University Physics 226N/231N
Old Dominion University

Newton and Forces

First "Midterm" is this Wednesday, September 19!
On paper (not MasteringPhysics), open book, open computer…

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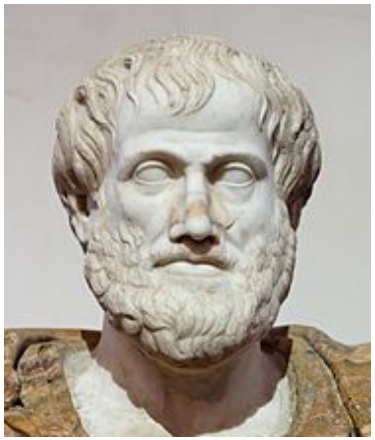
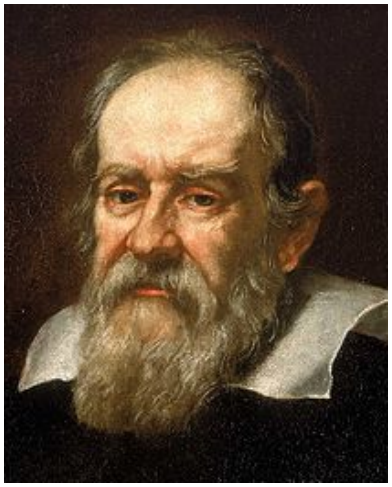
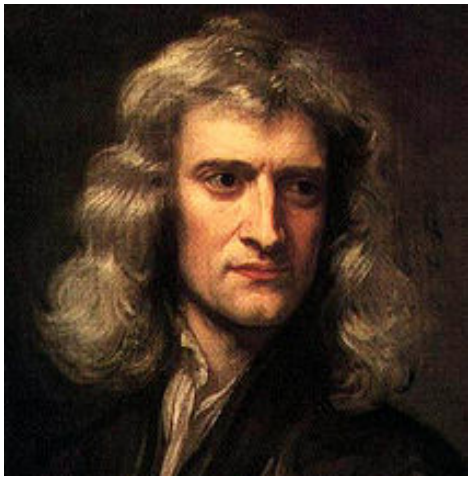
Happy Birthday to Jimmie Johnson, Konstantin Tsiolkovsky, and Anne Bancroft!
Happy Constitution Day, Apple Dumpling Day, and Responsible Dog Owners' Day!

In the Footsteps of….

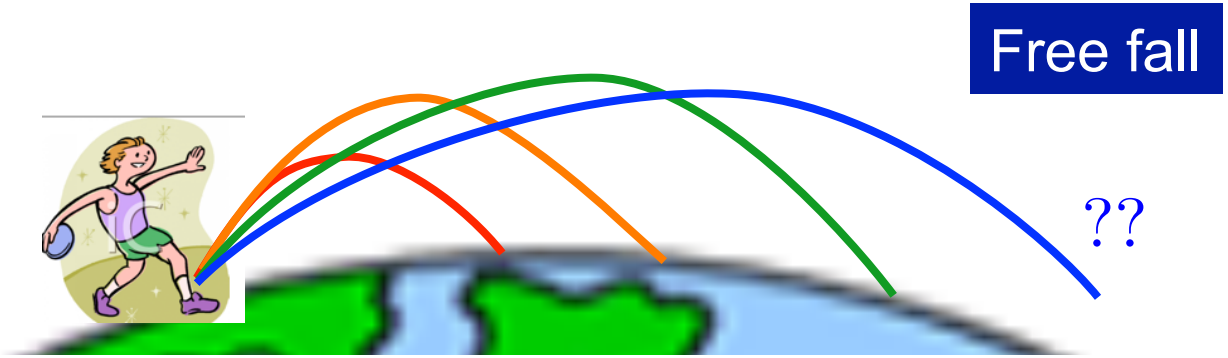
- We've been describing motion with three related attributes
  - **Position** in space: $\vec{x}$
  - **Velocity**, how position changes with time: $\vec{v} = \Delta\vec{x}/\Delta t = d\vec{x}/dt$
  - **Acceleration**, how velocity changes with time: $\vec{a} = \Delta\vec{v}/\Delta t = d\vec{v}/dt$
  - These are all **vectors** (magnitude and direction) and have **components**

