

Today's Topics

Monday, February 3, 2025 (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?

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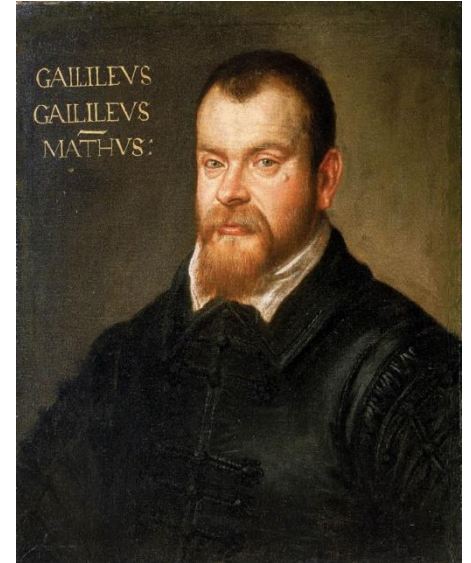
3. How come the mass of a body does not affect its orbit?

- 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

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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]

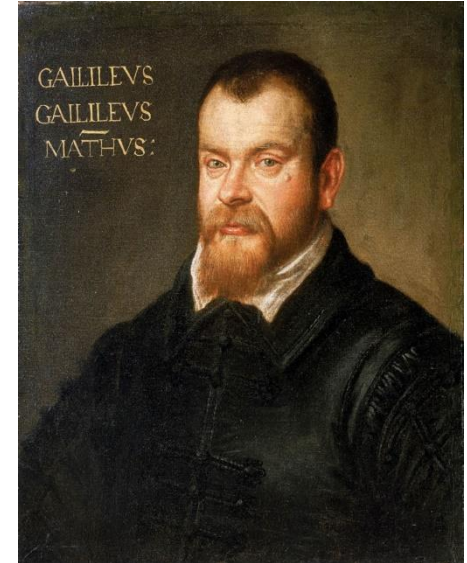
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Physics contributions – classical mechanics

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



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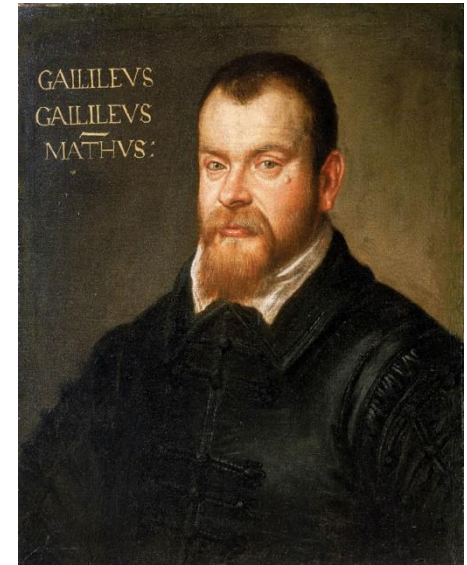
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Physics contributions – classical mechanics

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

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.



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

Acceleration

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(e.g. meters per second, km per hr)

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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 **$g = 9.8 \text{ m/s per second}$**
 $= 9.8 \text{ m/s}^2$

Parabolic Trajectories

Constant speed: $x = vt$

[x = position, v = speed, t = time (elapsed)]

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Constant acceleration: $v = at$

[a = acceleration]

Distance traveled: $x = \frac{1}{2}at^2$

[factor of $\frac{1}{2}$ needed because speed is not constant]

(calculus required)

