Newton’s Three Laws

By the end of this unit, you will be able to:

- Explain the idea behind center of mass
- Explain how Galileo discovered that an object will move in uniform motion unless acted upon by a non-zero net force
- Explain Newton’s first law
- Explain reference frames
- Draw free-body diagrams
- Explain Newton’s second law
- Solve problems with Newton’s second law
- Explain Newton’s third law

- Force (F)
  - Force is a vector quantity
    - Units: kg*m/s^2
      - Also called a Newton (N)
  - A force is a push or pull on an object
  - Since an object can have multiple forces acting on it, we will often refer to the net force on an object
    - The net force is the sum of all the forces acting on the object
    - The net force matters because I want to know how large and in what direction the sum of the forces acts, not each individual force
  - Since force is a vector, the forces need to be added by components, or each direction independently
    - Just like when we were adding vectors and breaking vectors into components

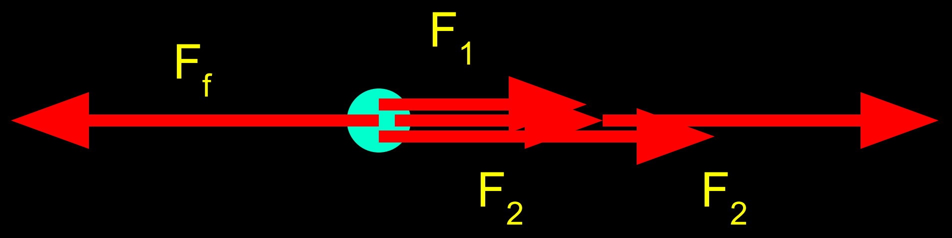
$$\Sigma F = F_{net}$$

ΣF is the summation of the Forces

- Center of Mass
  - The object moves and acts as though all the mass is concentrated in the center of the object
    - This means that we do not care about the shape of the object and what it looks like
    - We only care about the center of mass
      - » The center of mass is represented by a dot in your drawings

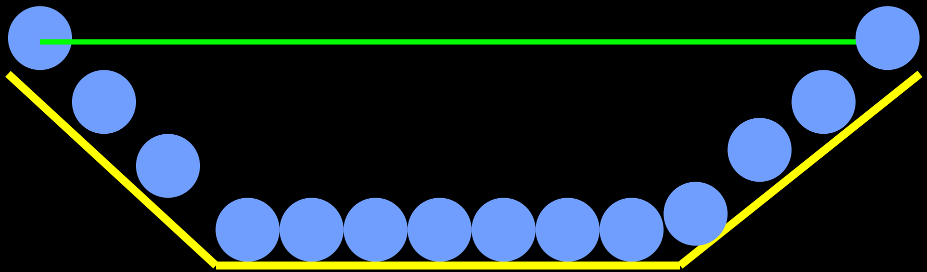
– Free-body Diagrams

- Represents the object and the forces ***acting on it***
  - Don't draw the forces that the object is exerting on other objects
- They are useful in determining the net force on an object
- Example
  - Two people are pushing a stalled car. One person pushes the car with a force of 275 N. The other person pushes the car with a force of 395 N. The force of friction opposes the motion of the car with a force of 560 N. Find the net force on the car.



- So, the force in the +x direction is 670 N and the force in the –x direction is 560.
- Thus the net force on the object is 110 N.

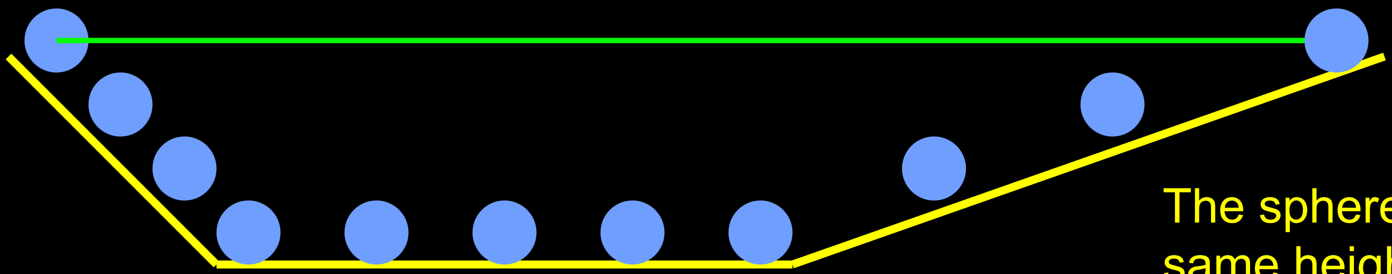
- Galileo Galilei (1564 – 1642)
  - Italian Mathematician
  - Stated that, if there was no interference on a moving object, it would keep moving in a straight line forever
    - This is a radical conclusion to reach because it is impossible to test a situation where there was no interference
      - Because there is always friction
  - He tested his hypothesis using inclined planes
    - He set up two inclined planes with different angles from the horizontal
    - He started a sphere rolling down one plane
      - It would then roll across the bottom and then up the second inclined plane
      - He realized that the sphere would roll up to the same height that it started at