- We'll review the application of these for the midterm in the second half of class today, but in the first hour…
  - We'll revisit a ponderable and walk in the footsteps of giants

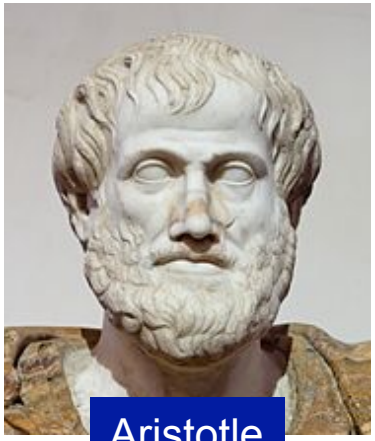




Prior Ponderable: Falling Around The Earth

- Taking projectile motion to the extreme…
  - The Earth is not flat: it is not "level ground" forever
  - Experience tells us that gravity always points towards the center of the Earth, wherever I am on the Earth
  - So it might be possible to shoot something really small and aerodynamic fast enough to "miss" the Earth even while the acceleration of gravity continuously makes it "fall"



"Aristotle, Aristotle…"



Aristotle

- Aristotle's world view: my object will always eventually stop
  - Forces are continuously required for objects to move
  - That is, **forces are required to maintain velocity**
  - An object's "natural" state is at rest and it will always return to being at rest if forces don't keep it moving
- These are fairly reasonable statements
  - Our world is full of what we now know as frictional forces
  - Even people need to constantly exert themselves to keep going
- **But** there are some problems with this philosophy of physics

Ponderable: The Greek Aristotelian World (5 min)

- **All physics is based on observations of our universe**
  - Think of some observations that might have been accessible to the Greeks that create problems for Aristotle's world view

    Aristotle: "Force is required for motion" (motion=velocity)

  - Motion without forces? Different motion with same "force"?
  - Aristotle also believed **heavier** objects would fall **faster**
    - After all, they clearly have a larger attraction to the Earth!

Ponderable: The Greek Aristotelian World

- **All physics is based on observations of our universe**

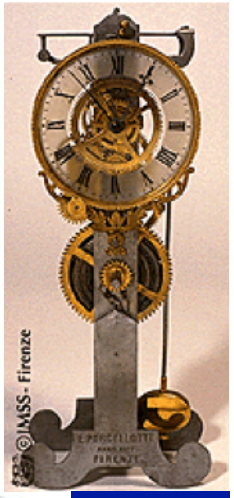
  Aristotle: "Force is required for motion" (motion=velocity)

- Some challenges include
  - Same object behaving differently (e.g. rock on ice vs on rock)
    - Objects with different weights falling same distance in same time
  - Anything with force "at a distance": gravity and magnets
  - The perpetual motion of the sun, moon, planets, stars
    - If they move forever, what's "pushing" them?

"I call on the resting soul of Galileo…"

- A "thought experiment" (1589)
  - Two different weight balls
    - Dropped separately
    - Dropped tied together
- **Are they fundamentally different?**
  - (Don't drop them on people's heads!)
- The different forces of weight are balanced by different resistance to motion
  - All objects drop in same **time**
    - (Ignoring air resistance)
  - These led to early concepts of **Inertia** and **Mass**
    - Innate resistance to changes in motion