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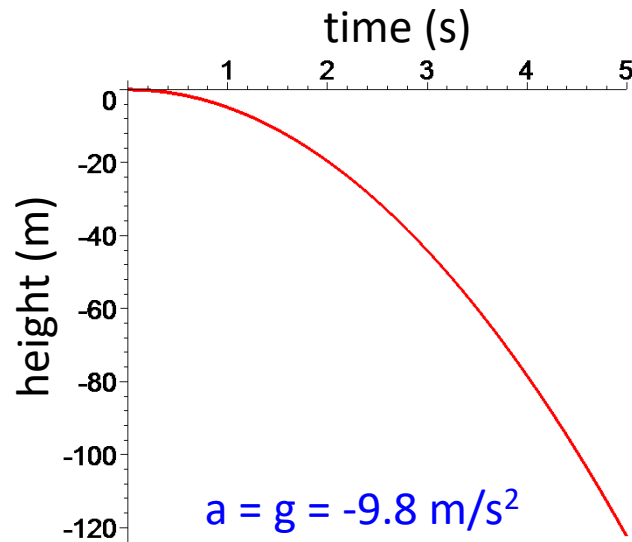
[a = acceleration]

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Dropped Object



Parabolic Trajectories

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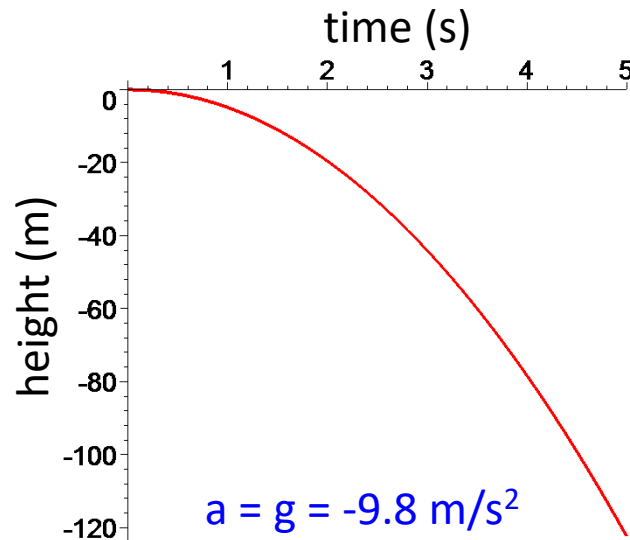
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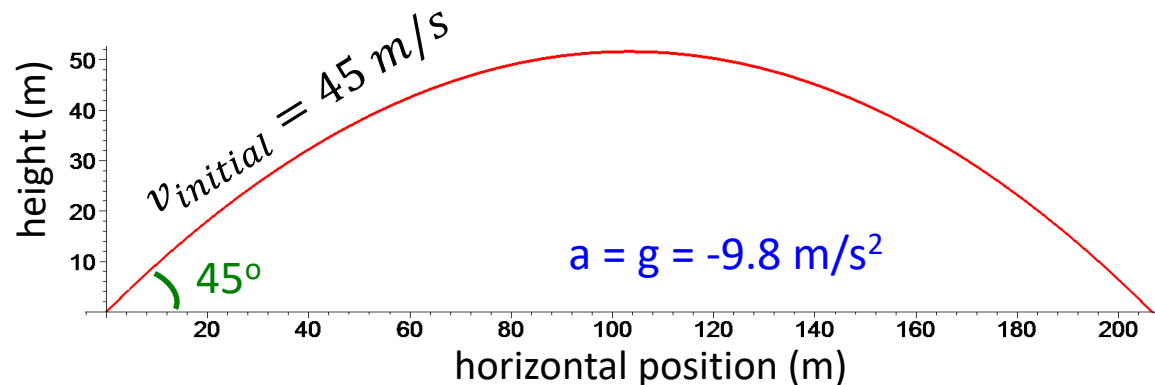
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Dropped Object



Baseball: homerun trajectory



Galilean Relativity

Definition

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.