The sphere rolls to the same height that it started at

– He then tested it with a different set of planes, this time with one at a significantly different angle

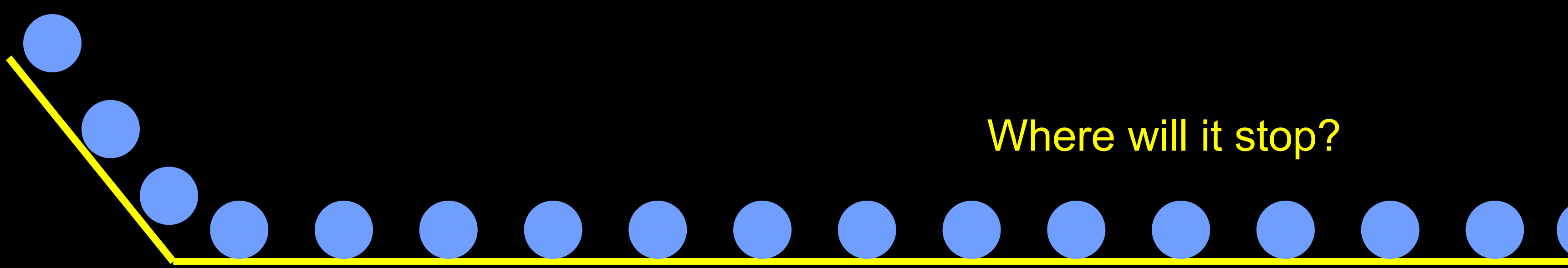
– He found that the sphere still reached the same height



The sphere still rolls to the same height that it started at

– This led him to conclude that gravity is stopping the sphere’s motion, no other outside influence

– So what happens if there is no second inclined plane? In other words, what will happen if there is no chance for gravity to act on the sphere again?



Where will it stop?

– Galileo realized that without another inclined plane to raise it above the ground and allow gravity to slow it that the sphere should continue to roll, **forever**

