Forces

Newton’s Laws of Motion

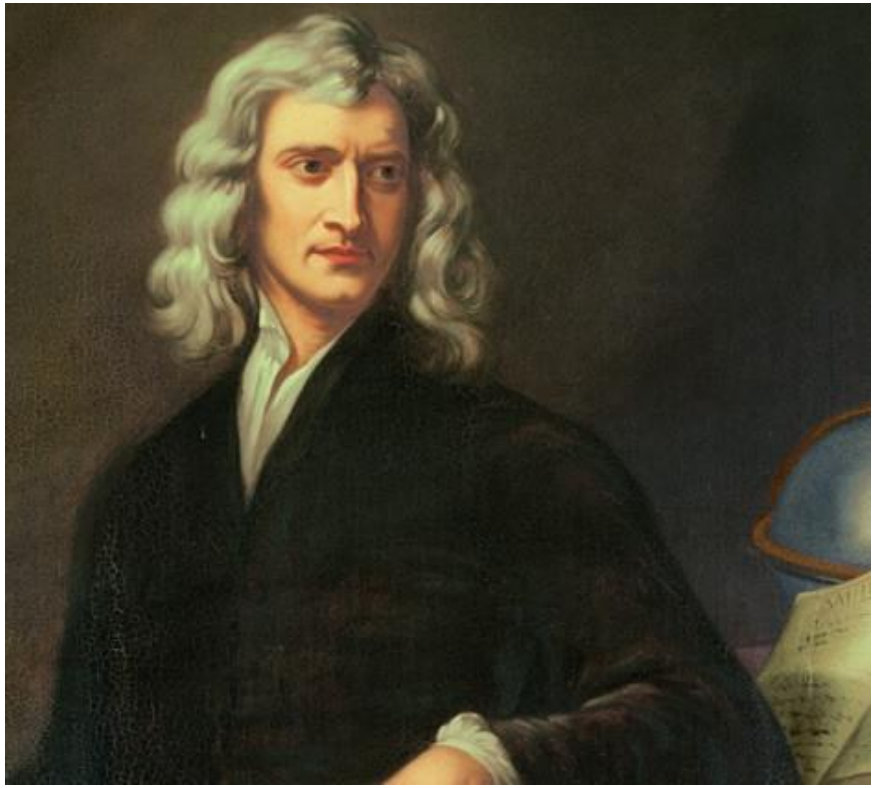
What would happen if you…

- roll a bowling ball down a straight, level surface?
- slide a book across the floor of the classroom?
- hold a baseball out in front of you and let go?
- place a book on a bookshelf and let go?

What is different in these scenarios that causes the differences in motion?

