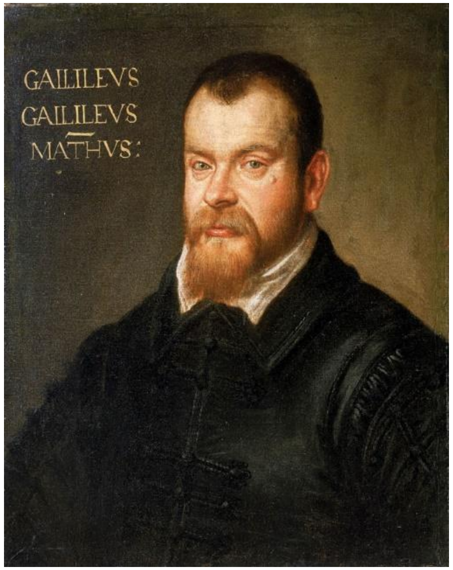

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Astronomy contributions

- Key developer of the **telescope** for astronomy.
- Discovered the **moons of Jupiter**.
- Discovered the ***phases of Venus*** (similar to Moon phases).
- Proponent of **heliocentric** view.

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Examples:

1. A car's acceleration is advertised as "0-100 km/h in 5 seconds."

2. Acceleration due to gravity is **g = 9.8 m/s per second**
= 9.8 m/s^2

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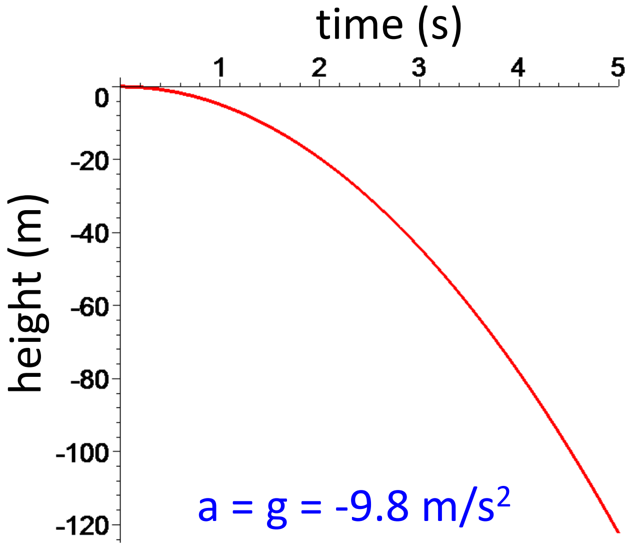

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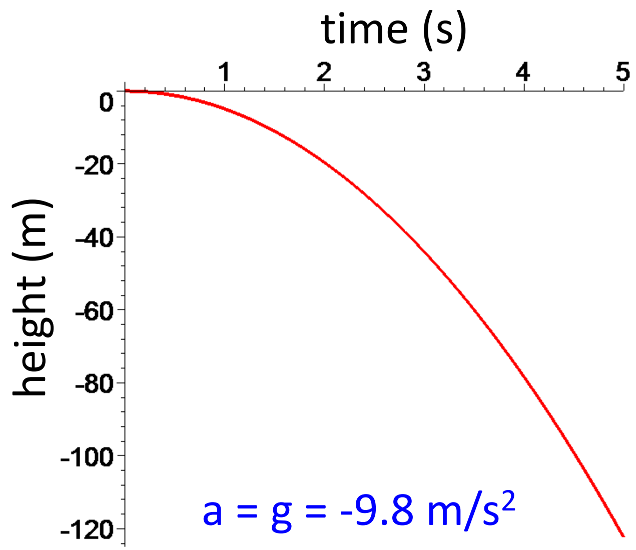
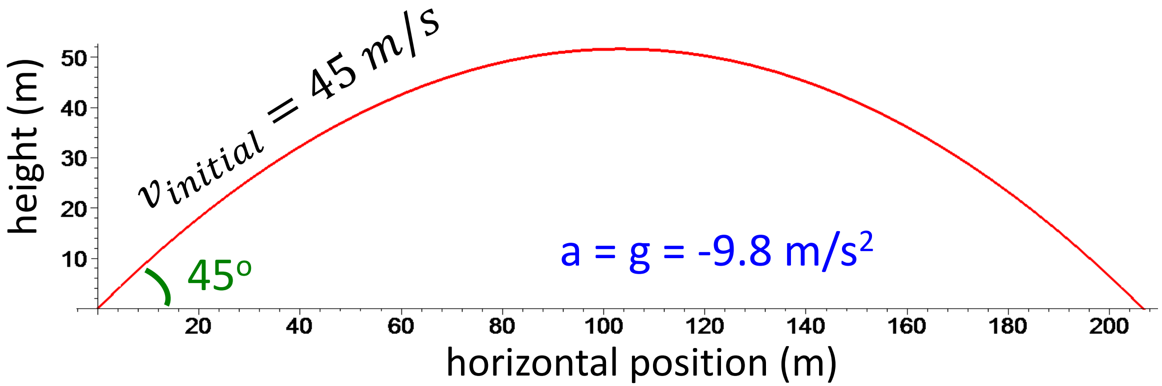