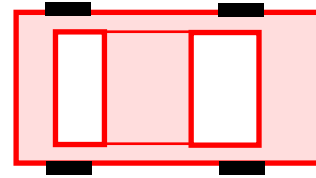
Examples:

- 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

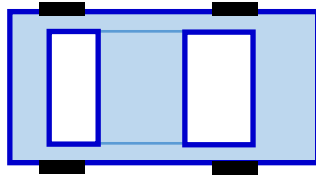
Earth / road's reference frame

car #2



120 km/h

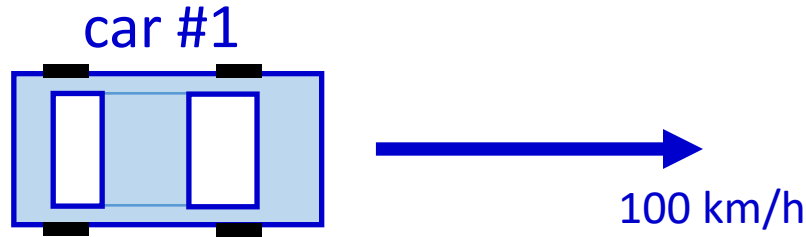
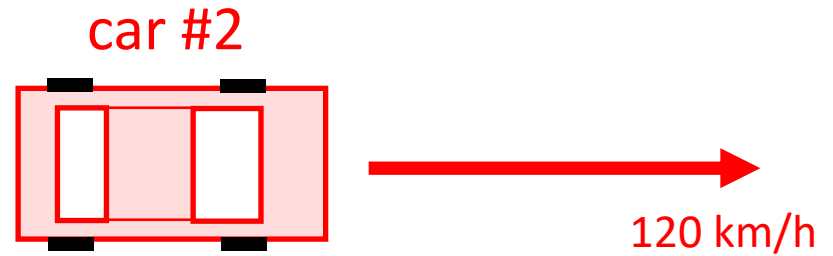
car #1



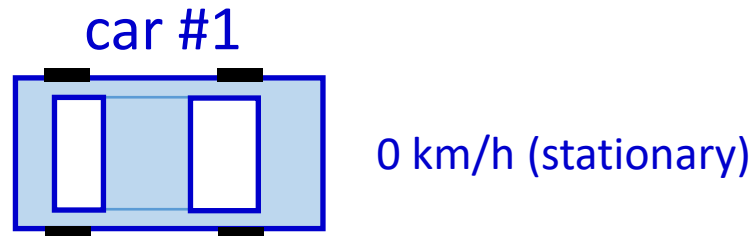
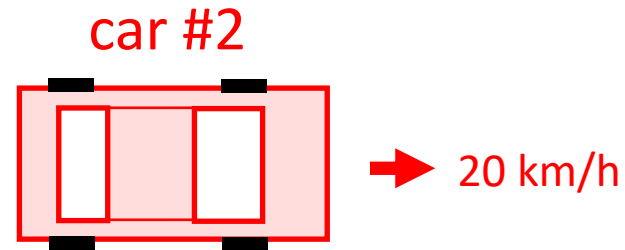
100 km/h

Galilean Relativity Example

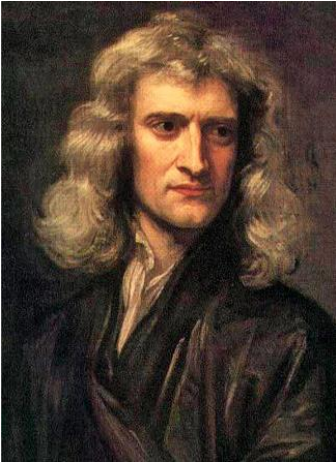
Earth / road's reference frame



Car # 1's reference frame



Isaac Newton: Founder of Classical Mechanics

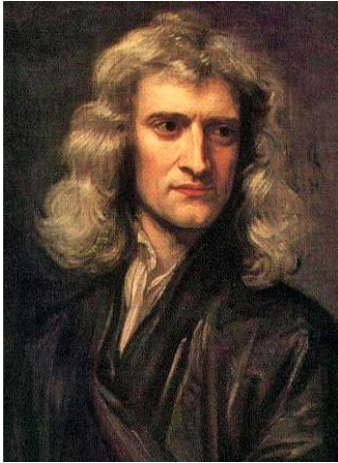


Newton (1689) [by G. Kneller]