Balanced Forces vs. Unbalanced Forces

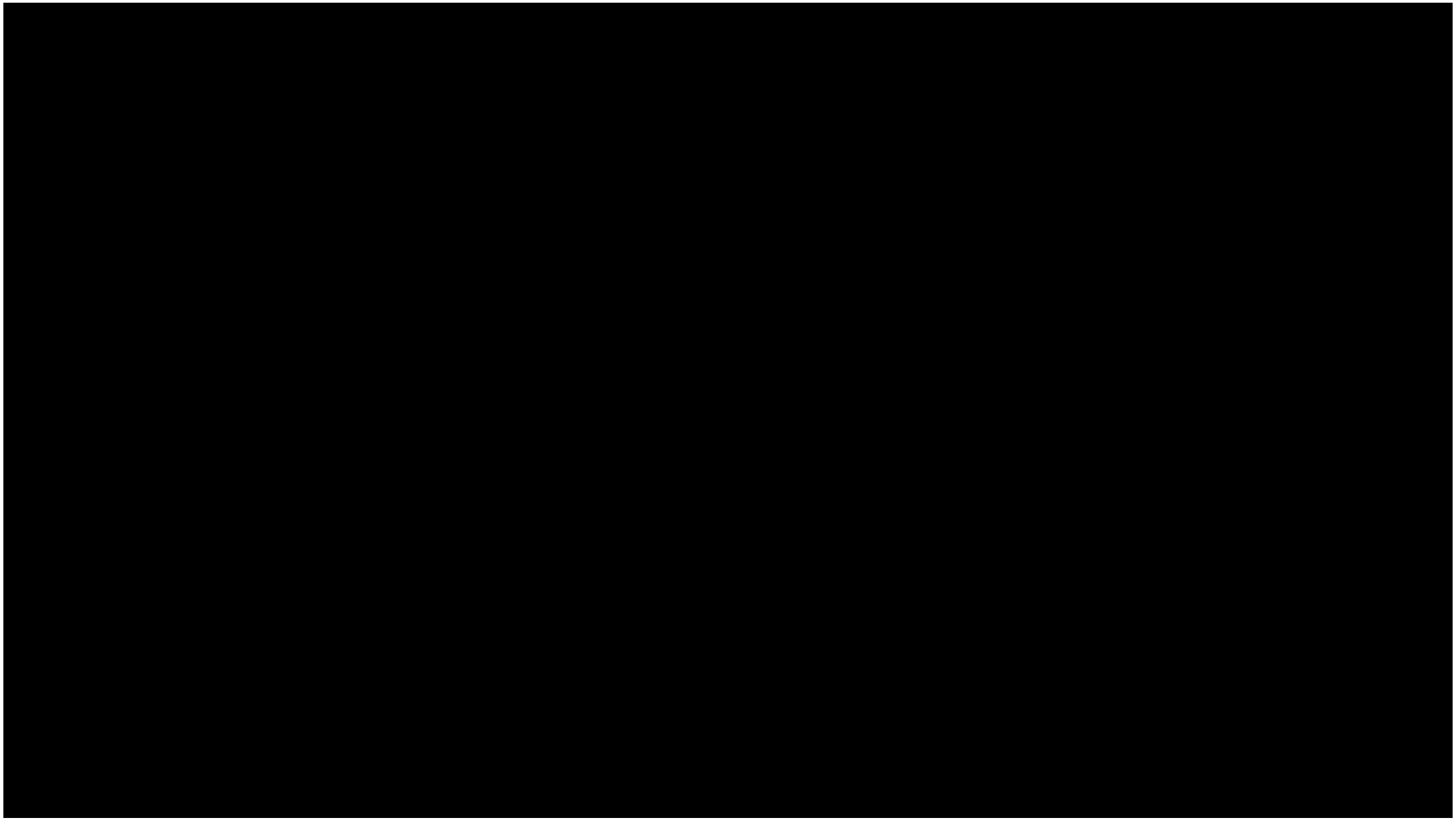
- As we learned last week, forces can affect motion (whether they are balanced or unbalanced).
- Sir Isaac Newton developed three laws to describe the motion of objects experiencing different types of forces…



Newton's First Law of Motion

- An object at rest will remain at rest, and an object in motion will remain in constant motion (*constant velocity and direction*) unless acted on by an unbalanced force.
  - *In other words…**"The only way to <u>change</u> an object's motion is to apply an unbalanced force."***