Baseball: homerun trajectory



Galilean Relativity

<u>Definition</u>

An **inertial frame** is a *coordinate system* moving at constant velocity.

[constant velocity = constant speed & constant direction]

→ Inertial frame = space that travels with you, e.g. car, airplane, rocket, etc …

→ Note: an accelerating/rotating system is NOT an inertial frame.

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Galilean relativity posits that in any inertial frame:

"you cannot tell that you are moving based on local measurement."

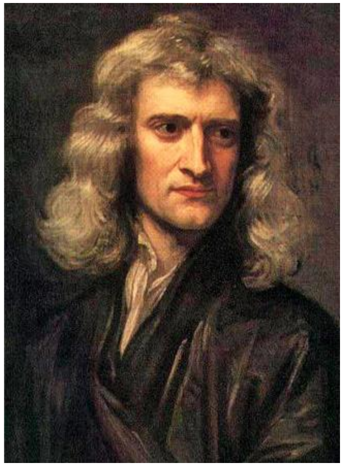
→ i.e. an inertial frame locally behaves as if it is at rest (locally).

→ **corollary:** an object in uniform motion will tend to stay in uniform motion.

Examples:

1. **Car:** You cannot tell that a car is moving (when at constant velocity) unless you look out window.
2. **Airplane:** You cannot tell an airplane is moving (when at constant velocity) unless you look out window (or hit turbulence).

Isaac Newton: Founder of Classical Mechanics



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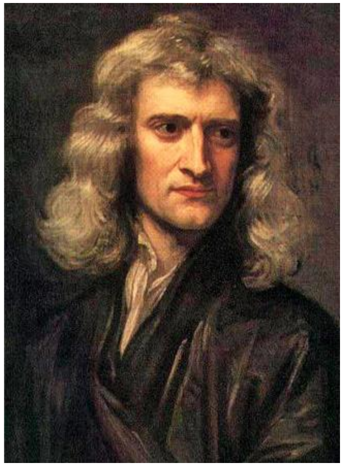

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- "Newton's Laws" of classical mechanics.
- Law of universal gravitation.
- Newton's laws are used for ***calculating planetary & stellar motion***.

(+ Einstein's "Special Relativity")

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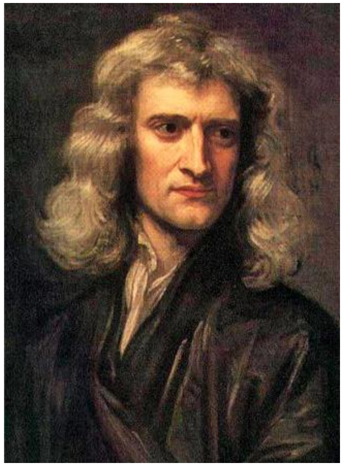

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Astronomy

- **Optics:** white light &colors, refraction.
- Invented the **reflecting telescope**.

Newton's Laws

of Classical Mechanics

1st Law: An object moves at constant velocity if there is no net force acting on it.

[**fine print:** in an inertial reference frame]

2nd Law: Force = mass × acceleration.

3rd Law: For any force, there is always an equal and opposite reaction force.

Newton's 1st Law

An object moves at constant velocity if there is no net force acting on it.

[**fine print:** in an inertial reference frame]

Note: *This law is a variation on the* *<u>Galilean relativity</u>* *statement.*

Newton's 2nd Law

Force = Mass × Acceleration

or

$$F = ma$$

F = net force
m = mass
a = acceleration

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Note 1: This equation is mostly useful if you know the net force applied.

Note 2: If the acceleration is zero, then the net force is zero.