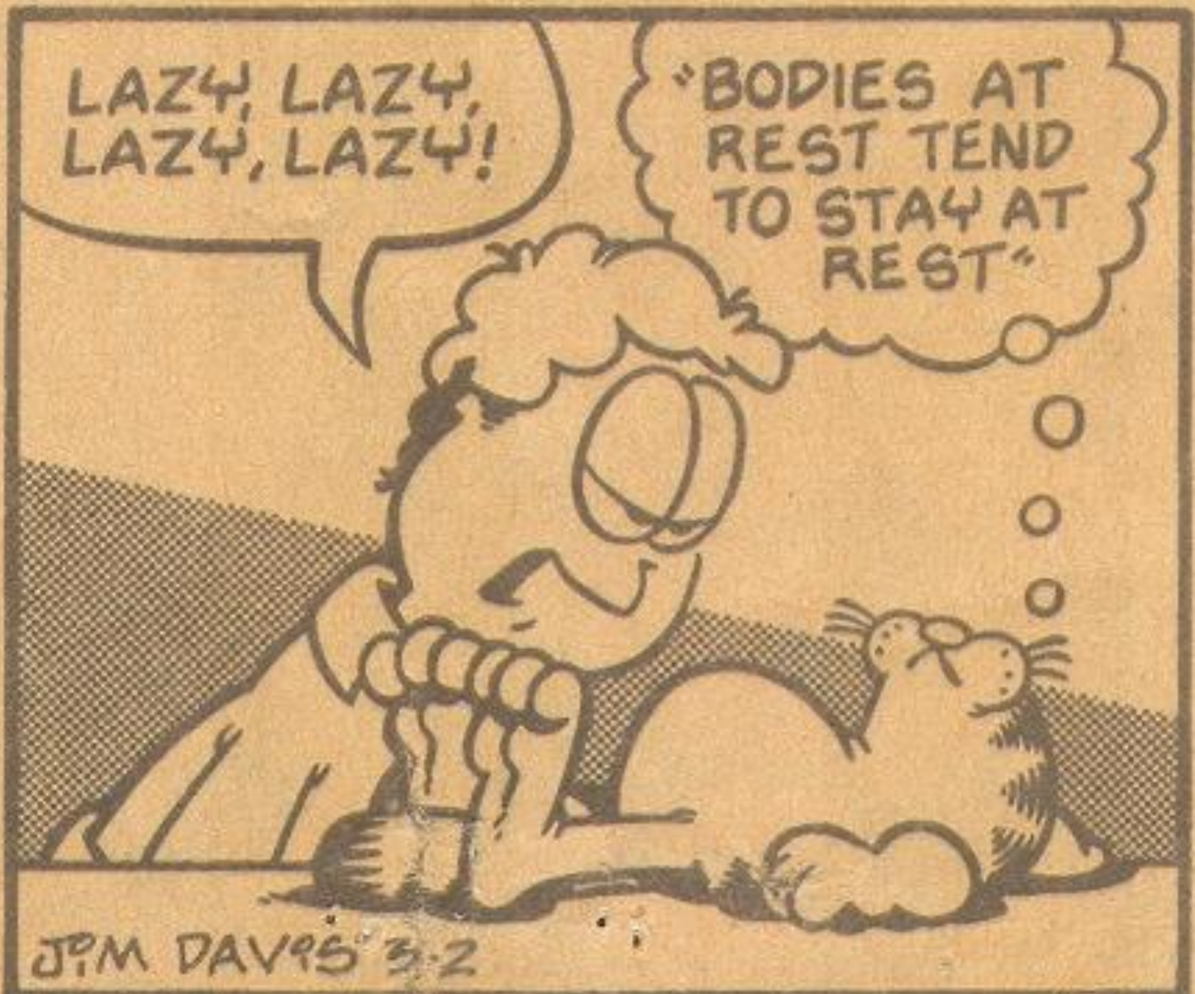
- Sir Isaac Newton (1642 – 1727)
  - English Scientist
  - Developed his three laws of motion before he was 23
  - Newton's First Law
    - Newton's first law of motion states that:
      - Any object that is at rest or any object in uniform motion will remain at rest or in uniform motion unless acted upon by a non-zero net force
        - » Uniform motion means that the object is not accelerating
          - » So, the object is not changing direction or changing speed
        - » Net Force
          - » The net force is the vector sum of all forces acting on an object
    - Also called the Law of Inertia
      - Inertia is the amount of resistance an object has to a change in motion
        - » Inertia is quantified as the mass of the object
        - » More massive the object, the more inertia the object has
    - Mass (m)
      - A measure of the inertia of an object
        - » Units: kilograms (kg)

- Reference Frame
  - A system of objects that are not moving with respect to each other
    - » Typically the background around the object
  - Used to identify motion
    - » This is done by comparing an object that is moving to the reference frame
  - Without a reference frame, there is no available outside information. Therefore, there it is impossible to detect motion
- Inertial Reference Frame
  - A reference frame where Newton’s Law of Inertia is valid
    - » For our purposes, the classroom (and for that matter the school) is an inertial reference frame
  - Accelerating reference frames are not inertial reference frames

