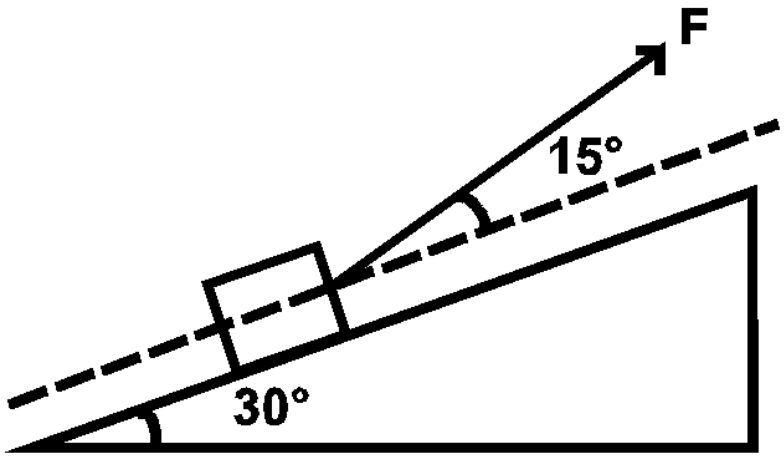
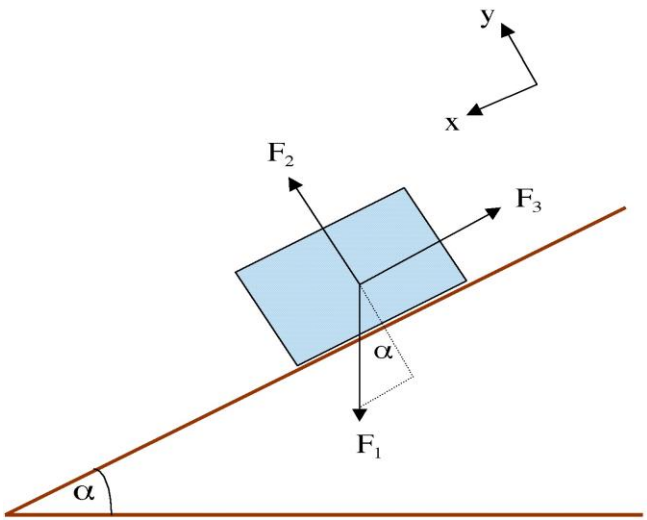
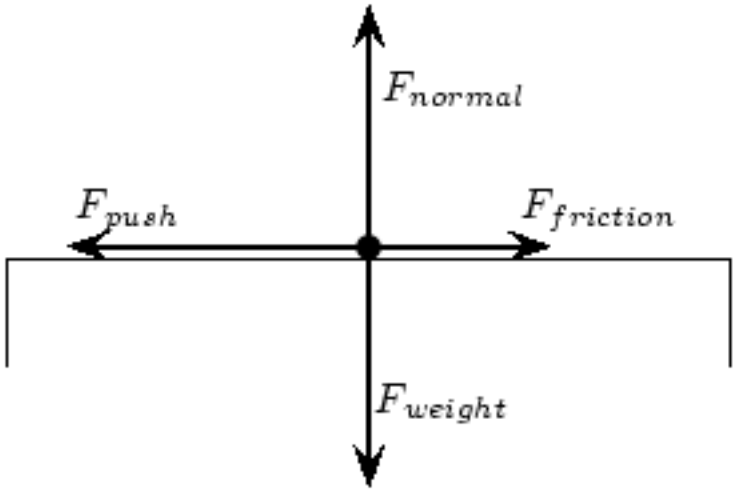
UNIT #3

