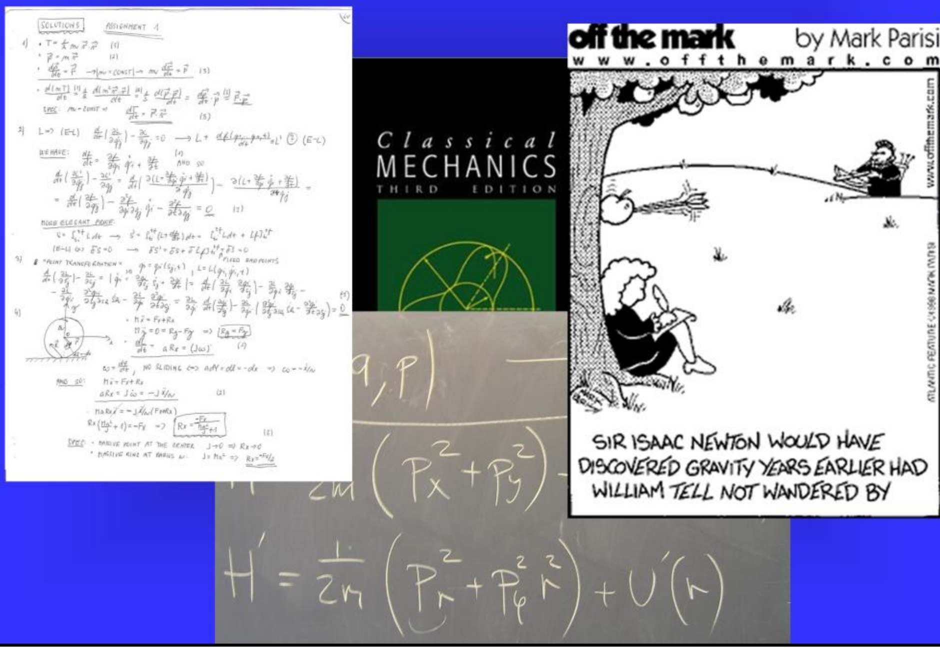
Classical Mechanics



Newton's First Law

The Law of Inertia

The **NATURAL** state of motion is to ***resist changes***.

Aristotle says:

The natural state of objects on the Earth is a state of rest.

Newton Says:

The natural state of motion of an object is to keep doing what it's doing.

Galileo had already said this.

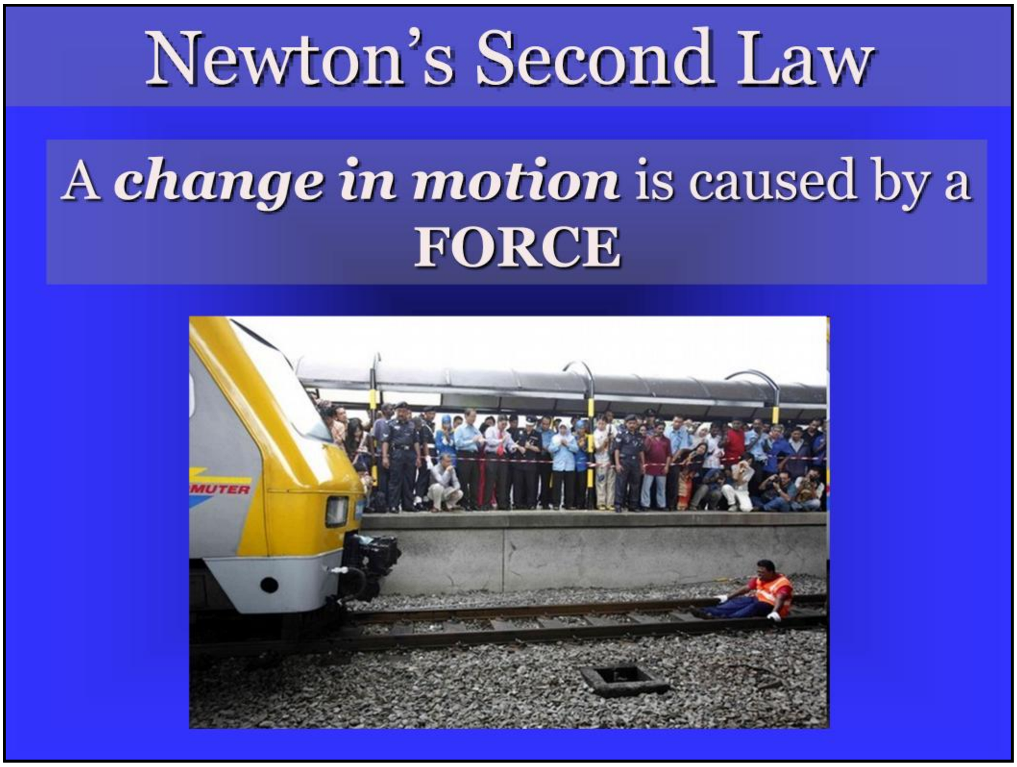
Aristotle divided the universe into "The Heavens" and "The Earth"

The "Heavens" were eternal and unchanging. The natural state of the heavens was perfect motion.

