Today's Topics

Monday, February 2, 2026 (Week 2, lecture 5) – Chapter 3.

0. Examples of Kepler's laws.
1. Galileo, gravity, and relativity.
2. Newton's laws

Motivating Questions:

1. Where do Kepler's Laws come from?

2. Can Kepler's laws be applied outside the Solar System?

3. How come the mass of a body does not affect its orbit?

Motivating Questions:

1. **Where do Kepler's Laws come from?**

2. **Can Kepler's laws be applied outside the Solar System?**

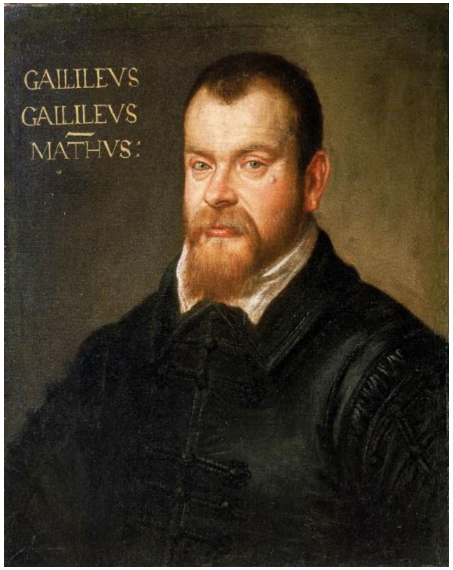
3. **How come the mass of a body does not affect its orbit?**

- Kepler's laws are descriptive, but also predictive.
- They do not really explain **why** the planets orbit in the way that they do.

Galileo Galilei: Birth of Classical Mechanics

Galileo Galilei (1564-1642)

- 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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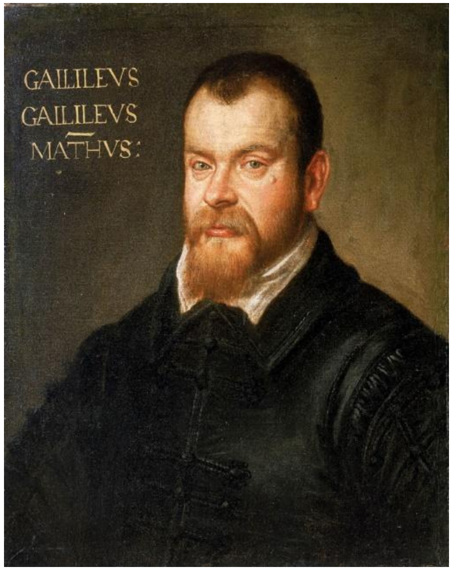
Physics contributions – classical mechanics

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



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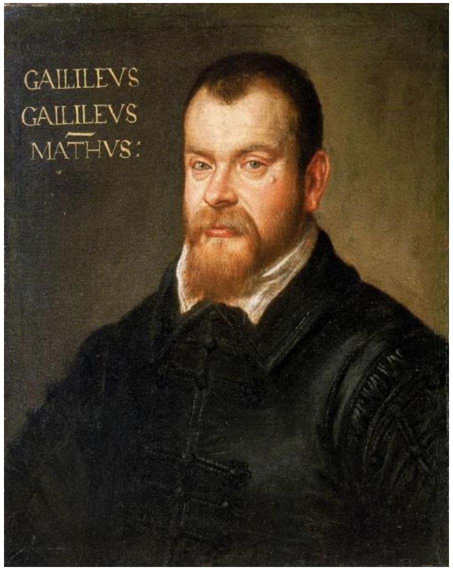

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Astronomy contributions

- 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

Parabolic Trajectories

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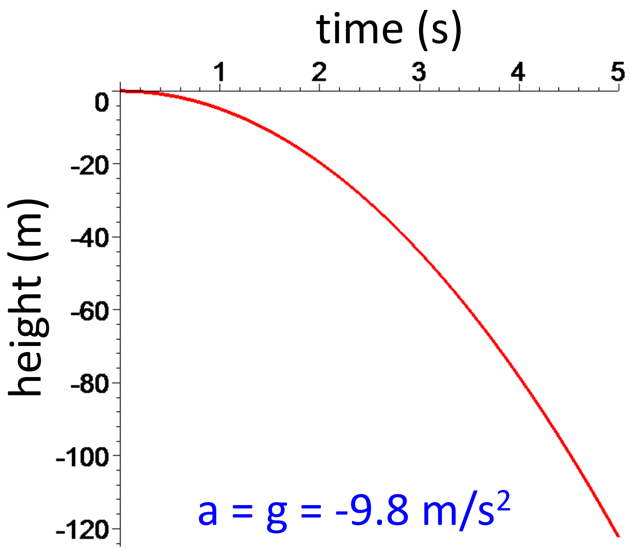
Dropped Object