Sir Isaac Newton (1643-1727)

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

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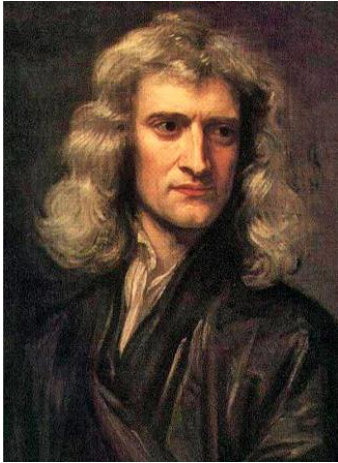
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Classical Mechanics

- “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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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

[fine print: in an inertial reference frame]

Newton's 2nd Law

Force = Mass × Acceleration

or

$$F = ma$$

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[fine print: in an inertial reference frame]

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

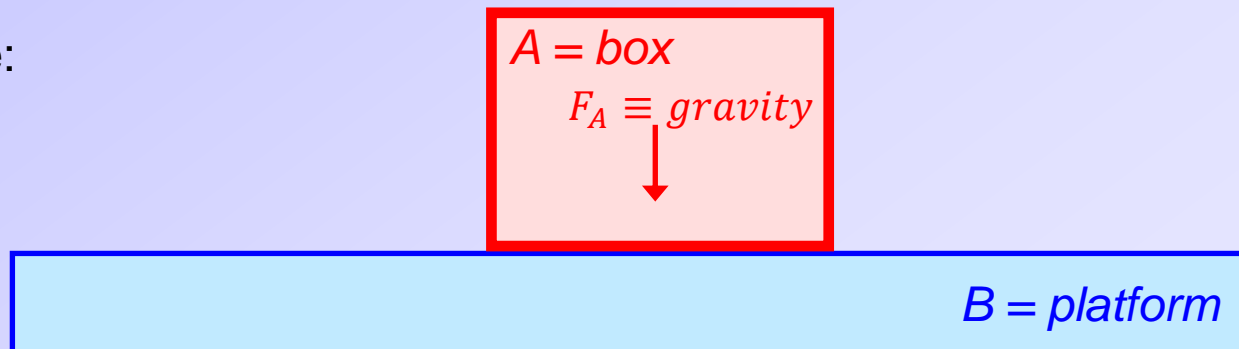
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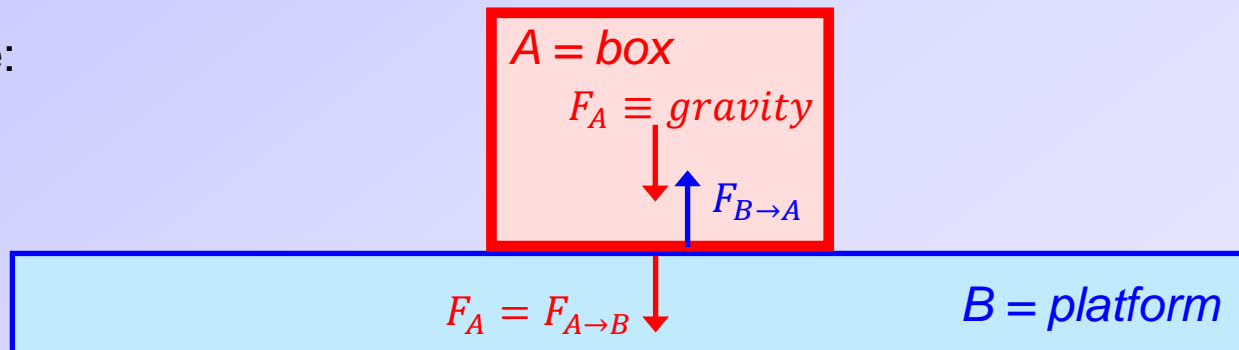