The Earth was temporary and ever changing.

The natural state of motion of Earth bound objects was rest.

Newton (and Galileo) said that the natural state of motion is to not change.

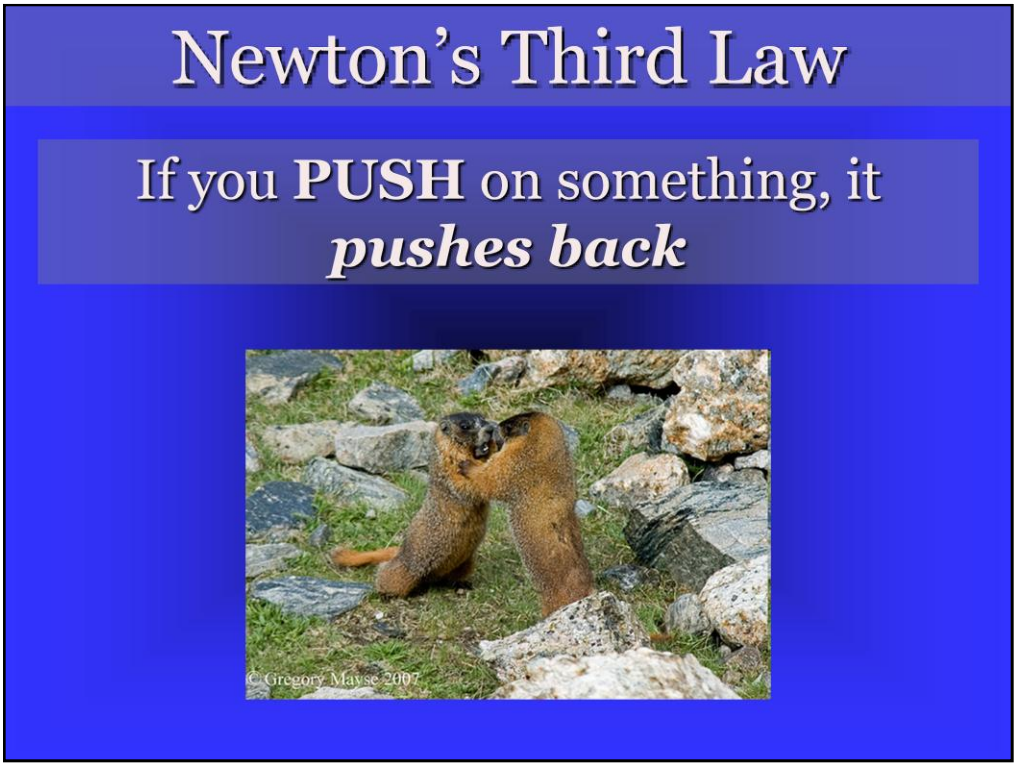


Galileo didn't say this.

To get an object to change, a force must be applied.

When we push the gas pedal in the car, the engine generates a force causing the car to move.

Why does the car stop if I stop pushing with the engine?

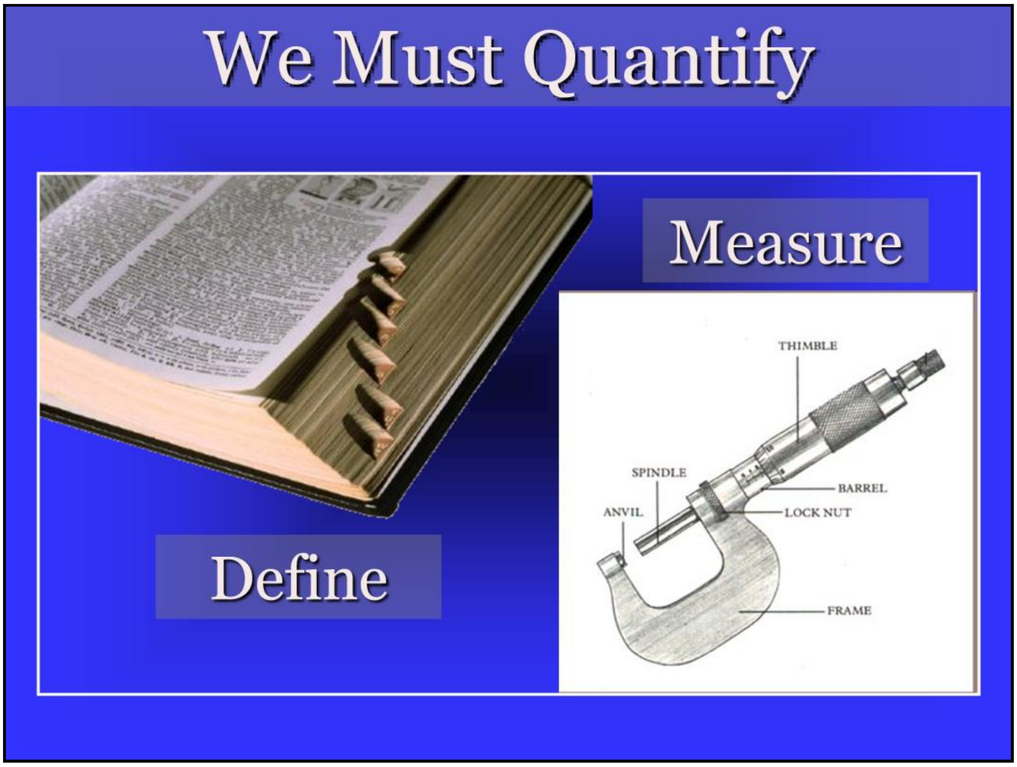


Forces come in pairs.