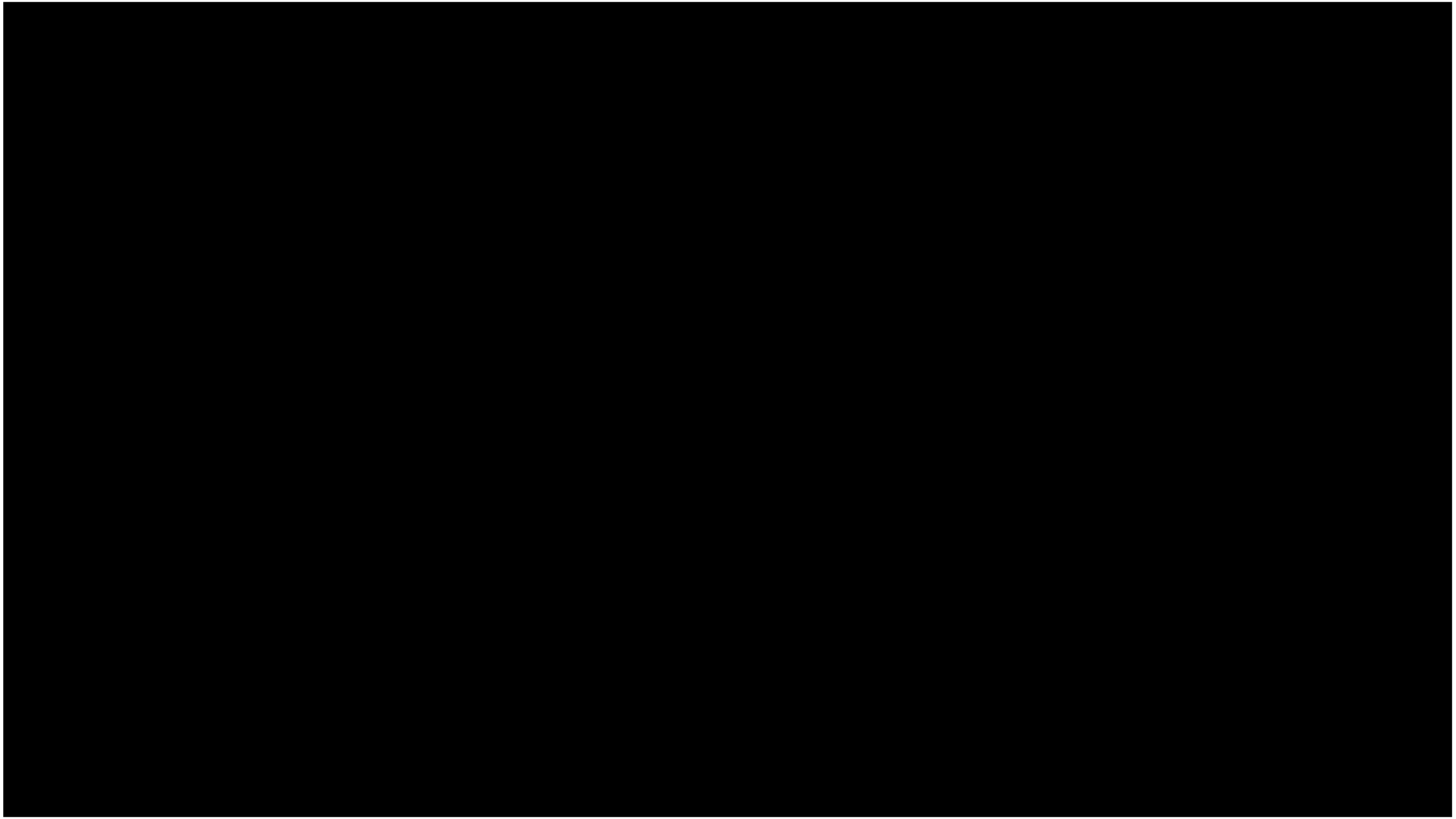
Newton’s First Law of Motion



Newton's 1st Law (cont.)

- **Inertia**
  - the tendency of an object to resist a change in its motion
    - Imagine riding in a car and stopping suddenly at a red light. You continue moving forward in your seat due to inertia.
- Inertia depends on mass
  - The greater an object's mass, the more inertia it has.
  - *The greater it will resist a change in its motion*
    - Imagine trying to push a box with a refrigerator in it…
    - Now imagine trying to push the same box, but empty…

Which will hit the ground first?