Forces

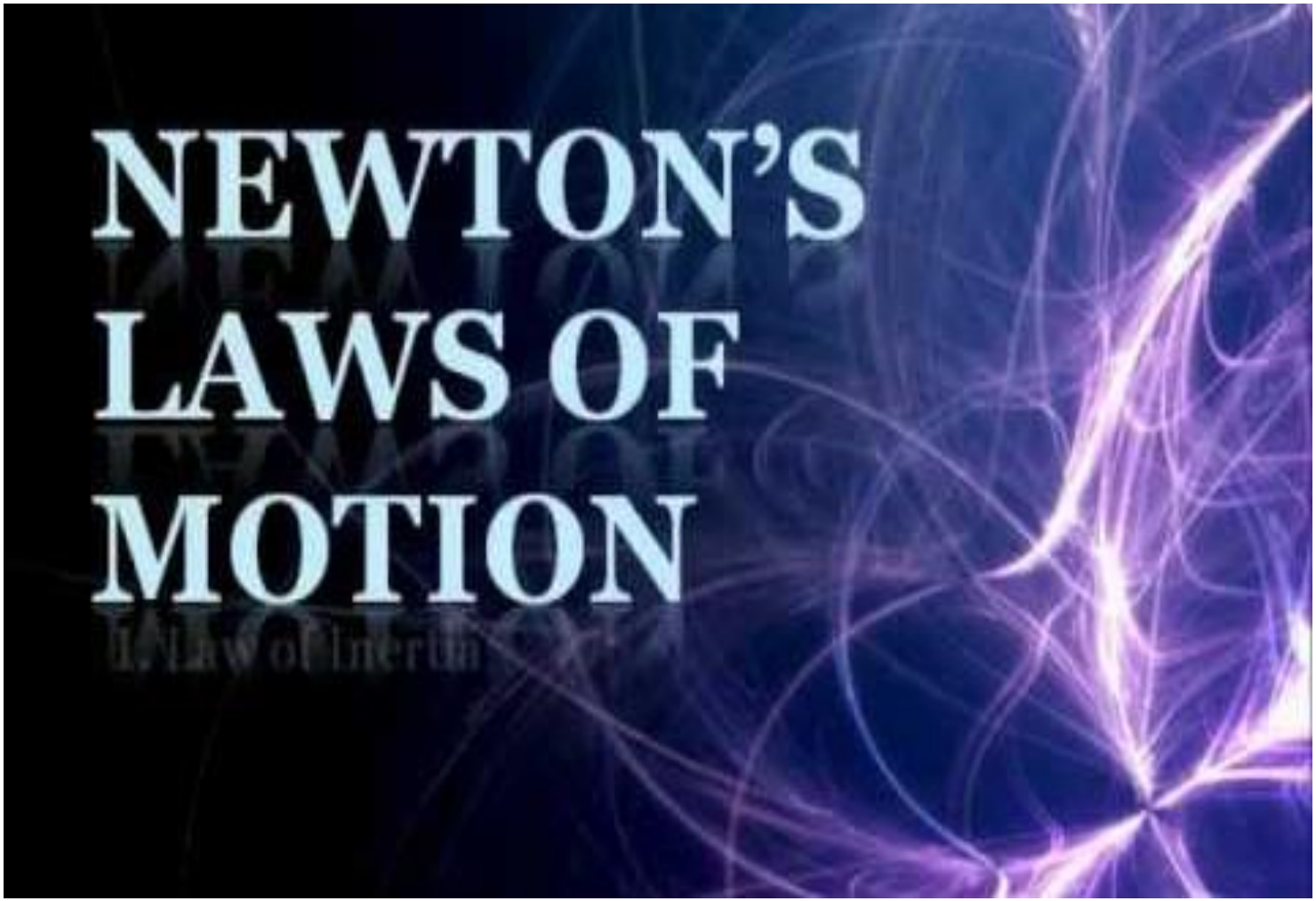




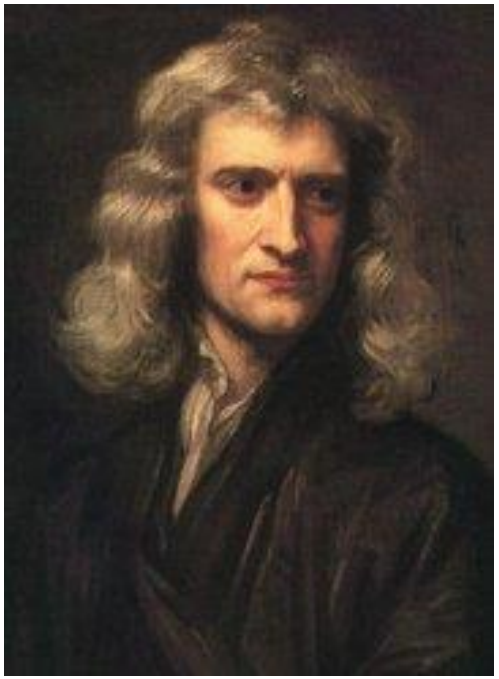


Section #6

Newton's Laws of Motion



Newton's Laws of Motion



"If I have seen farther than others, it is because I was standing on the shoulders of giants."