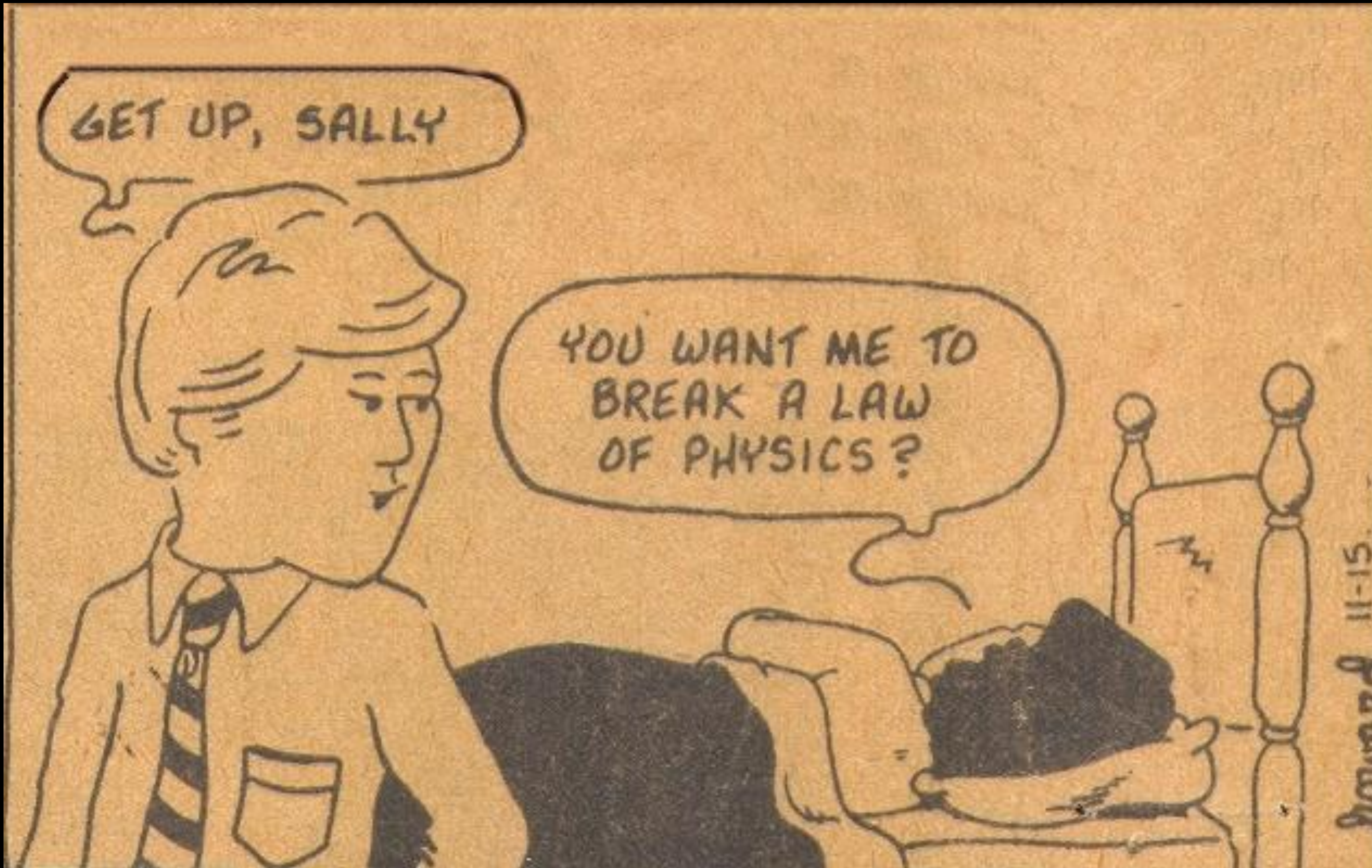

GARFIELD
YOU'RE LAZY, GARFIELD
I HAPPEN TO BE CONDUCTING A SCIENTIFIC EXPERIMENT, THANK YOU


LAZY, LAZY
I'M TESTING THE FIRST LAW OF PHYSICS...
© 1995 PAWS, INC./Distributed by Universal Press Syndicate

By Jim Davis


LAZY, LAZY, LAZY, LAZY, LAZY!
"BODIES AT REST TEND TO STAY AT REST"
JIM DAVIS 3-2


SALLY FORTH
IT'S SEVEN O'CLOCK... WHY AREN'T YOU GETTING UP?
INERTIA... A BODY AT REST TENDS TO REMAIN AT REST
© Field Enterprises, Inc., 1982


GET UP, SALLY
YOU WANT ME TO BREAK A LAW OF PHYSICS?
11-15.

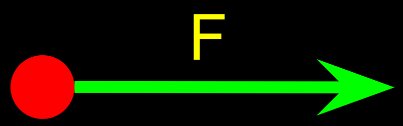
- Newton's Second Law
  - States that the acceleration that results when a net force acts on the object is directly proportional to the net force and inversely proportional to the mass of the object

$$F_{net} = ma$$

  - This is the most important law or theory that we will learn this year
    - From Newton's second law you can derive almost everything we will talk about this year

– Example

- A plane, starting from rest, has a force of 5 x 10^5 N acting on it from the engines as it rolls down the runway. If the plane has a mass of 100,000 kg, how long will it take the plane to reach a take off velocity of 63 m/s?
- Given
  - F_{net} = 5 x 10^5 N
  - m = 100,000 kg
  - v = 63 m/s
  - v_o = 0 m/s
  - t = ?