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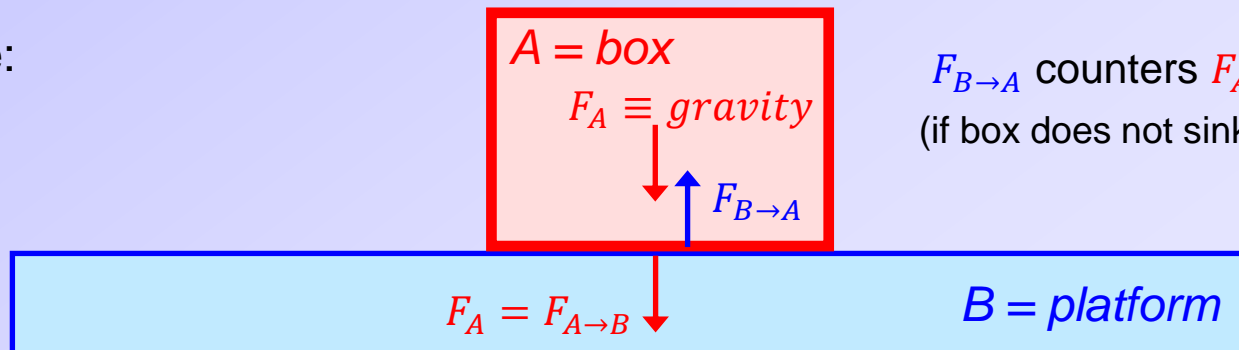


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Example:



$F_{B \rightarrow A}$ 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.

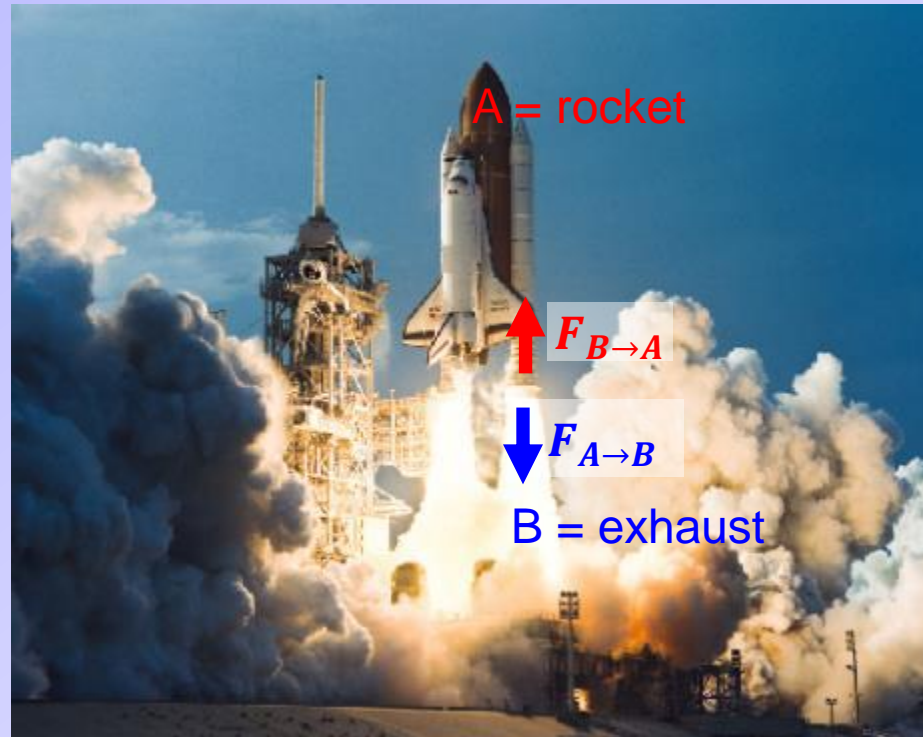


A rocket does NOT push on the air to accelerate.

A rocket does NOT push on its platform to accelerate.

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