If you apply a force to something, it responds by pushing back.

As I push against a baseball to throw it, I can FEEL it pushing back.

This is how rockets work. We push mass out the back of the rocket and the opposing force pushes back, propelling the rocket forward.



We have described Newton’s three laws in a general QUALITATIVE way.

But, as we learned from our Time Gnome discussion, we need to be much more precise.

We have to carefully DEFINE our terms so that we can make careful MEASUREMENTS.

We use mathematics to build models so we need to figure out how to QUANTIFY the world.

What EXACTLY does the first law mean?

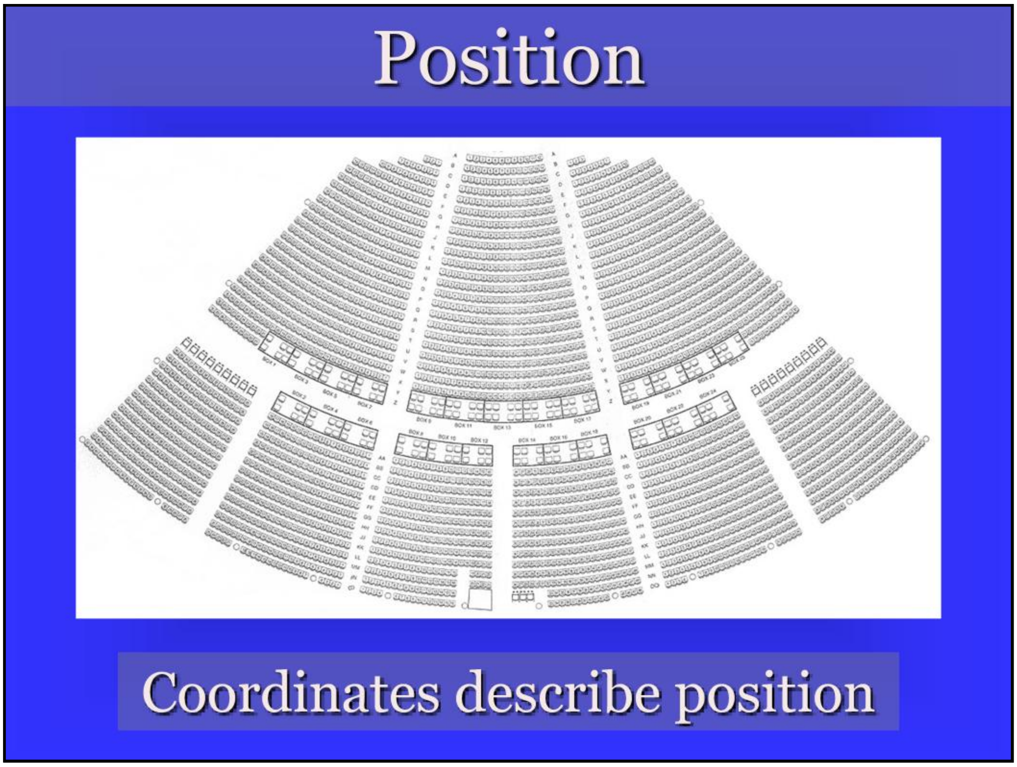
What do we mean by “Motion”

What do we mean by “Rest”

ABCD

How many numbers do we need to describe our POSITION in the Universe?

- **A. One**
- **B. Two**
- **C. Three**
- **D. More than three**



How would you describe your position in the class room?

We need two numbers or “Coordinates”

The row and column of the seat…

We also have to define our point of reference

Our Coordinates give our position RELATIVE to what? The “origin” of the coordinate system.

Where precisely is the ‘orgin’ of the coordinate system?