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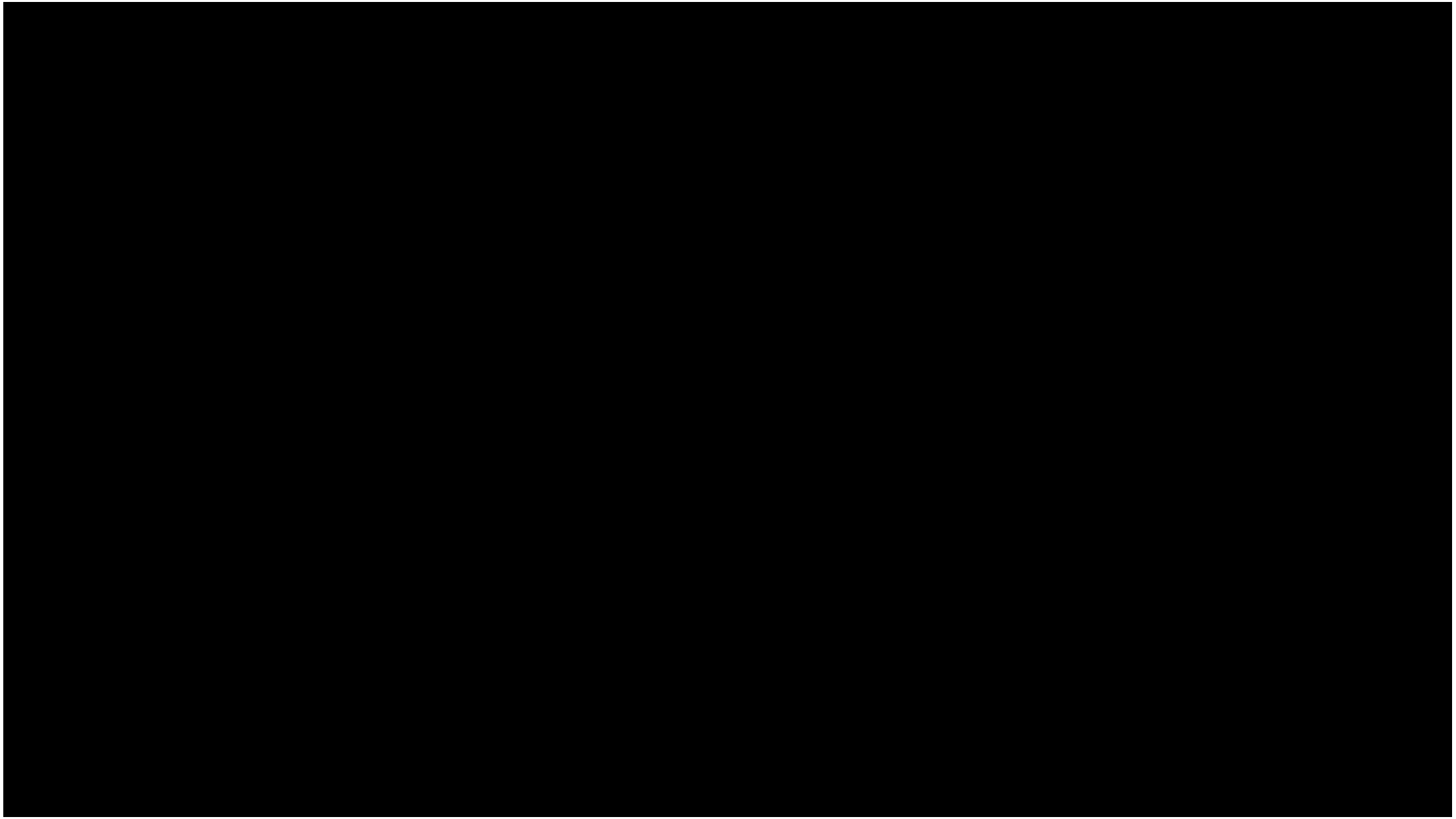
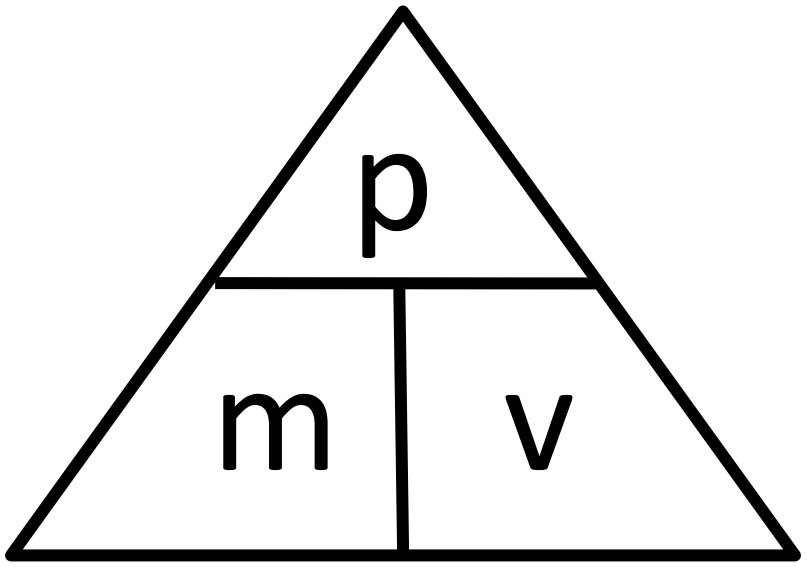


