



# Newton's Laws of Motion

I. Law of Inertia

II.  $F=ma$

III. Action-Reaction



*While most people know what Newton's laws say, many people do not know what they mean (or simply do not believe what they mean).*

# Newton's Laws of Motion

- 1<sup>st</sup> Law – An object at rest will stay at rest, and an object in motion will stay in motion at constant velocity, unless acted upon by an unbalanced force.
- 2<sup>nd</sup> Law – Force equals mass times acceleration.
- 3<sup>rd</sup> Law – For every action there is an equal and opposite reaction.

# **1<sup>st</sup> Law of Motion** **(Law of Inertia)**

*An object at rest will stay at rest, and an object in motion will stay in motion at constant velocity, unless acted upon by an unbalanced force.*

# 1<sup>st</sup> Law

- *Inertia is the tendency of an object to resist changes in its velocity: whether in motion or motionless.*



These pumpkins will not move unless acted on by an unbalanced force.

# 1<sup>st</sup> Law

- Once airborne, unless acted on by an unbalanced force (gravity and air – fluid friction), it would never stop!



# 1<sup>st</sup> Law

- Unless acted upon by an unbalanced force, this golf ball would sit on the tee forever.



Why then, do we observe every day objects in motion slowing down and becoming motionless seemingly without an outside force?

*It's a force we sometimes cannot see –  
friction.*



*Objects on earth, unlike the frictionless space the moon travels through, are under the influence of friction.*

What is this unbalanced force that acts on an object in motion?

# Friction!!

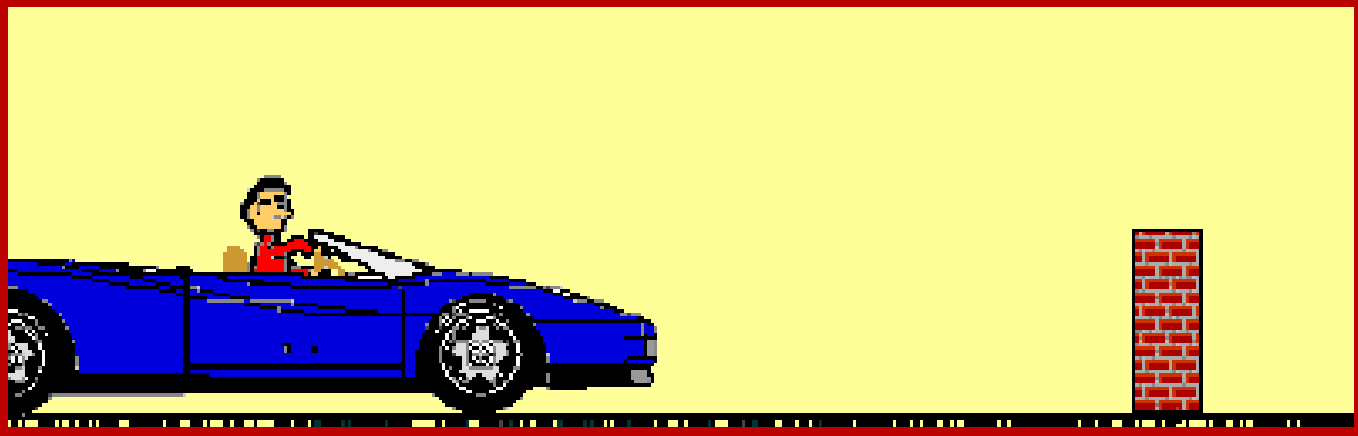
- There are four main types of friction:
  - Sliding friction: ice skating
  - Rolling friction: bowling
  - Fluid friction (air or liquid): air or water resistance
  - Static friction: initial friction when moving an object

Slide a book  
across a table and  
watch it slide to a rest  
position. The book  
comes to a rest  
because of the  
*presence* of a force -  
that force being the  
force of friction -  
which brings the book  
to a rest position.



- In the absence of a force of friction, the book would continue in motion with the same speed and direction - forever! (Or at least to the end of the table top.)

# Newton's 1<sup>st</sup> Law and You



Don't let this be you. Wear seat belts.

Because of inertia, objects (including you) resist changes in their motion. When the car going 80 km/hour is stopped by the brick wall, your body keeps moving at 80 m/hour.

## 2<sup>nd</sup> Law

$$F = m \times a$$



## 2<sup>nd</sup> Law

*The net force of an object is equal to the product of its mass and acceleration, or  $F \equiv ma$ .*

## 2<sup>nd</sup> Law

- When mass is in kilograms and acceleration is in  $\text{m/s/s}$ , the unit of force is in newtons (N).
- One newton is equal to the force required to accelerate one kilogram of mass at one meter/second/second.