The origin is where we start counting. Row 1, Seat 1, Level 1

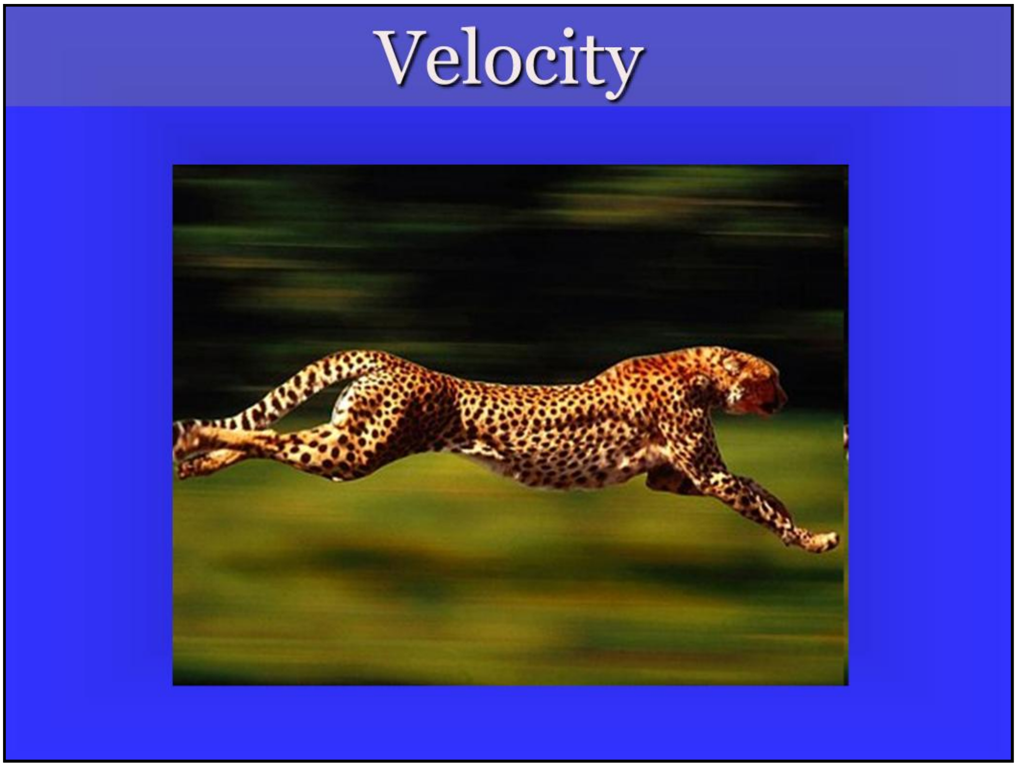
What if there were several balconies also? Then we would need a THIRD number.

Think about baseball tickets.

Section, row, seat AND… TIME.

We also need to know WHEN to be there.

An alternate description is DISTANCE and DIRECTION.



Velocity has something to do with changes in SPATIAL position.

The other element is time.
Velocity is the RATE of change in position.
It takes into account direction.

VELOCITY is the thing that remains constant barring outside influence.

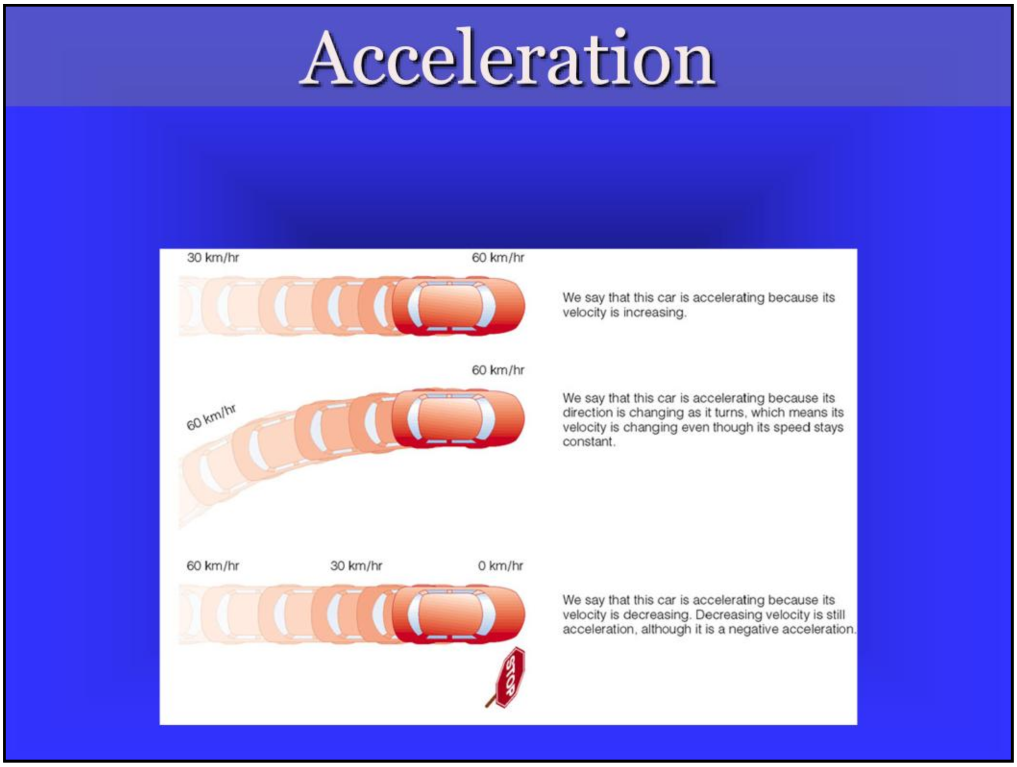
Acceleration

Define velocity… Note that it is a combination of Speed AND Direction.