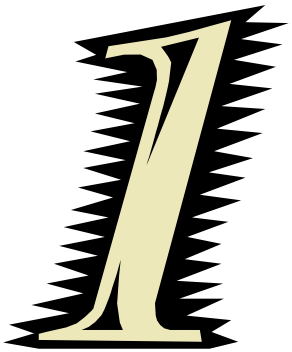
-Sir Isaac Newton

Background

Sir Isaac Newton (1643-1727) an English scientist and mathematician famous for his discovery of the law of gravity also discovered the three laws of motion.

He published them in his book Philosophiae Naturalis Principia Mathematica (mathematic principles of natural philosophy) in 1687. Today these laws are known as Newton's Laws of Motion and describe the motion of all objects on the scale we experience in our everyday lives.

Newton's First Law



"Law of Inertia"

An object at rest wants to stay at rest and an object in motion wants to stay in motion unless acted on by an unbalanced force.

Newton's Law of Inertia

Newton's first law, usually called the law of inertia, is a restatement of Galileo's idea that a force is not needed to keep an object moving.

What is meant by unbalanced force?

If the forces on an object are equal and opposite, they are said to be balanced, and the object experiences no change in motion.

If they are not equal and opposite, then the forces are unbalanced and the motion of the object changes.

Objects at Rest

Simply put, things tend to keep on doing what they're already doing.

- **Objects in a state of rest tend to remain at rest.**
- **Only a force will change that state.**

Objects in Motion

Now consider an object in motion.

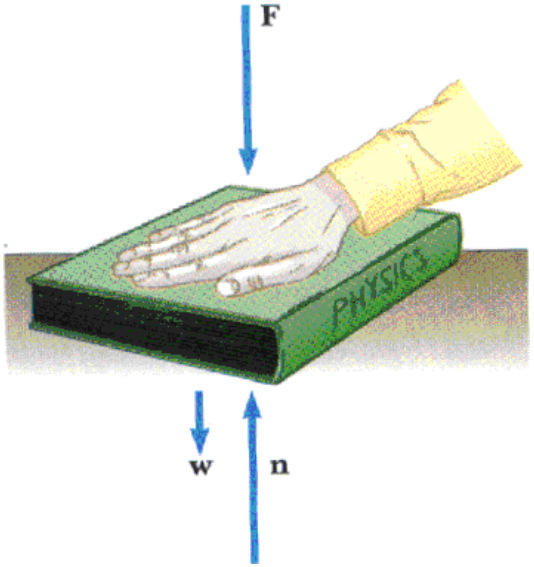
- **In the absence of forces, a moving object tends to move in a straight line indefinitely.**

- **Toss an object from a space station located in the vacuum of outer space, and the object will move forever due to inertia.**

Be Careful!!!

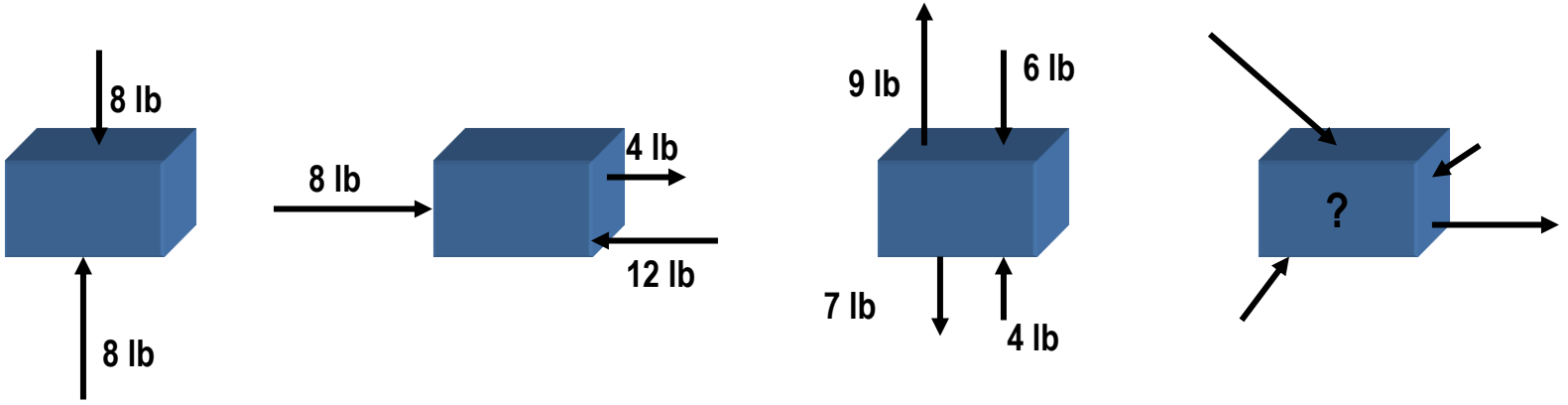
If an object is remaining at rest, it is incorrect to assume that there are no forces acting on the object.