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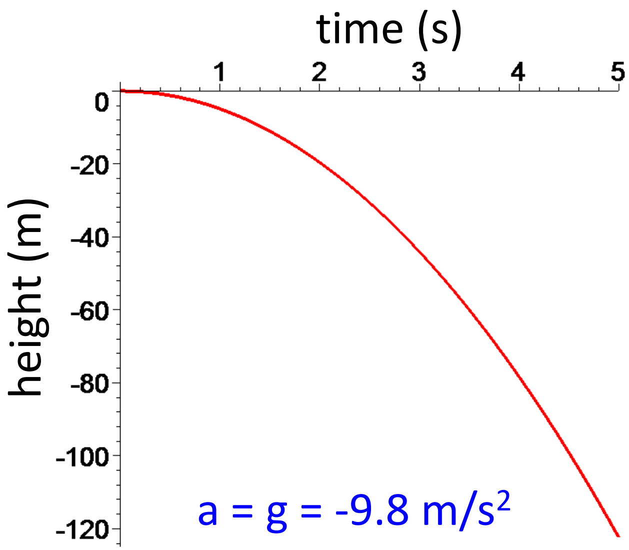
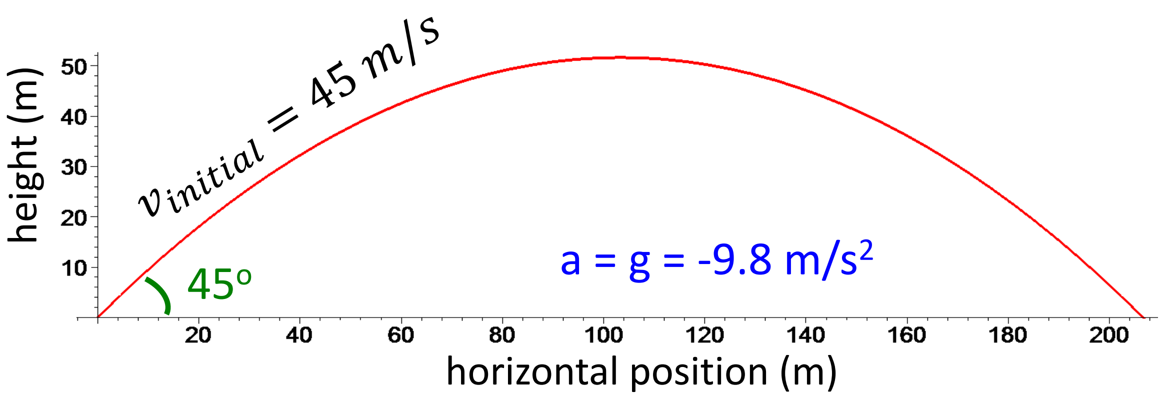


Baseball: homerun trajectory



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).

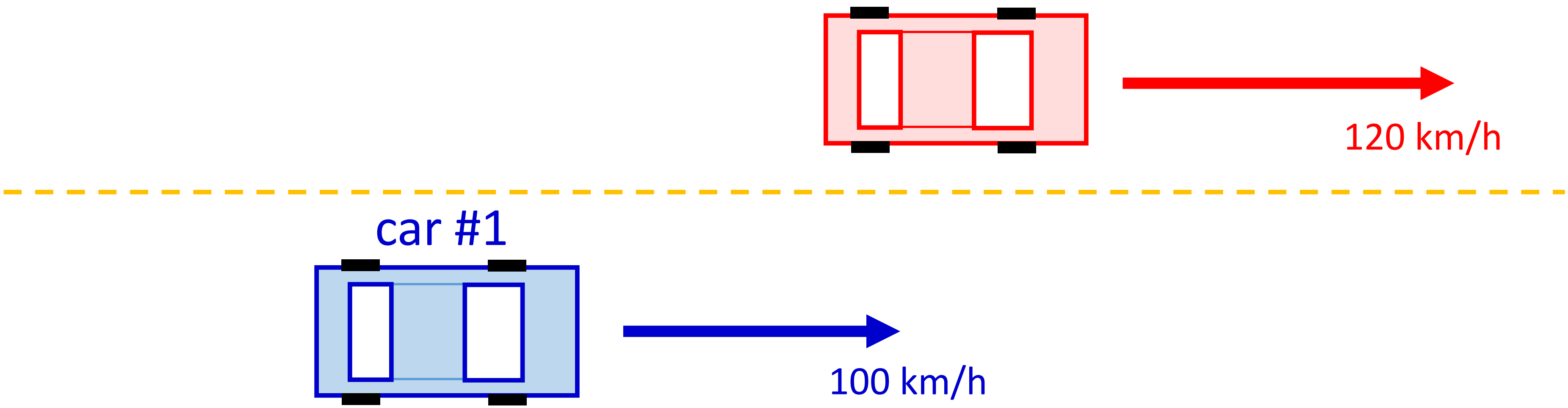
→ **corollary:** an object in uniform motion will tend to stay in uniform motion.