If you are not drawing out pictures at this point for each problem, you **really** should be

I am looking for the time

I cannot find the time at this point because I do not have enough information, so I should solve for the acceleration first

I know I need to solve for acceleration

The only way I can do this is by using Newton's First Law

$$\vec{F}_{net} = m\vec{a} \therefore \vec{a} = \frac{F_{net}}{m}$$

Solve for the acceleration

$$\vec{a} = \frac{5x10^5 N}{100{,}000kg}$$

$$a = 5m/s^2$$

Once you have acceleration, use kinematics to solve for time

$$v = v_o + at \therefore t = \frac{v - v_o}{a}$$

$$t = 12.6s$$

– Force as a ~~Vader~~ Vector

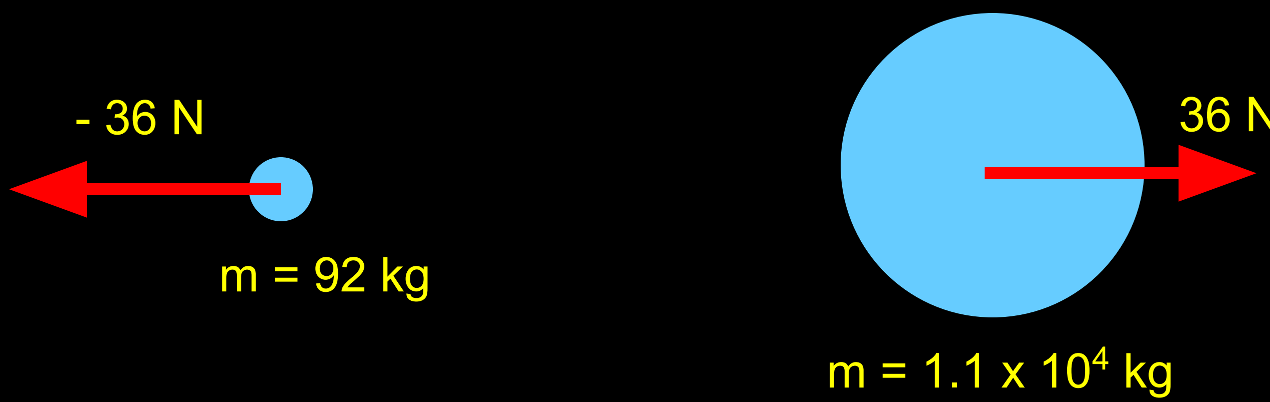
- Since Force is a vector, it can be split into components
- Newton’s Second Law applies to each direction
- Any situation involving Forces off of the two axes requires that the forces be split into components first

$$F_{net\,x} = ma_x$$

$$F_{net\,y} = ma_y$$

- Newton's Third Law
  - Whenever one body exerts a force on a second body, the second body exerts an oppositely directed force of equal magnitude on the first body
    - Also called the Law of Action – Reaction
  - Simply put, for every action, there is an equal and opposite reaction
    - This implies that forces come in pairs
      - » These pairs always are exerted on different objects
    - Example
      - » You lean against a wall, the wall pushes against you to keep you upright.
      - » You push against a wall with a force of 100 N. What is the force that the wall exerts on you?

- Example
  - An astronaut (m = 92 kg) pushes against a spaceship (1.1×10^4 kg) with a force of 36 N. What is the acceleration of the spaceship and the astronaut?
  - Given
    - » $m_a = 92$ kg $\qquad$ $m_s = 1.1 \times 10^4$ kg
    - » $F_{\text{Astronaut on Spaceship}} = 36$ N
  - Draw a Free-body Diagram(s)



I can draw a force on the astronaut from the spaceship because I know from Newton's Third Law that the force is 36 N in the opposite direction

$$\vec{F}_{net} = m\vec{a} \therefore \vec{a} = \frac{F_{net}}{m}$$

Starship

$$\vec{a} = \frac{36N}{11{,}000kg} \rightarrow a = .0033m/s^2$$

Astronaut

$$\vec{a} = \frac{-36N}{92kg} \rightarrow a = -.39m/s^2$$

Why should it make sense that the acceleration of the astronaut is large than the acceleration of the spaceship?