Define force as causing a change in velocity

A change in direction… IS a change in velocity

Note net force… sum of all forces…



So… forces cause changes in velocity… or accelerations.

The acceleration is proportional to the force… and inversely proportional to the mass.

ABCD

My car is going 60 mph in a straight line. Its acceleration is:

A. 60

B. zero

C. less than zero

D. greater than zero but not 60

ABCD

A baseball is falling towards the Earth. Its acceleration is:

A. zero

B. Not zero

C. There's no way to know

ABCD

I have thrown a baseball up in the air. As it is rising, its acceleration is:

A. zero

B. Not zero

C. There's no way to know

ABCD

I have thrown a baseball up in the air. At the peak of its trajectory, its acceleration is:

A. zero

B. Not zero

C. There's no way to know

Newton's Second Law

Quantitative definition of Force

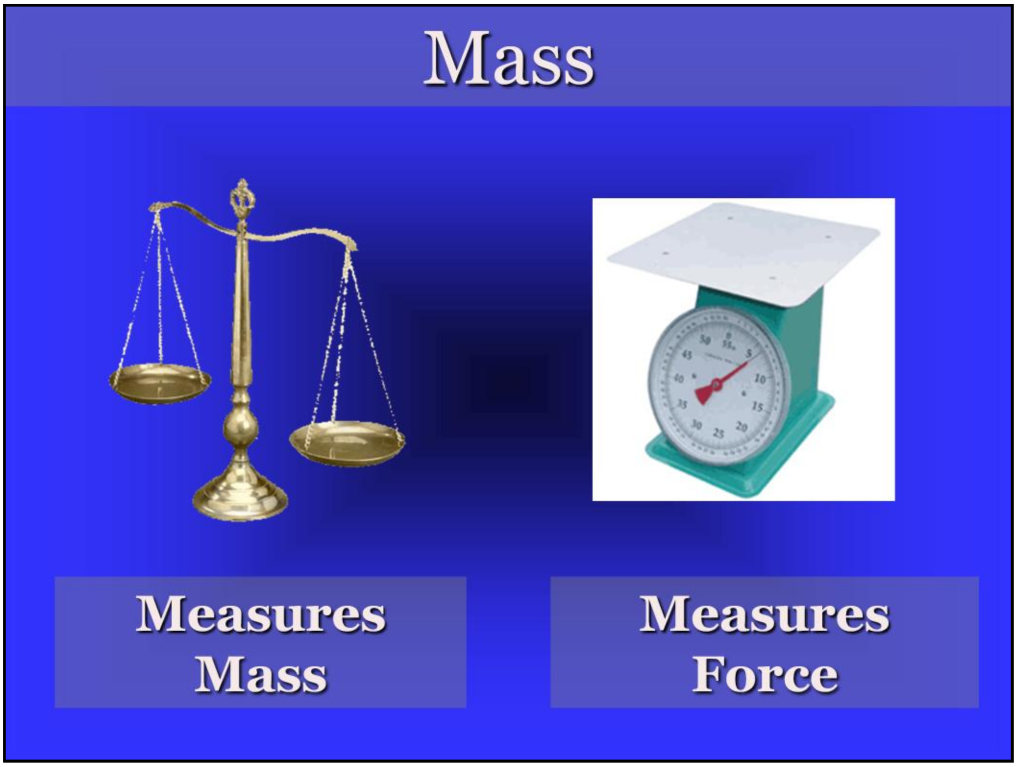
$$F = ma$$

Describes **precisely** how force modifies velocity

We can actually make mathematical predictions with this equation…

This equation DEFINES what we mean by inertial mass.

Massive objects are hard to accelerate.



Balance scale:

Balance test object against a REFERENCE mass

Independent of gravitational force.

You'll get the same answer on Mars as on Earth

Spring scale.

Measurement is dependent on gravitational force.