Momentum

- Newton called it “the quantity of motion.”
- The more momentum an object has, the harder it is to stop.
  - Momentum is a type of inertia (*the inertia of a moving object*)
- $p = mv$
  - p = momentum
  - m = mass
  - v = velocity
- Units = $kg \times {}^{m}/_{s}$



Momentum Calculations

- Suppose a 5 kg ball is falling at a speed of 10 m/s when you catch it. How much momentum will it have?
  - $p = mv$
  - $p = (5kg)(10m/s)$
  - $p = 50\ {}^{kg_x m}/_{s}$

- If a 6 kg object has a momentum of 18 ${}^{kg*m}/_{s}$, how fast is it moving?
  - $v = p/m$
  - $v = (18\ {}^{kg_x m}/_{s}) / (6\ kg)$
  - $v = 3\ m/s$

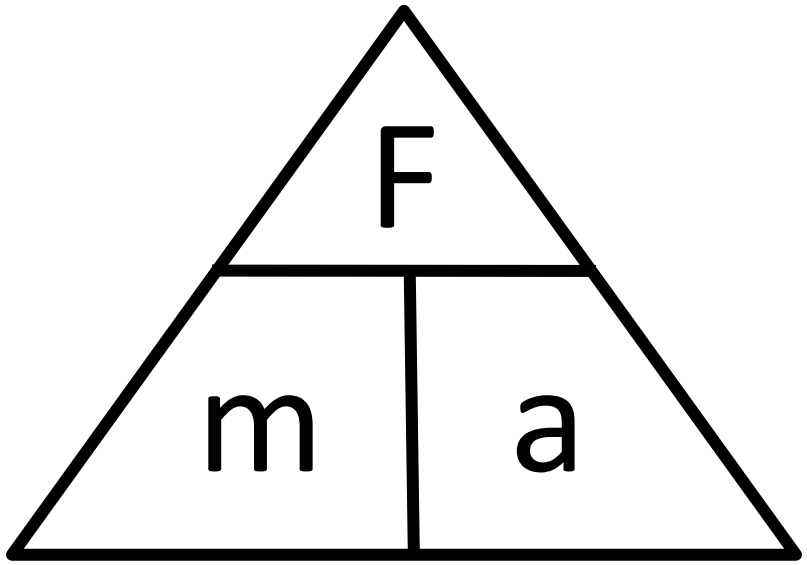
Newton's Second Law of Motion

- An object will accelerate in the direction of a net force that is applied to it.
  - If gravity applies a downward unbalanced force on an object, it will accelerate down.

Newton was at home from university (*which, interestingly enough, was temporarily closed due to an outbreak of the bubonic plague*) sitting in an apple orchard when he observed an apple fall from a tree. He wondered what caused the apple to fall down in a straight line toward the ground. This question led him to his laws of motion as well as his theory of universal gravitation.

Calculating Newton's Second Law

- The net force on an object is equal to the product of its acceleration and its mass.
- In other words…
  - **NET FORCE** equals **MASS** times **ACCELERATION**
  - **F = ma**
- Unit of Force = Newton (*N*)
  - Named after Sir Isaac Newton
  - 1N (Force) = 1kg (mass) x 1m/s^2 (acceleration)



Newton's 2nd Law (cont.)

- Weight is a form of Newton's 2nd Law.
- Weight is the effect of the Earth's gravity on an object's mass.
  - **w = mg** (weight = mass x gravity)
    - weight is the **force** of gravity acting on an object
    - "g" represents the **acceleration** due to gravity
  - So, really…
    - "**w = mg**" is just a specific example of "**F = ma**"

Newton's 2nd Law Practice

- A 40kg wagon is being pulled by a boy. The force the boy exerts on the wagon causes it to accelerate at $2m/s^2$. What is the force exerted on the wagon?