We can only conclude that the net force on the object is zero.



The net force acting on an object is the vector sum of all the forces acting on it.

Examples:



Inertia

The tendency of an object to resist changes in its state of motion

The first Law states that all objects have inertia. The more mass an object has, the greater its inertia and the more force it takes to change its state of motion.

The amount of inertia an object has depends on its *mass* - which is roughly the amount of material present in the object.

Inertia Example

You can tell how much matter is in a can when you kick it. Kick an empty can and it moves. Kick a can filled with sand and it doesn't move as much.

Mass Is Not Volume

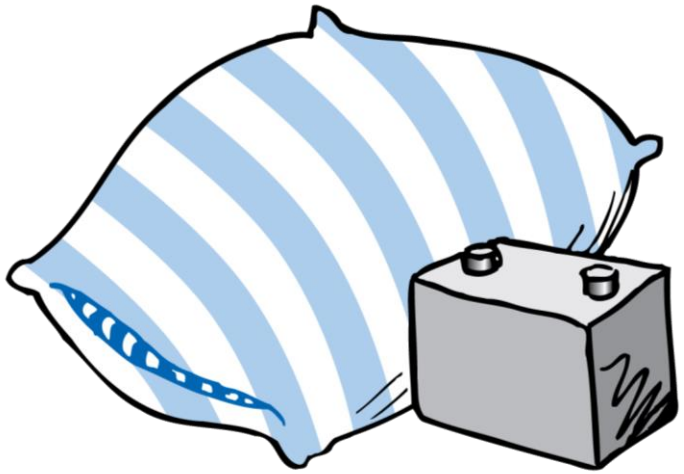
Do not confuse mass and volume.

Volume is a measure of space and is measured in units such as cm^3, m^3, and liters.

Mass is measured in the fundamental unit of kilograms.

Which has more mass, a feather pillow or a common automobile battery?

The pillow has a larger size (volume) but a smaller mass than the battery. But, clearly an automobile battery is more difficult to set into motion. This is evidence of the battery's greater inertia and hence its greater mass.



Mass Is Not Weight

Mass is often confused with weight.

- **Mass is a measure of the amount of material in an object.**
- **Weight, on the other hand, is a measure of the gravitational force acting on the object.**

Mass Is Inertia

The amount of material in a particular stone is the same whether the stone is located on Earth, on the moon, or in outer space.

- **The mass of the stone is the same in all of these locations.**
- **The weight of the stone would be very different on Earth and on the moon, and still different in outer space.**

We can define mass and weight as follows:

- **Mass is the quantity of matter in an object.**

- **Weight is the force of gravity on an object.**

It is common to describe the amount of matter in an object by its gravitational pull to Earth, that is, by its weight.

In most parts of the world the measure of matter is commonly expressed in units of mass, the kilogram (kg).

At Earth's surface, 1 kilogram has a weight of 9.81 Newton's.

The SI unit of *force* is the Newton ($kg \bullet m/s^2$)

The SI symbol for the Newton is N.

If you know the mass of something in kilograms and want its weight in Newton's at Earth's surface, multiply the number of kilograms by $9.81\ m/s^2$.

If objects in motion tend to stay in motion, why don't moving objects keep moving forever?

Things don't keep moving forever because there's almost always unbalanced forces' acting upon it.