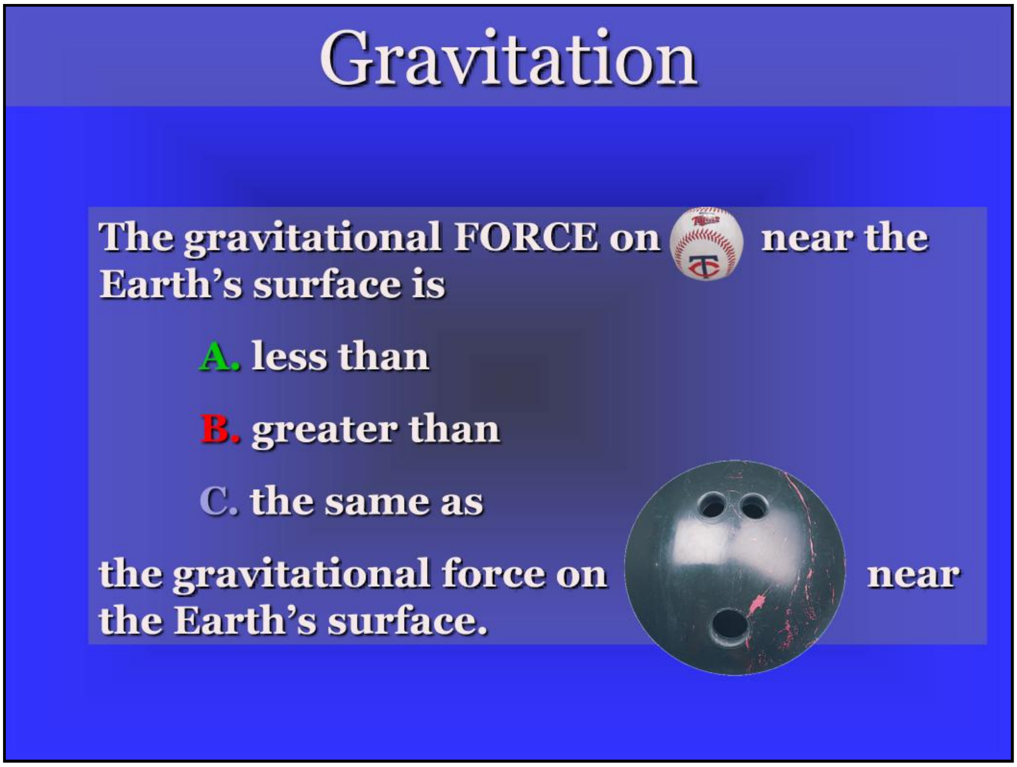
Measures how far a spring is stretched or compressed,
which is a measure of FORCE.

You'll get DIFFERENT answers on Earth versus Mars

Universal Law of Gravitation

$$F = G\frac{M_1 M_2}{r^2}$$

Objects with **mass** exert an attractive force on one another.



Gravitational force is DIRECTLY PROPORTIONAL to the mass of the objects in question.

more mass = more force.

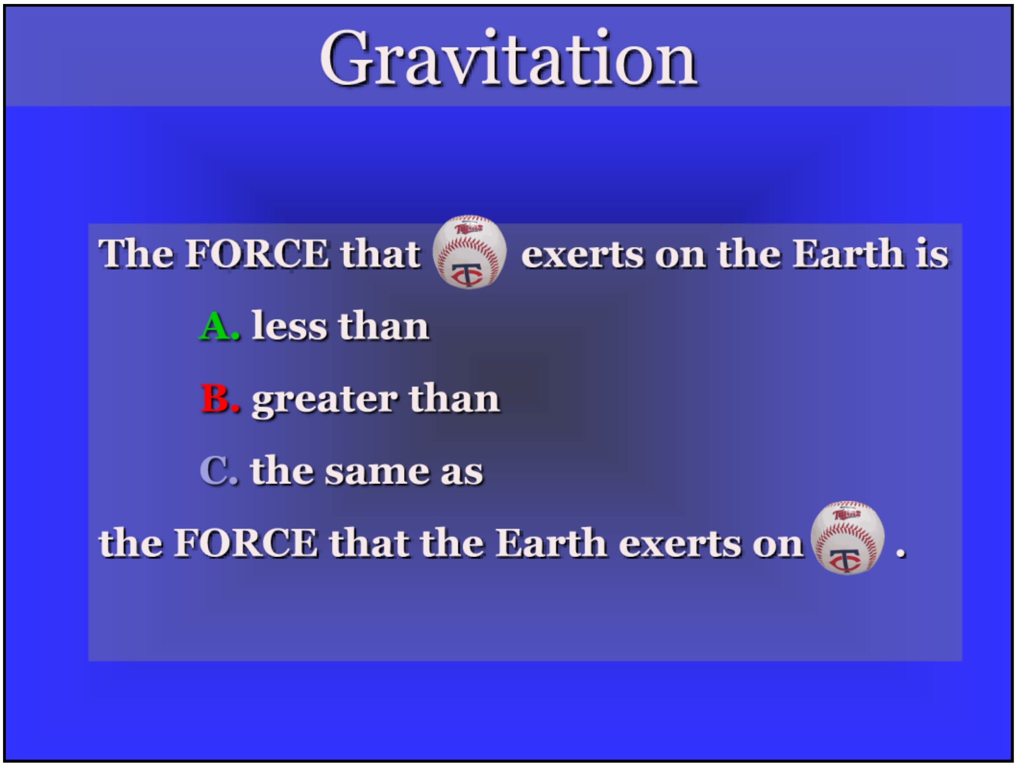
If the mass doubles, the gravitational force doubles.

Remember! We are talking about the force to due BOTH masses:

The Earth and the ball.