Examples:

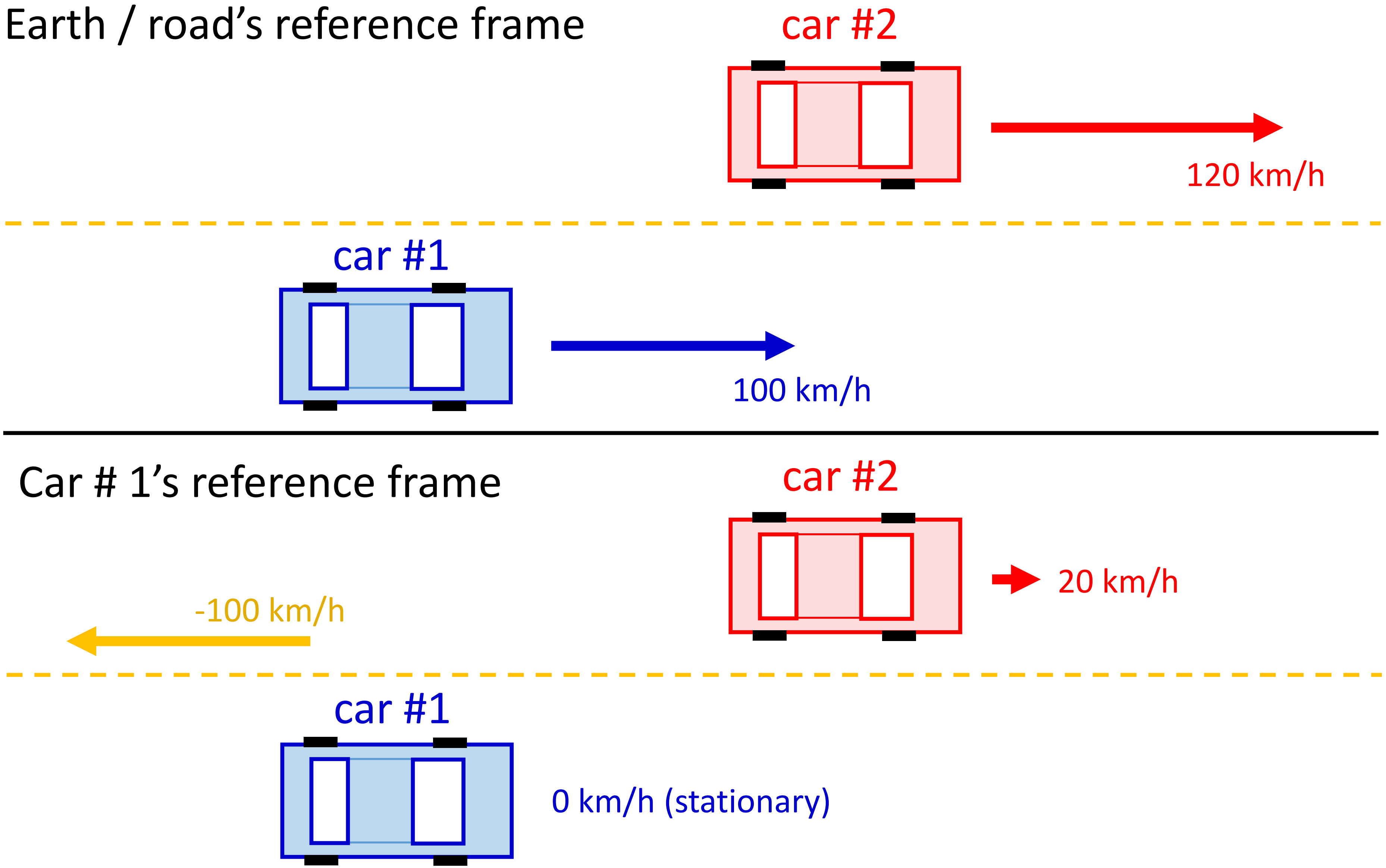
1. **Car:** You cannot tell that a car is moving (when at constant velocity) unless you look out window.
2. **Airplane:** You cannot tell an airplane is moving (when at constant velocity) unless you look out window (or hit turbulence).