A book sliding across a table slows down and stops because of the force of friction.

If you throw a ball upwards it will eventually slow down and fall because of the force of gravity.

Friction

Friction is a force that arises due to the relative motion of two surfaces.

1. Two solid surfaces: Sliding friction, rolling friction
2. A solid and a fluid: Air resistance
3. Two fluids

The direction of the friction force always acts in the opposite direction of motion.

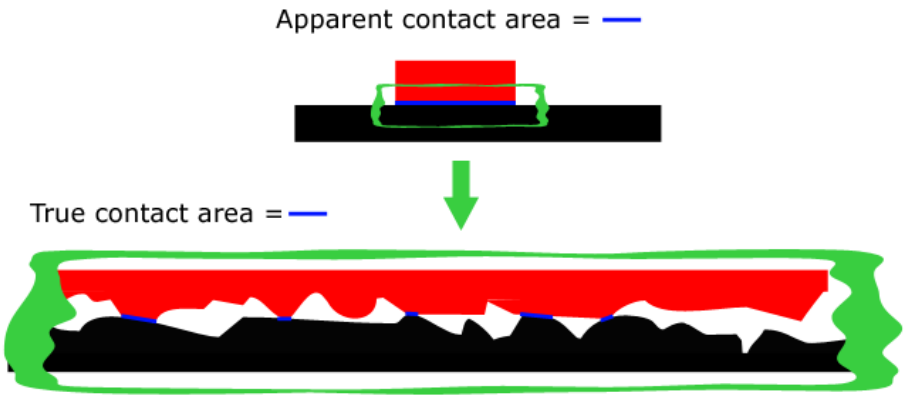
Friction

The amount of sliding friction <u>depends</u> on:

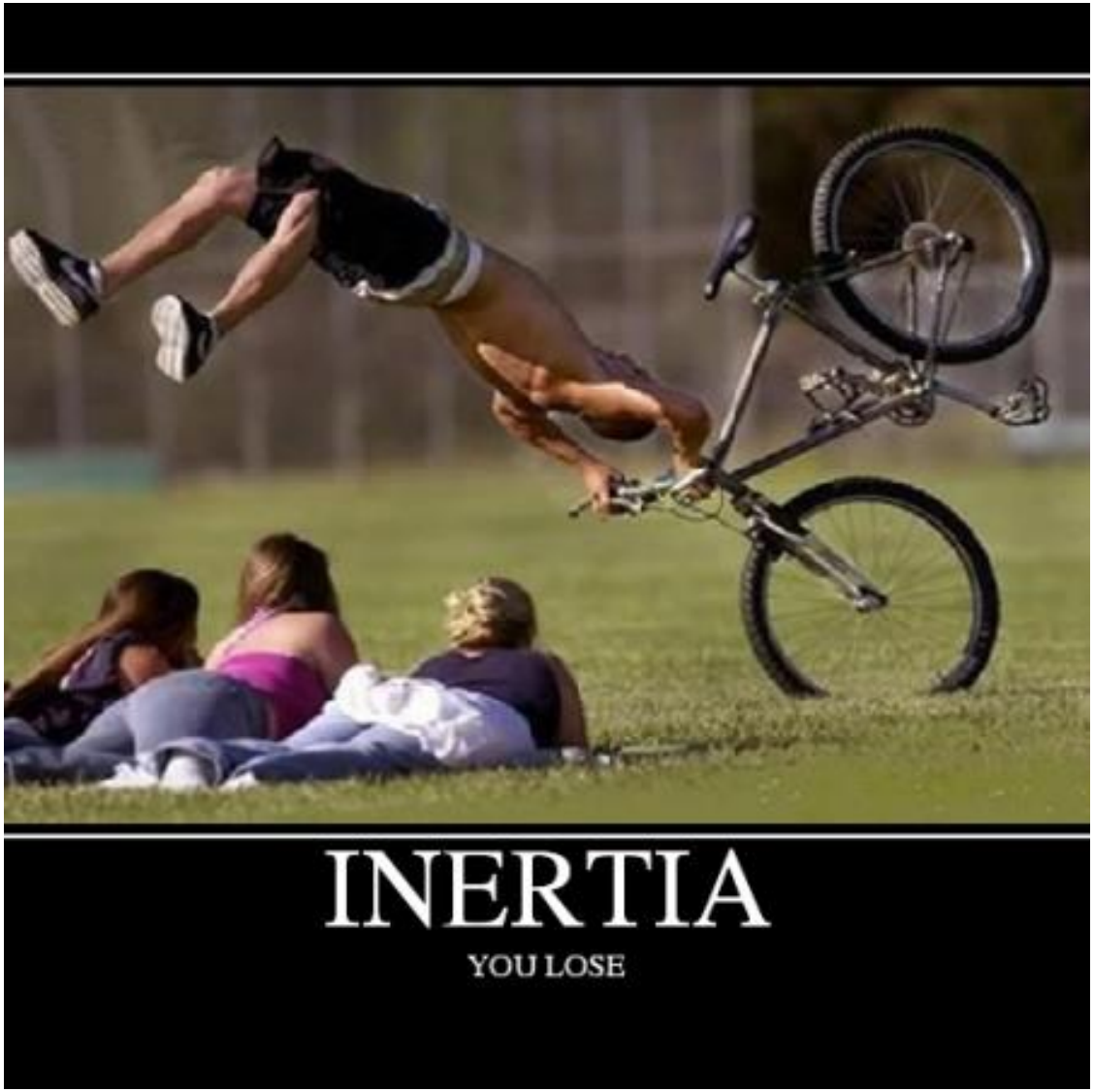
1. The surface material (smoothness/roughness)
2. The normal force between the surfaces