If I double the mass of the Earth: the gravitational force doubles

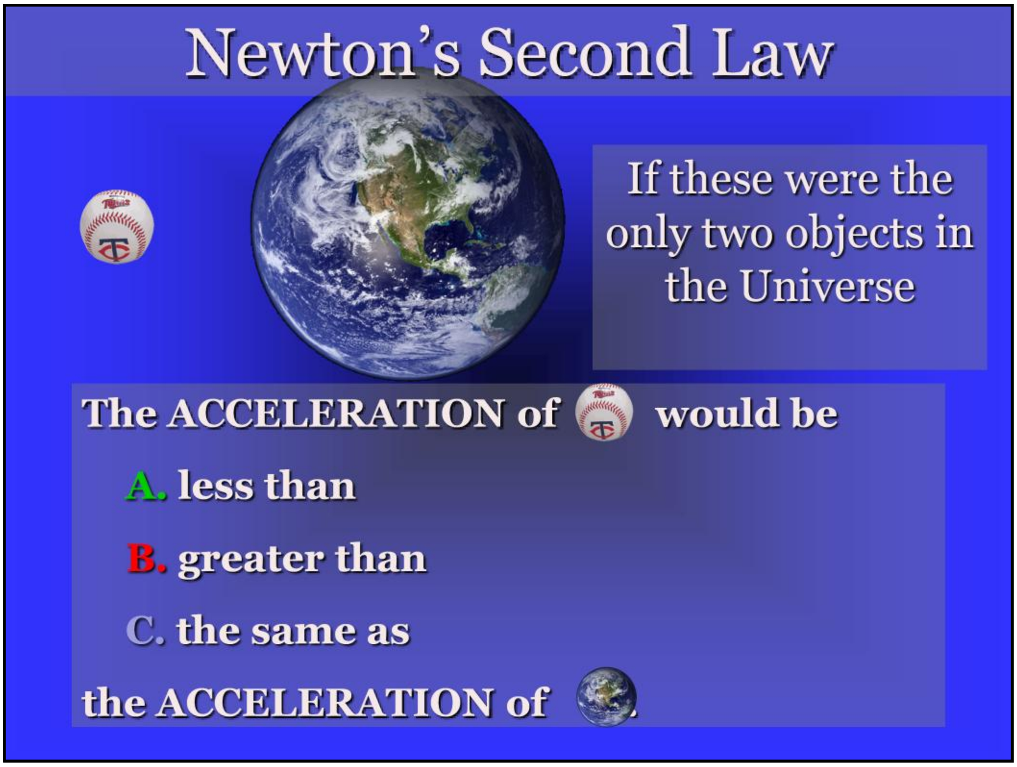
If I double the mass of the ball: the gravitational force doubles



Forces come in PAIRS.

For every force, there is an EQUAL AND OPPOSITE force.

The ball is pulling on the Earth just as hard as the Earth is pulling on the ball.



MASS and INERTIA are the same thing.

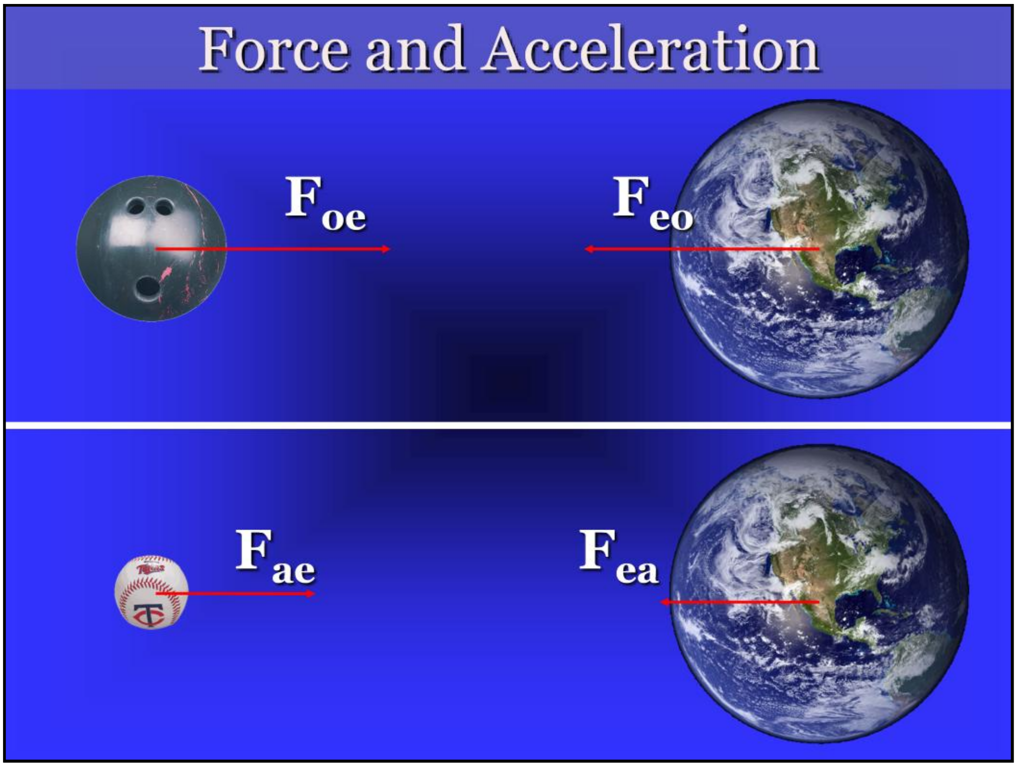
It's a measure of an object's RESISTANCE to change.