$F=ma$

$F=(40kg)(2m/s^2)$

$F=80N$

Newton's 2nd Law Practice

- A woman uses a 70N force to push a 35kg shopping cart. What is the resulting acceleration?

$F=ma$

$a=F/m$

$a=(70N) / (35kg)$

$a=2m/s^2$

Newton's 2nd Law Practice

- A boy throws a ball by exerting a 10N force. The ball accelerates at $10m/s^2$. What is the mass of the ball?

$F=ma$

$m=F/a$

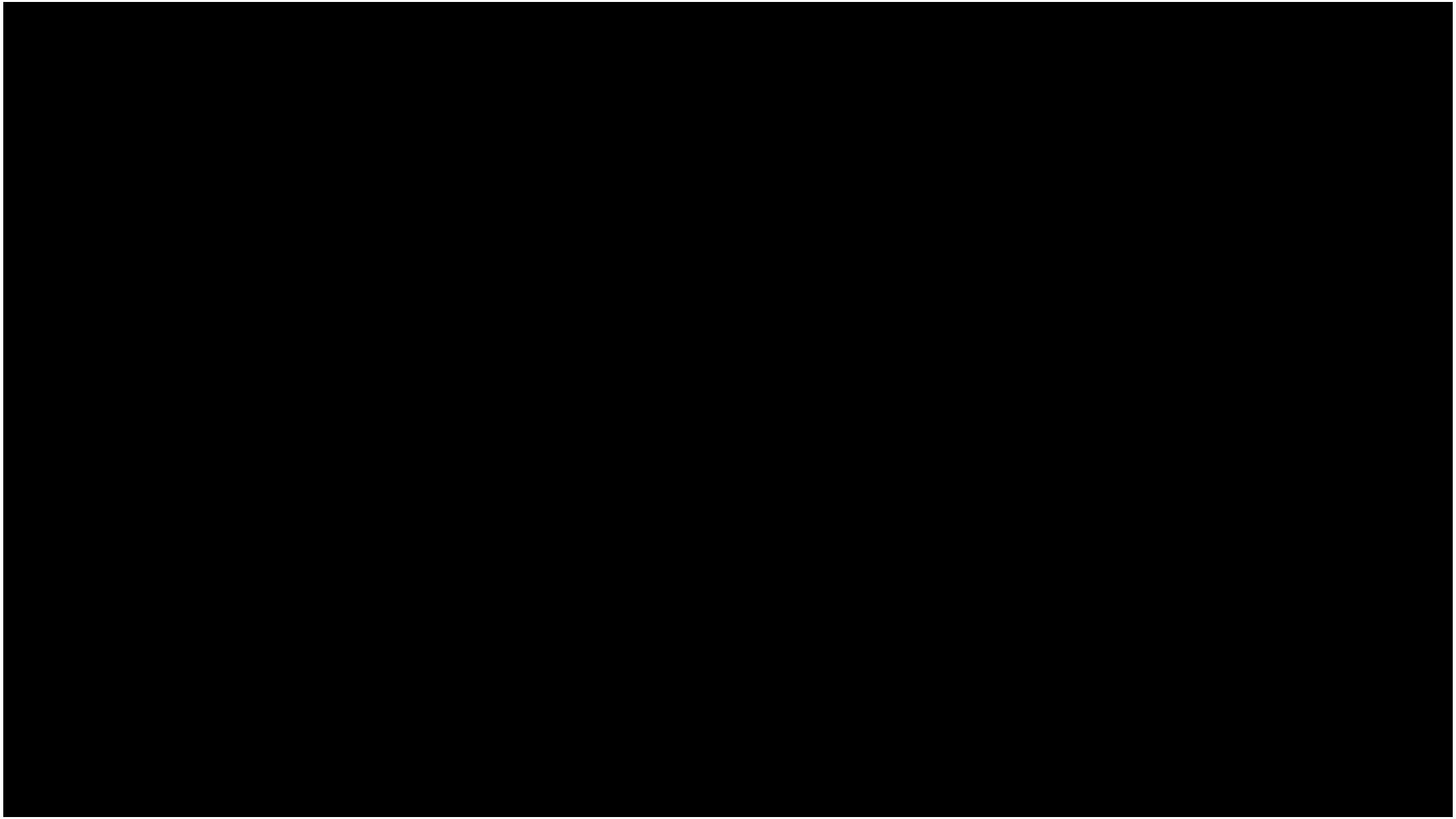
$m=(10N) / (10m/s^2)$

$m=1kg$

Newton's Third Law of Motion

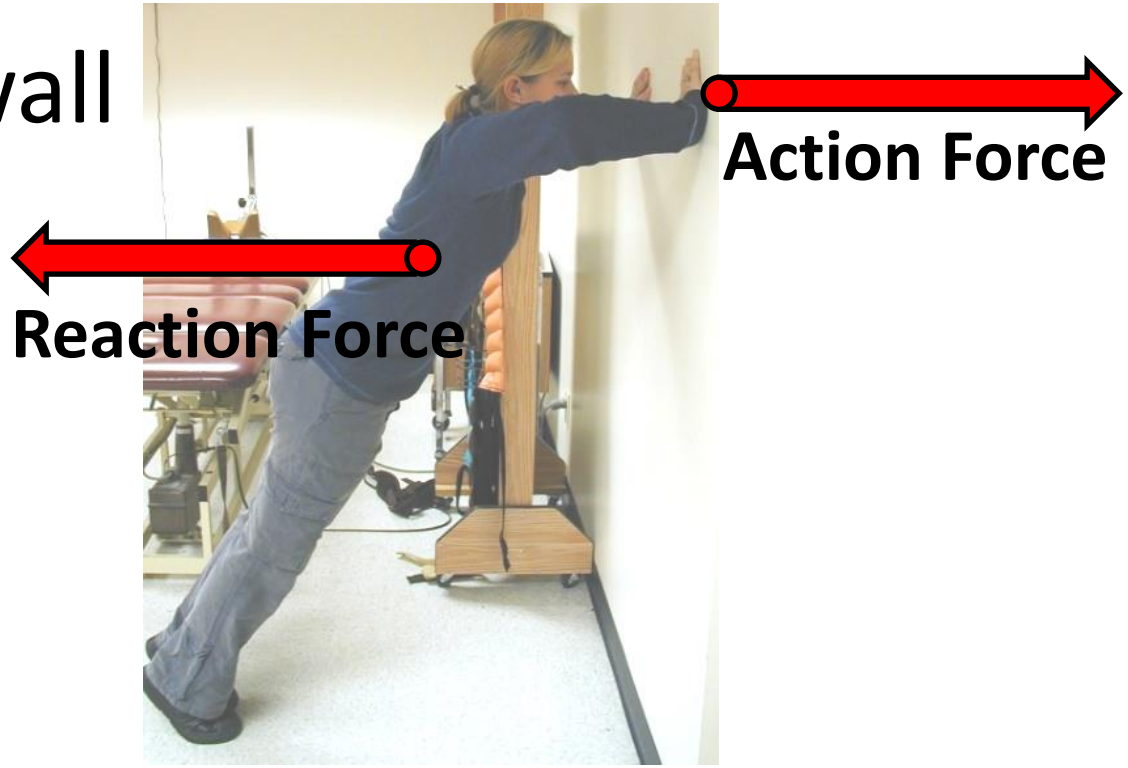
- If one object exerts a force on another object, then the second object exerts an equal but opposite force on the first.
  - "Every action has an equal and opposite reaction." (Action-Reaction)
- If you push on a wall with 250N of force, then the wall pushes back with 250N of force.
- The "Normal Force" is an example of Newton's 3rd Law.

Newton’s Third Law of Motion



Newton's Third Law Diagrams

- Key point: The action and reaction forces are acting on **<u>two different objects</u>**! (This is what makes a 3rd law diagram different from a force diagram!)
- Ex: a person pushing on a wall



Newton's Laws of Motion in Review

- Newton's 1st Law
  - **INERTIA** – objects will resist a change in their motion
- Newton's 2nd Law
  - **F=ma** – a net force causes an acceleration in the direction of the net force
- Newton's 3rd Law
  - **Action/Reaction** – an action force results in an equal and opposite reaction force