The amount of sliding friction <u>does not</u> depend on:

1. Area of contact
2. Relative speed



Inertia in pictures

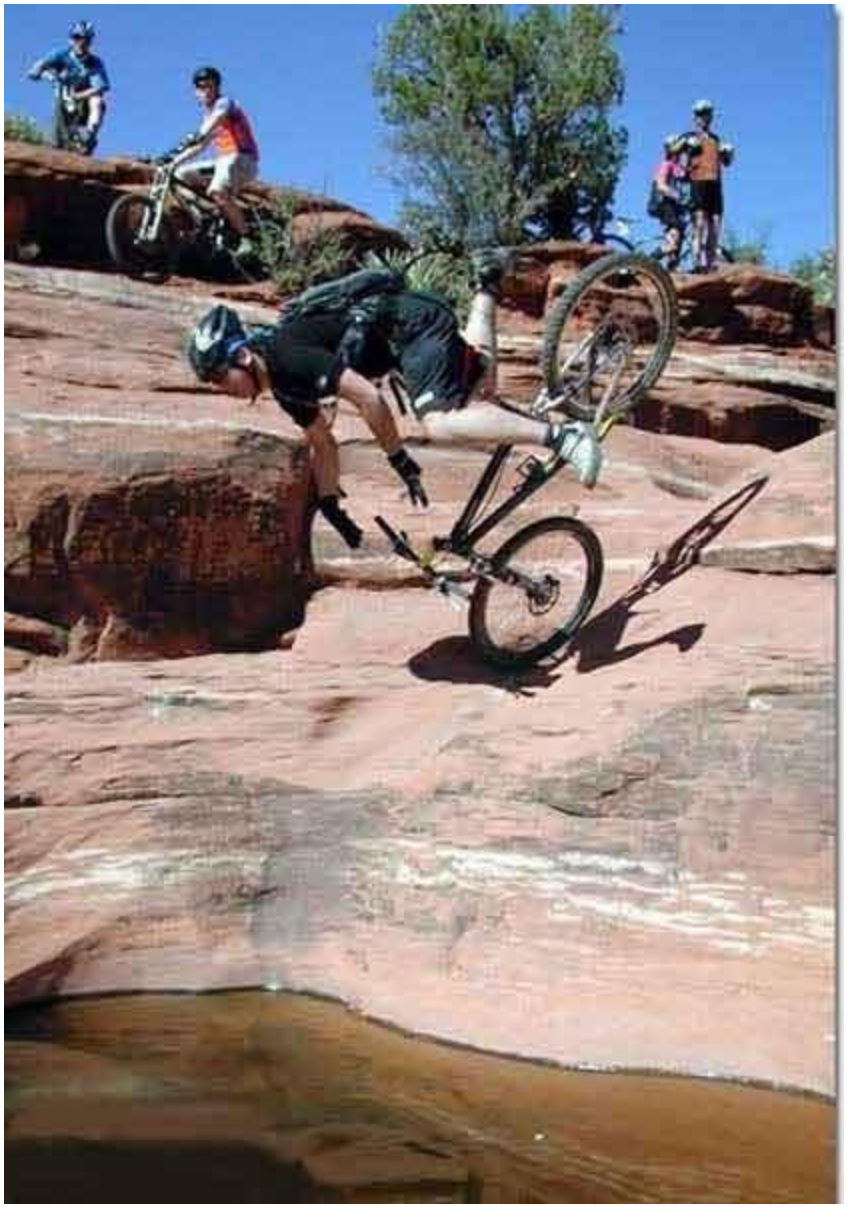

INERTIA
YOU LOSE

Inertia – Bumper Cars

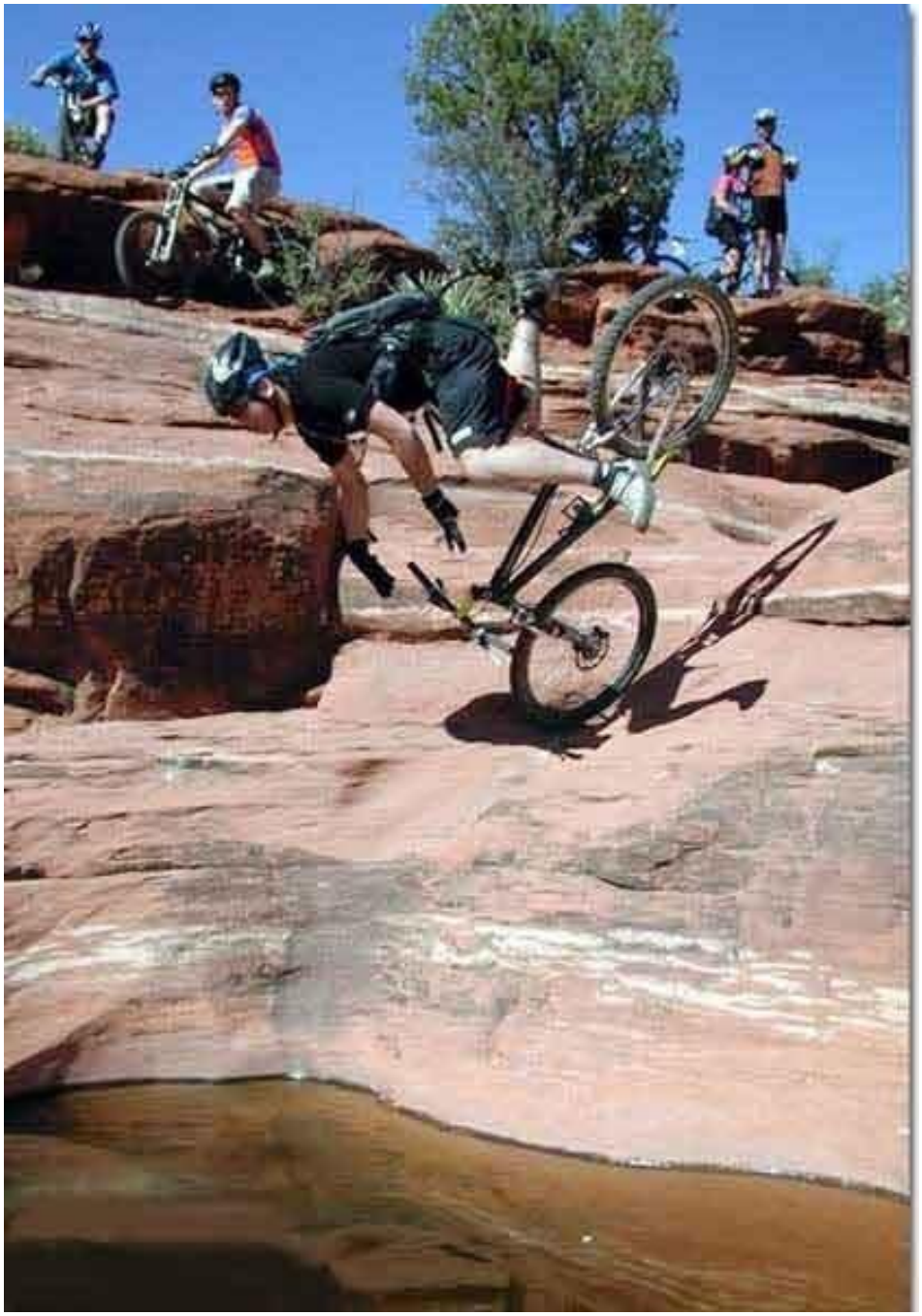
LAW OF INERTIA

You can't NOT obey it

Inertia – Bicycles




INERTIA



INERTIA

Your truck has brakes...the massive hunk of stone doesn't


LEXUS RX300

6.1 Assessment Questions

Question #1

If gravity between the Sun and Earth suddenly vanished, Earth would continue moving in a(n):

a. curved path.
b. straight-line path.
c. outward spiral path.
d. inward spiral path.

6.1 Assessment Questions

Question #1

If gravity between the Sun and Earth suddenly vanished, Earth would continue moving in a(n):

a. curved path.
b. straight-line path.
c. outward spiral path.
d. inward spiral path.

6.1 Assessment Questions

Question #2

To say that 1 kg of matter weighs 9.81 N is to say that 1 kg of matter

a. **will weigh 9.81 N everywhere.**
b. **has ten times less volume than 9.81 kg of matter.**
c. **has ten times more inertia than 9.81 kg of matter.**
d. **is attracted to Earth with 9.81 N of force.**

6.1 Assessment Questions

Question #2