It's REALLY hard to convince the Earth to change. (what do I mean by change here?)

The baseball isn't as hard to convince.

The FORCE on the two of them is the SAME so …

Why?



Let’s let the Earth and a single ball be the ONLY things in the universe

When you are on the top of a building, your weight is ____ when you are on the ground floor.

A. slightly greater than

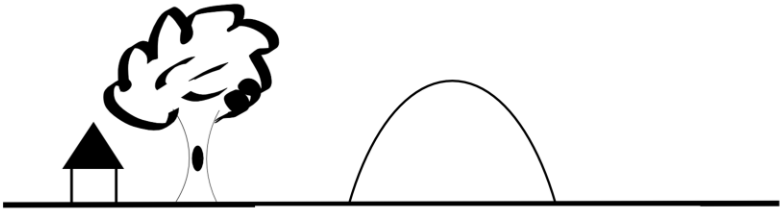
B. the same as

C. slightly less than

We buy it in the form of electricity and gas

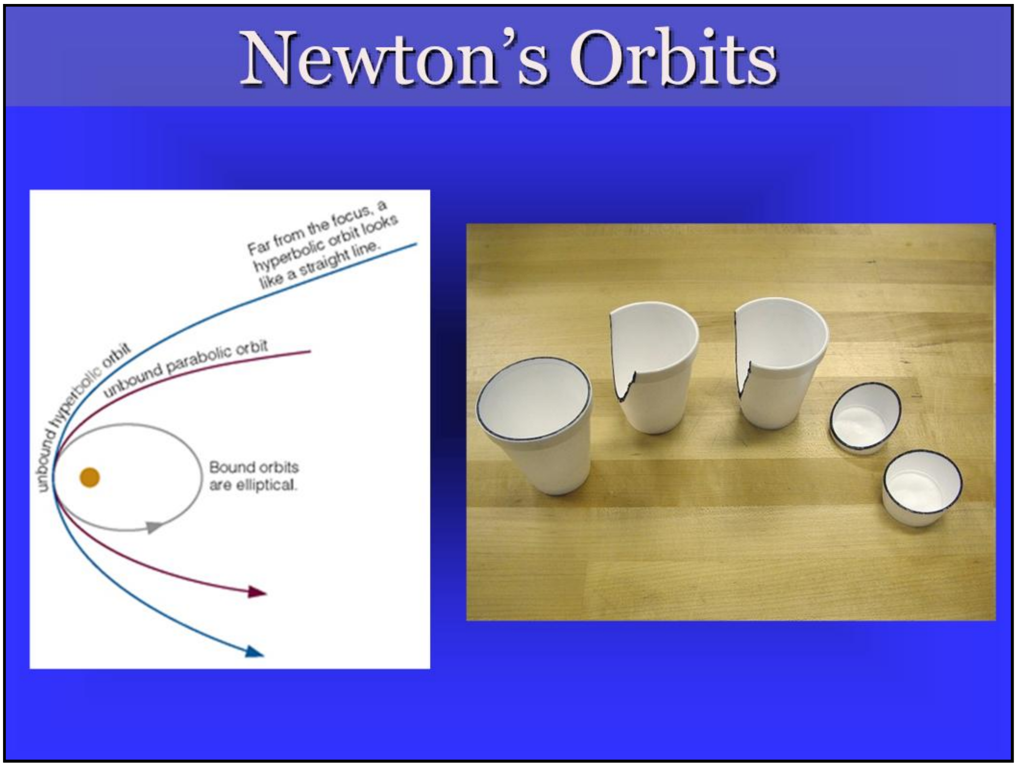
We gather it when we eat food and expend it when we do things.

Heaven and Earth United



What is an Orbit?

The knack lies in learning how to throw yourself at the ground and miss.
~Arthur Dent

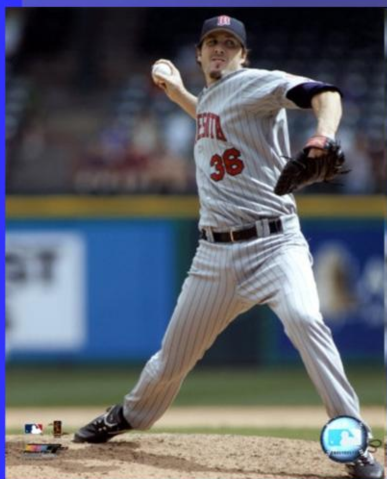


Newton figured out that orbits are Conic Sections.

Why are some orbits unbound?

Escape Velocity

When what goes up DOESN'T come down



V_{esc} = 25,000 mph

Newton versus Kepler

Kepler's laws are a special case of Newton's laws.