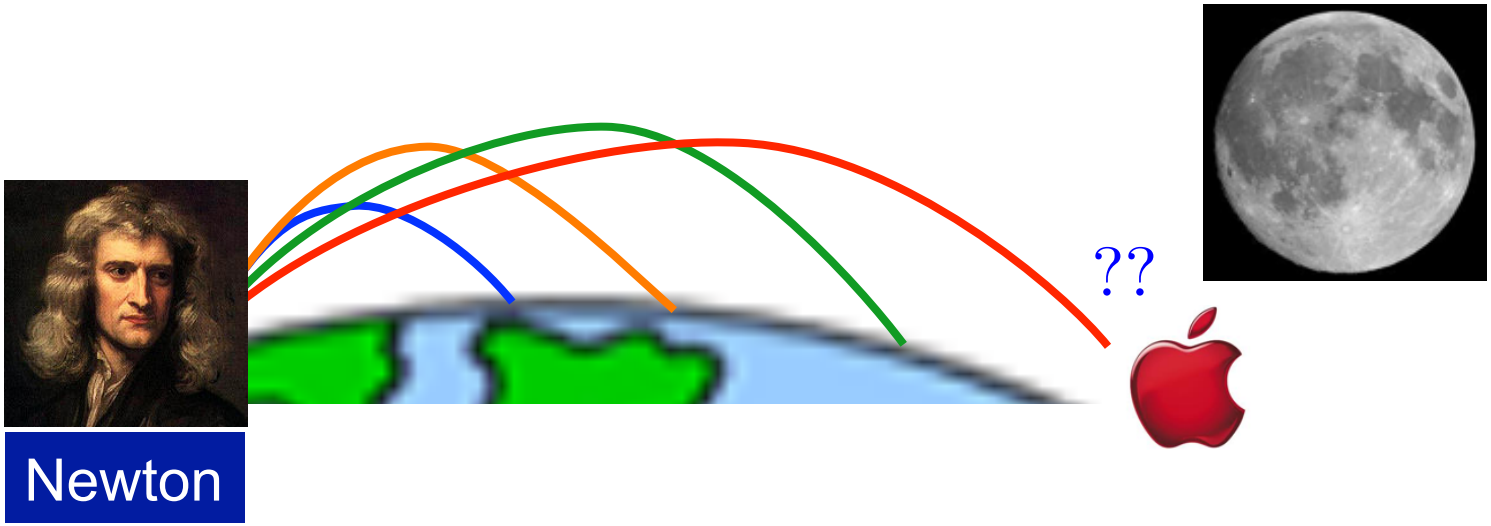
Galileo



Clock!

Prior Prior Ponderable: Falling Around The Earth

- Though the story about Newton's apple is apocryphal…
  - He did think about our ponderable about objects falling forever
  - He knew Galileo was right and Aristotle was wrong
  - He knew about the Copernican model: Earth goes around Sun
  - He also had a new "technology" to describe motion: **calculus**
- Newton's ponderable
  - **How is an apple thrown around the Earth like the moon?**



Pseudo-Ponderable (5 min)

- We had figured out the speed we need to throw an object "around" the earth, using centripetal acceleration and gravity

$$v = \sqrt{-g\, r_e} \approx 7.9 \text{ km/s}$$

- Assuming the moon is "falling" around the Earth, using just this and your knowledge that moon's orbital period is about 656 hours (27 days 7 hours)

Calculate the distance to the moon

The circumference of the orbit is the velocity times the orbital time…

Don't bother trying to look up this answer since this answer is wrong ☺

Back to Galileo and Newton

- We can resolve the inconsistencies!

- **Forces do not cause velocity**
- **Forces instead cause changes in velocity**
  - Hey, wait, this is just acceleration

- Yes, **forces are vectors** that are directly related to **acceleration**

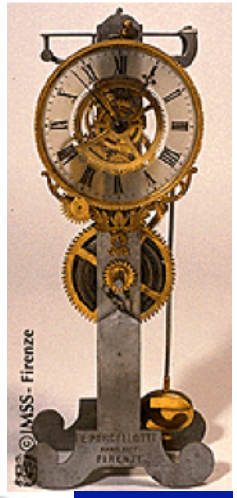
$$\vec{F}_{\text{net}} = m\vec{a}$$

Net Force

Mass or Inertia

Acceleration

Galileo



Clock!

Use the Force, Newt!

- Newton's three "laws" of motion (1687)
- Newton's First Law

  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.
- Newton's Second Law
  - This was basically $\vec{F}_{\text{net}} = m\vec{a}$
- Newton's Third Law

  If object A exerts a force on object B, then object B exerts an oppositely directed force of equal magnitude on A.