## 2<sup>nd</sup> Law ( $F = m \times a$ )

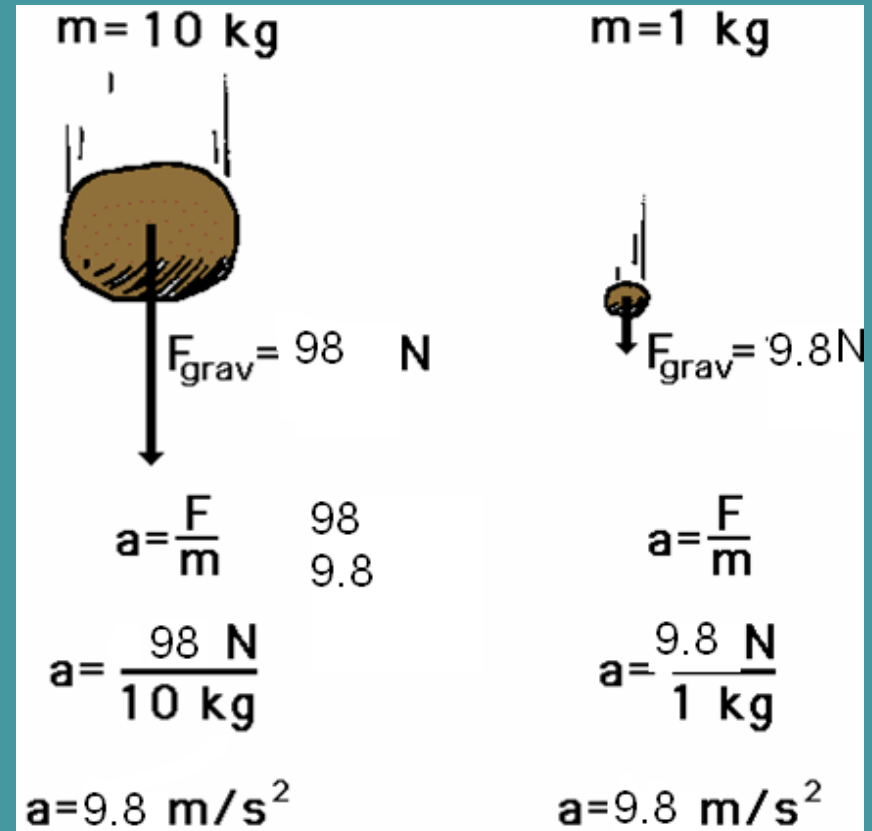
- How much force is needed to accelerate a 1400 kilogram car 2 meters per second/per second?
- Write the formula
- $F = m \times a$
- Fill in given numbers and units
- $F = 1400 \text{ kg} \times 2 \text{ meters per second/second}$
- Solve for the unknown
- 2800 kg-meters/second/second or **2800 N**

Net Force N	Mass Kilograms	Acceleration m/s/s
10	2	5 m/s/s
20	2	10 m/s/s
20		5 m/s/s
10	5	m/s/s
	1	10 m/s/s

If mass remains constant, doubling the acceleration, doubles the force. If force remains constant, doubling the mass, halves the acceleration.

***Newton's 2<sup>nd</sup> Law proves that different masses accelerate to the earth at the same rate, but with different forces.***

- We know that objects with different masses accelerate to the ground at the same rate.
- However, because of the 2<sup>nd</sup> Law we know that they don't hit the ground with the same force.



$$F = ma$$

$$98 \text{ N} = 10 \text{ kg} \times 9.8 \text{ m/s/s}$$

$$F = ma$$

$$9.8 \text{ N} = 1 \text{ kg} \times 9.8 \text{ m/s/s}$$

# Check Your Understanding

- 1. What acceleration will result when a 12 N net force applied to a 3 kg object? A 6 kg object?
- 2. A net force of 16 N causes a mass to accelerate at a rate of  $5 \text{ m/s}^2$ . Determine the mass.
- 3. How much force is needed to accelerate a 66 kg skier  $1 \text{ m/sec/sec}$ ?
- 4. What is the force on a 1000 kg elevator that is falling freely at  $9.8 \text{ m/sec/sec}$ ?

# Check Your Understanding

- 1. What acceleration will result when a 12 N net force applied to a 3 kg object?

$$12 \text{ N} = 3 \text{ kg} \times 4 \text{ m/s/s}$$

- 2. A net force of 16 N causes a mass to accelerate at a rate of  $5 \text{ m/s}^2$ . Determine the mass.

$$16 \text{ N} = 3.2 \text{ kg} \times 5 \text{ m/s/s}$$

- 3. How much force is needed to accelerate a 66 kg skier  $1 \text{ m/sec/sec}$ ?

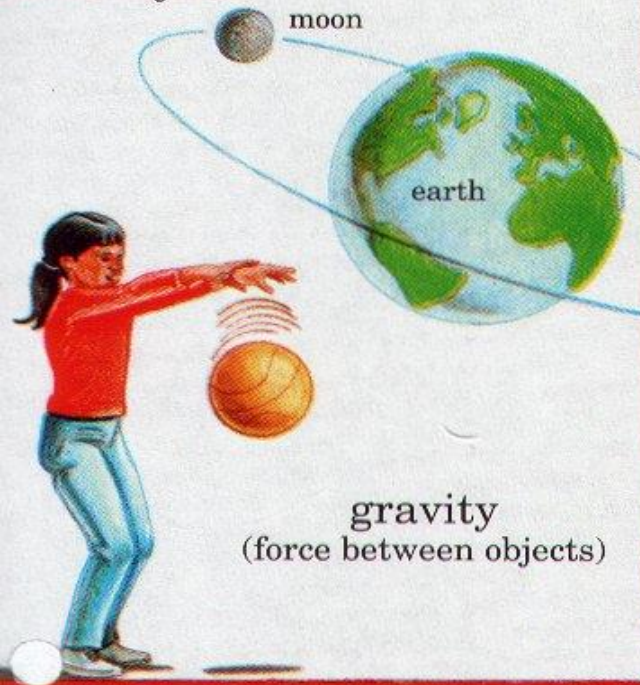
$$66 \text{ kg-m/sec/sec or } 66 \text{ N}$$