To say that 1 kg of matter weighs 9.81 N is to say that 1 kg of matter

a. **will weigh 9.81 N everywhere.**
b. **has ten times less volume than 9.81 kg of matter.**
c. **has ten times more inertia than 9.81 kg of matter.**
d. **is attracted to Earth with 9.81 N of force.**

6.1 Assessment Questions

Question #3

If the sum of all forces acting on a moving object is zero, the object will:

a. Slow down and stop
b. Change the direction of motion
c. Accelerate uniformly
d. Continue moving with a constant velocity

6.1 Assessment Questions

Question #3

If the sum of all forces acting on a moving object is zero, the object will:

a. Slow down and stop
b. Change the direction of motion
c. Accelerate uniformly
d. Continue moving with a constant velocity

6.1 Assessment Questions

Question #4

Which object has the greatest inertia?

a. A 5-kg mass moving at 10 m/s
b. A 10-kg mass moving at 1 m/s
c. A 15-kg mass moving at 10 m/s
d. A 20-kg mass moving at 1 m/s

6.1 Assessment Questions

Question #4

Which object has the greatest inertia?

a. A 5-kg mass moving at 10 m/s
b. A 10-kg mass moving at 1 m/s
c. A 15-kg mass moving at 10 m/s
d. A 20-kg mass moving at 1 m/s

6.1 Assessment Questions