Galilean Relativity Example

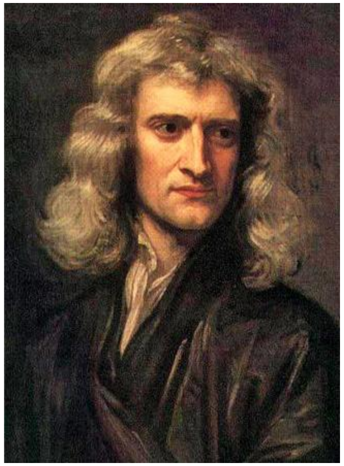
Earth / road's reference frame



Galilean Relativity Example



Isaac Newton: Founder of Classical Mechanics



Newton (1689) [by G. Kneller]

Sir Isaac Newton (1643-1727)

- Cambridge U.
- Founded **Classical Mechanics**.
- Discovered **Calculus**.
- Major contributions to **Optics & Astronomy**.

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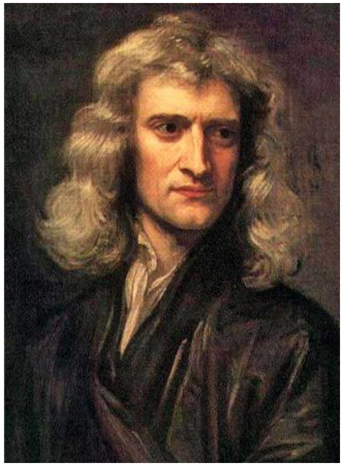

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Classical Mechanics

- "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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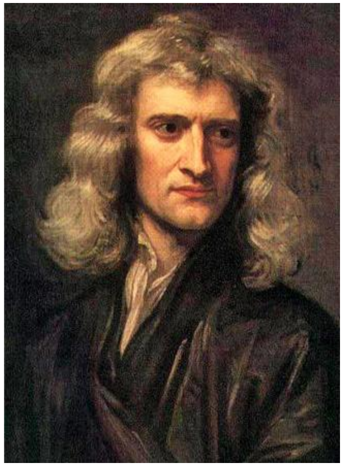

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Astronomy

- **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 $\times$ 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 Galilean relativity 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

$$F_{A\rightarrow B} = -F_{B\rightarrow A}$$

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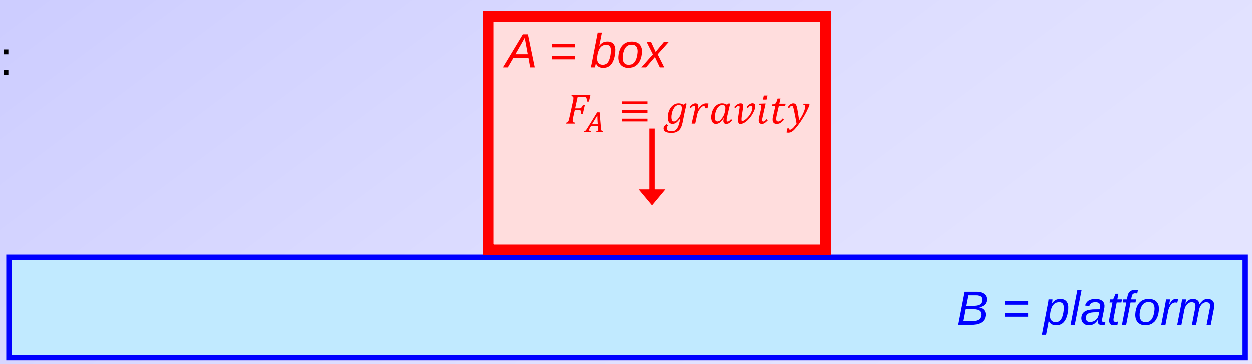

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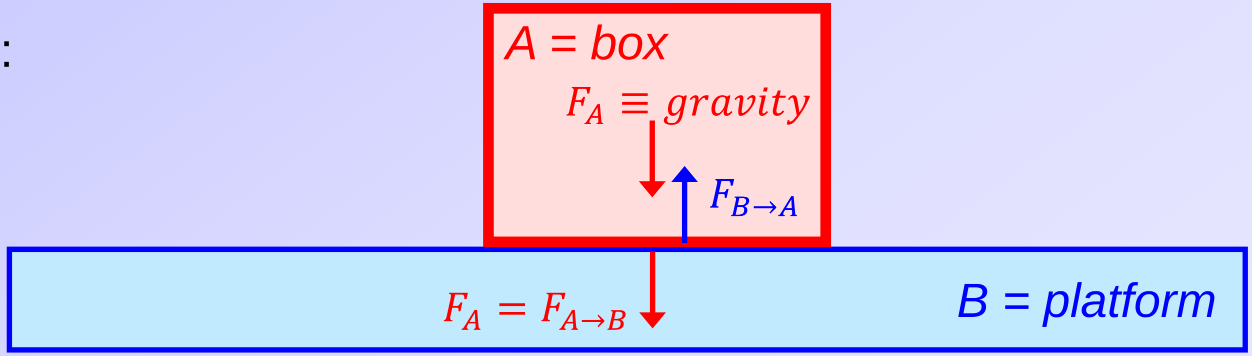