Newton's 3rd Law

For any force, there is always an equal and opposite reaction force

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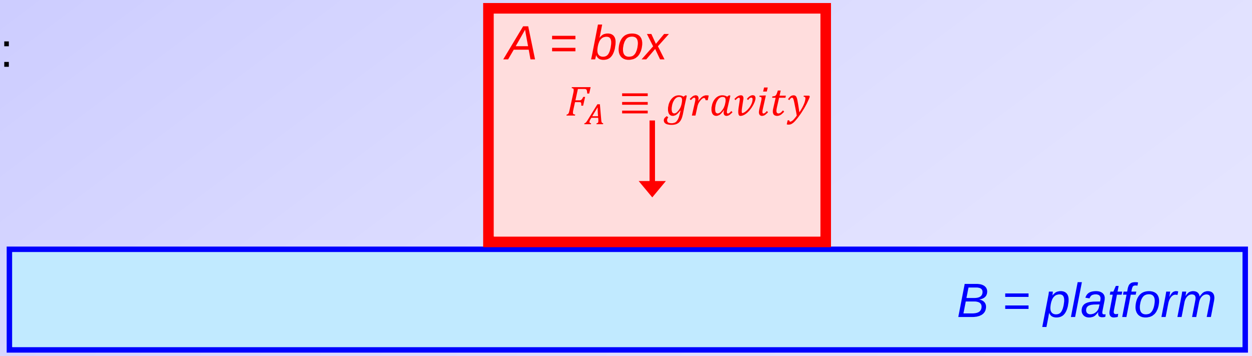

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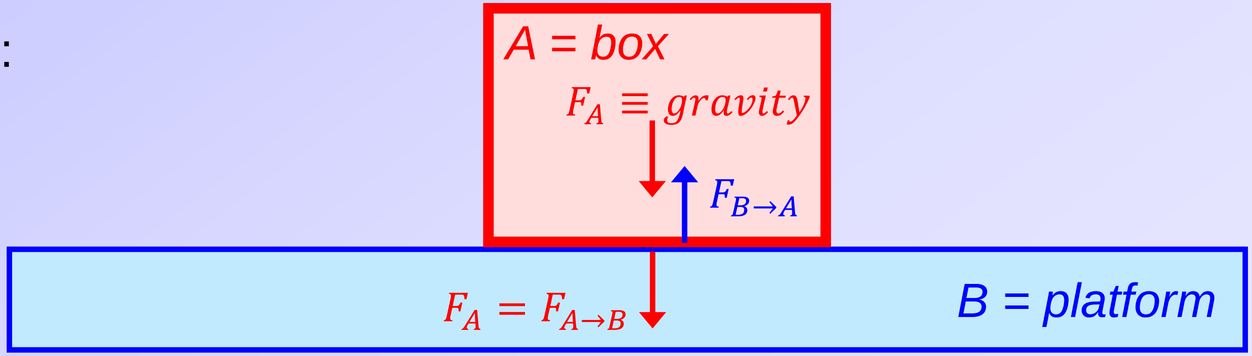

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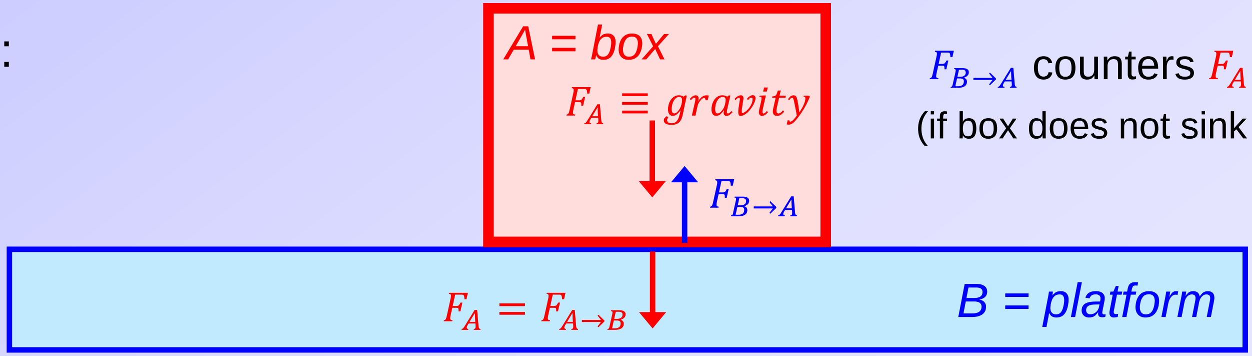

$F_{B\rightarrow A}$ counters F_A exactly.