- 4. What is the force on a 1000 kg elevator that is falling freely at  $9.8 \text{ m/sec/sec}$ ?

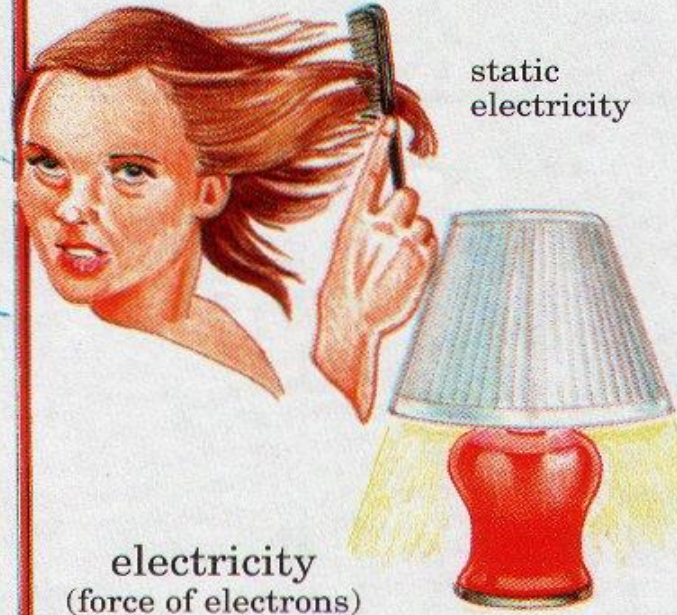
- $9800 \text{ kg-m/sec/sec or } 9800 \text{ N}$

# Force

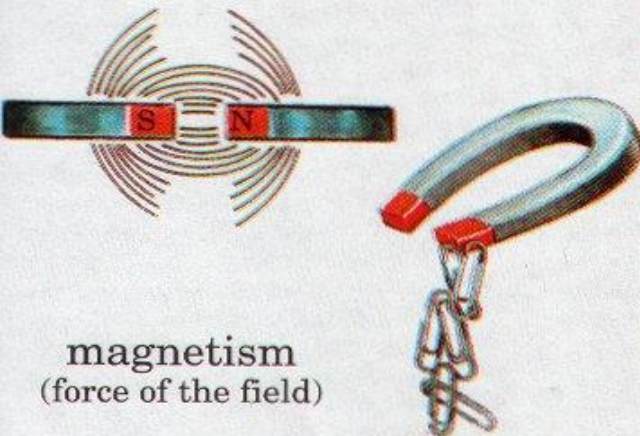
Force is the push or pull that causes a change in the motion of an object.



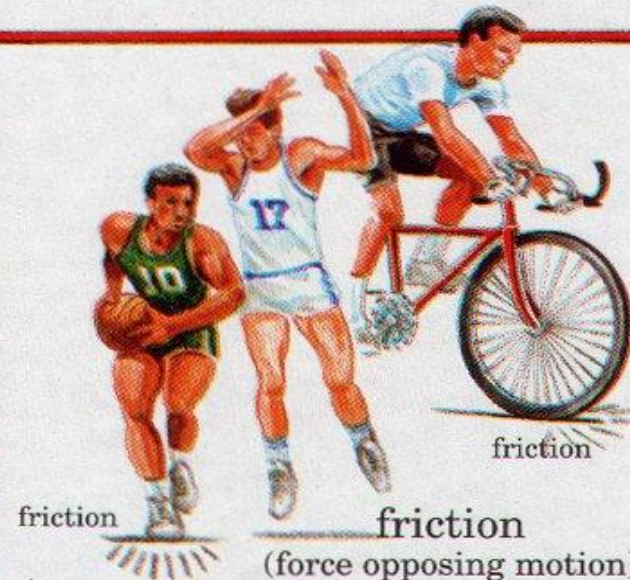
gravity  
(force between objects)



electricity  
(force of electrons)



magnetism  
(force of the field)



friction  
(force opposing motion)



## 3<sup>rd</sup> Law

- For every action, there is an equal and opposite reaction.

# 3<sup>rd</sup> Law

There are two forces resulting from this interaction - a force on the chair and a force on your body. These two forces are called *action* and *reaction* forces.







# *Other examples of Newton's Third Law*

- The baseball forces the bat to the left (an action); the bat forces the ball to the right (the reaction).