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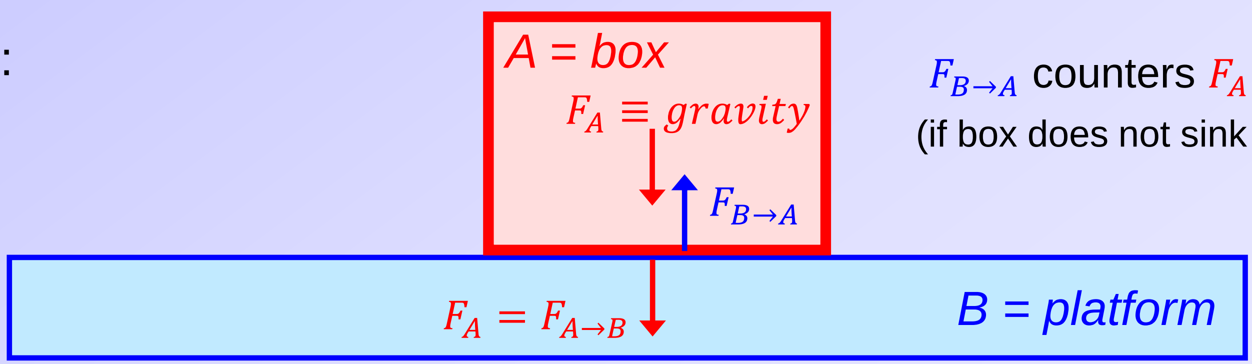

$F_{B\rightarrow A}$ counters F_A exactly.

(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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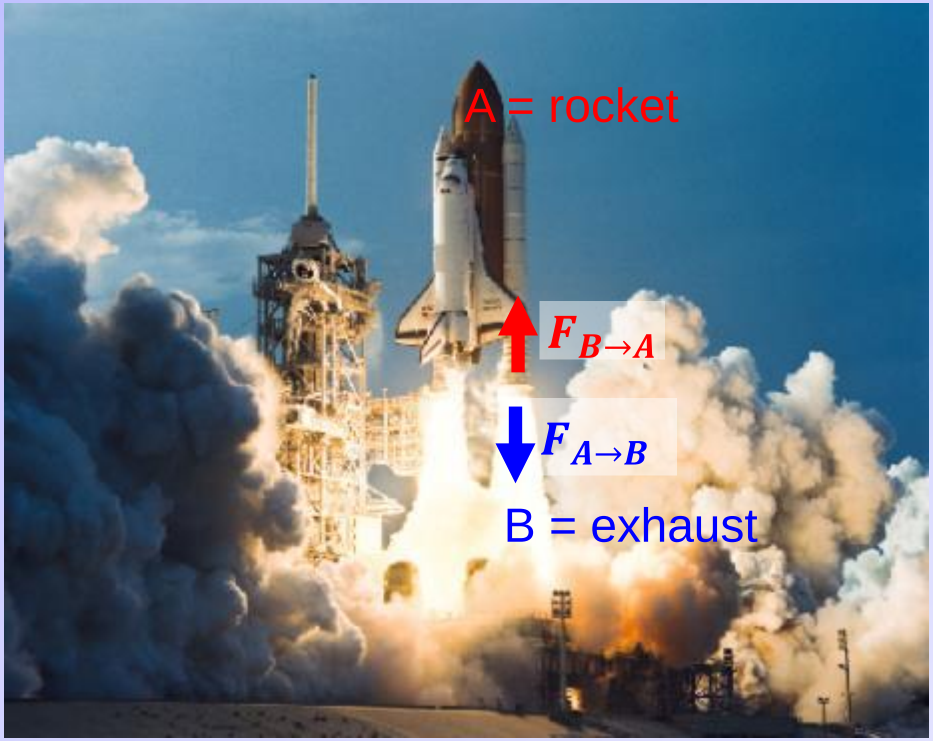

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