(if box does not sink into platform)

Newton's 3rd Law: Rocket Thrust

A rocket accelerates by pushing on its exhaust.

A rocket does NOT push on the air to accelerate.

A rocket does NOT push on its platform to accelerate.

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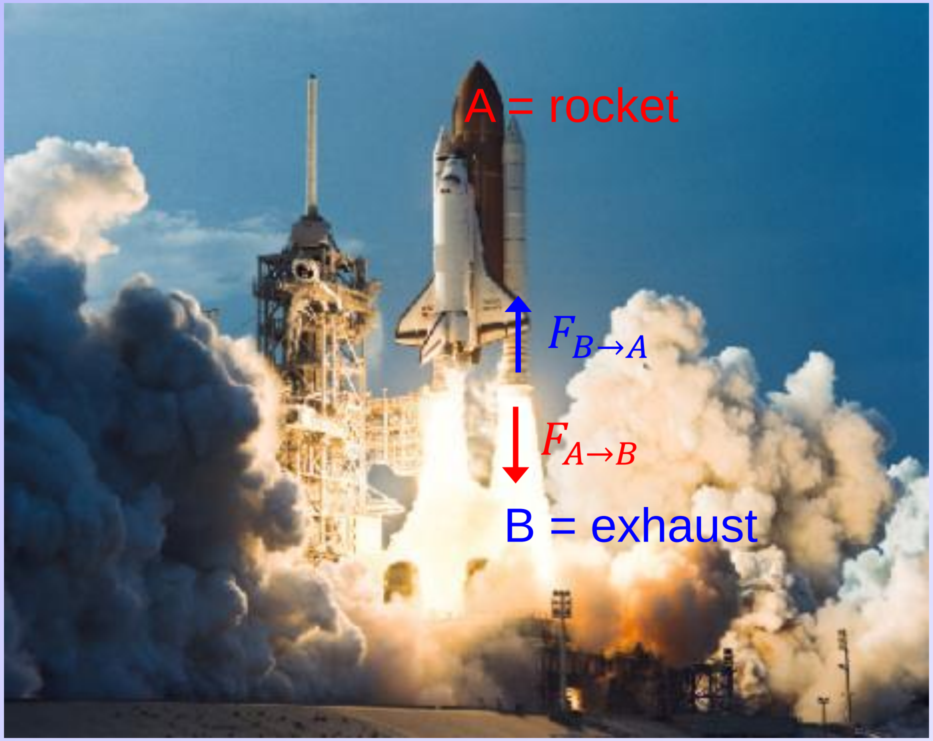

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Conservation of Momentum

momentum = mass $\times$ velocity

total momentum
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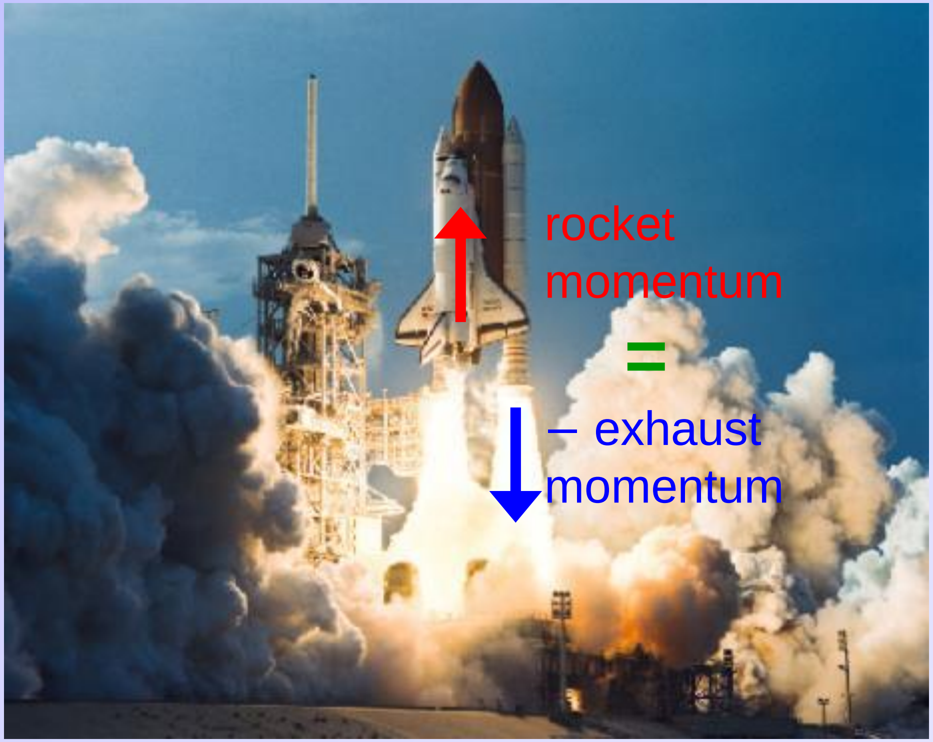
Conservation Law
The total momentum of a closed system never changes.