Question #5

Which object has the greatest inertia?

a. A 5-kg mass moving at 5 m/s
b. A 10-kg mass moving at 3 m/s
c. A 15-kg mass moving at 1 m/s
d. A 20-kg mass at rest

6.1 Assessment Questions

Question #5

Which object has the greatest inertia?

a. A 5-kg mass moving at 5 m/s
b. A 10-kg mass moving at 3 m/s
c. A 15-kg mass moving at 1 m/s
d. A 20-kg mass at rest

6.1 Assessment Questions

Question #6

Which object has the greatest inertia?

a. A 15-kg mass traveling at 5 m/s
b. A 10-kg mass traveling at 10 m/s
c. A 10-kg mass traveling at 5 m/s
d. A 5-kg mass traveling at 15 m/s

6.1 Assessment Questions

Question #6

Which object has the greatest inertia?

a. A 15-kg mass traveling at 5 m/s
b. A 10-kg mass traveling at 10 m/s
c. A 10-kg mass traveling at 5 m/s
d. A 5-kg mass traveling at 15 m/s

6.1 Assessment Questions

Question #7

Which object has the greatest inertia?

a. A falling leaf
b. A softball in flight
c. A seated high school student
d. A rising helium-filled toy balloon

6.1 Assessment Questions

Question #7

Which object has the greatest inertia?

a. A falling leaf
b. A softball in flight
c. A seated high school student
d. A rising helium-filled toy balloon