no external objects enter
no external forces

Momentum Conservation: Rocket Thrust

$$\text{Momentum}_{\text{rocket}} + \text{Momentum}_{\text{exhaust}} = 0$$



Conservation of Energy

Kinetic Energy $= E_k = \frac{1}{2}mv^2$

m = mass
v = speed

Potential Energy = “stored” energy

example: gravitational potential energy

Total Energy
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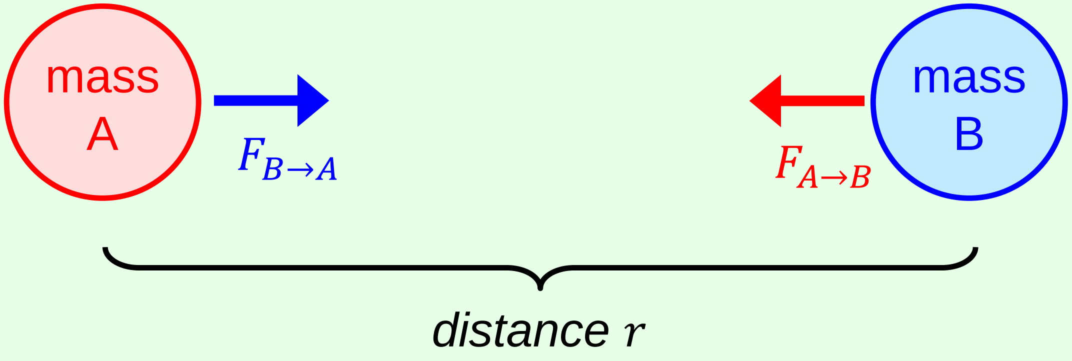
Newton's law of universal gravitation

All masses attract each other according to the following relation:

$$F_{A\to B} = -G\frac{M_A M_B}{r^2} = -F_{B\to A}$$



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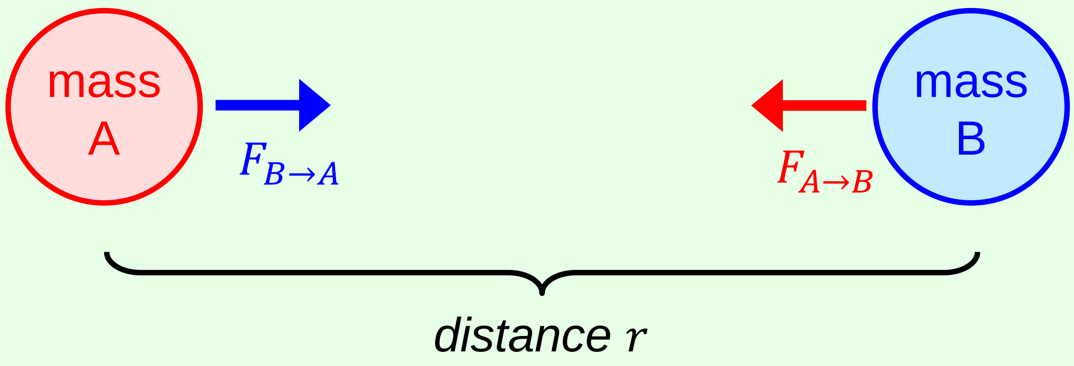

Properties

- Falls off as $1/r^2$.
- Proportional to M_A.
- Proportional to M_B.
- G = Newton's constant $= 6.67430(15) \times 10^{-11}$ $m^3/Kg \cdot s^2$