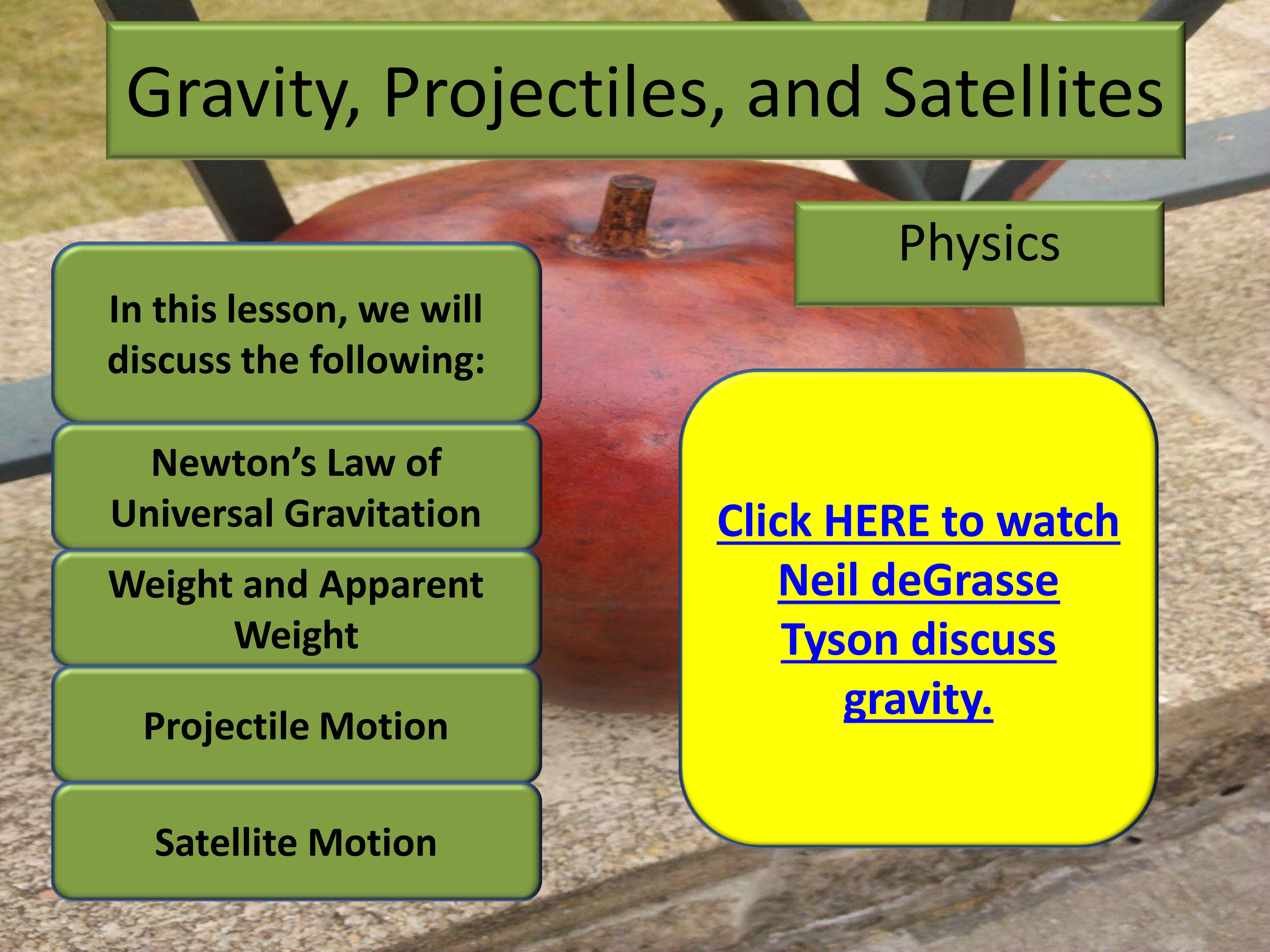

Gravity, Projectiles, and Satellites
Physics
In this lesson, we will discuss the following:
Newton's Law of Universal Gravitation
Weight and Apparent Weight
Projectile Motion
Satellite Motion
Click HERE to watch Neil deGrasse Tyson discuss gravity.

Newton's Law of Universal Gravitation

Isaac Newton did not discover gravity, but he discovered that gravity is universal. In other words, Newton found that gravity affects all objects with mass.

Newton’s Law of Universal Gravitation

Newton’s Law of Universal Gravitation says that all objects with mass are attracted to all other objects with mass.

Click HERE to watch Bill Nye demonstrate the force due to gravity.

Mathematical Statement of Newton's Law of Universal Gravitation

Using experimentation, Newton was able to develop a mathematical statement of his Law of Universal Gravitation.

Mathematical Statement of Newton's Law of Universal Gravitation

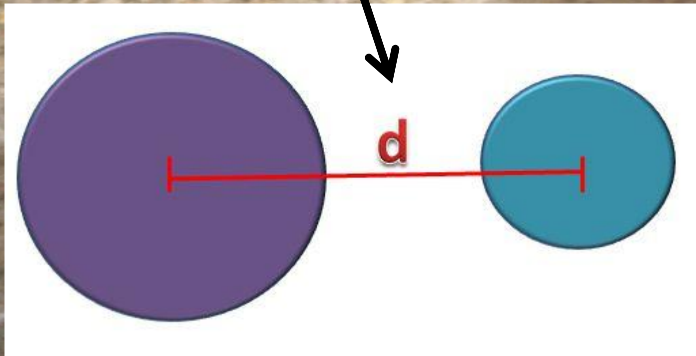
$$F_g = G\frac{m_1 \times m_2}{d^2}$$

The gravitational force between Object 1 and Object 2

The Gravitational Constant: 6.67×10^{-11} $N*m^2 / kg^2$

Masses of Object 1 and Object 2

The distance between the CENTERS of Object 1 and Object 2



Mathematical Statement of Newton's Law of Universal Gravitation

The force due to gravity is always ATTRACTIVE. In other words, the direction of the gravitational force on Object 1 is toward Object 2 and vice versa.

The gravitatio… force between Obje… d Object 2

The Gravitati… Con…

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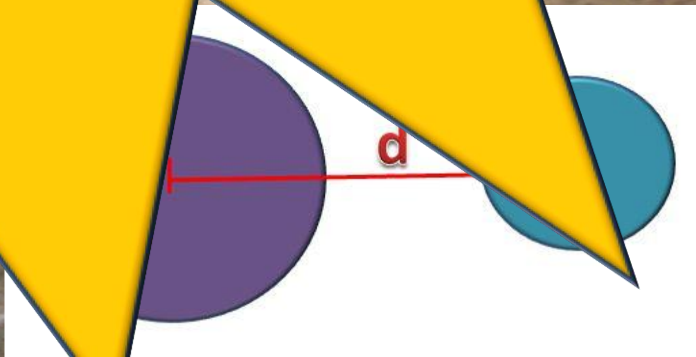


Mathematical Statement of Newton's Law of Universal Gravitation

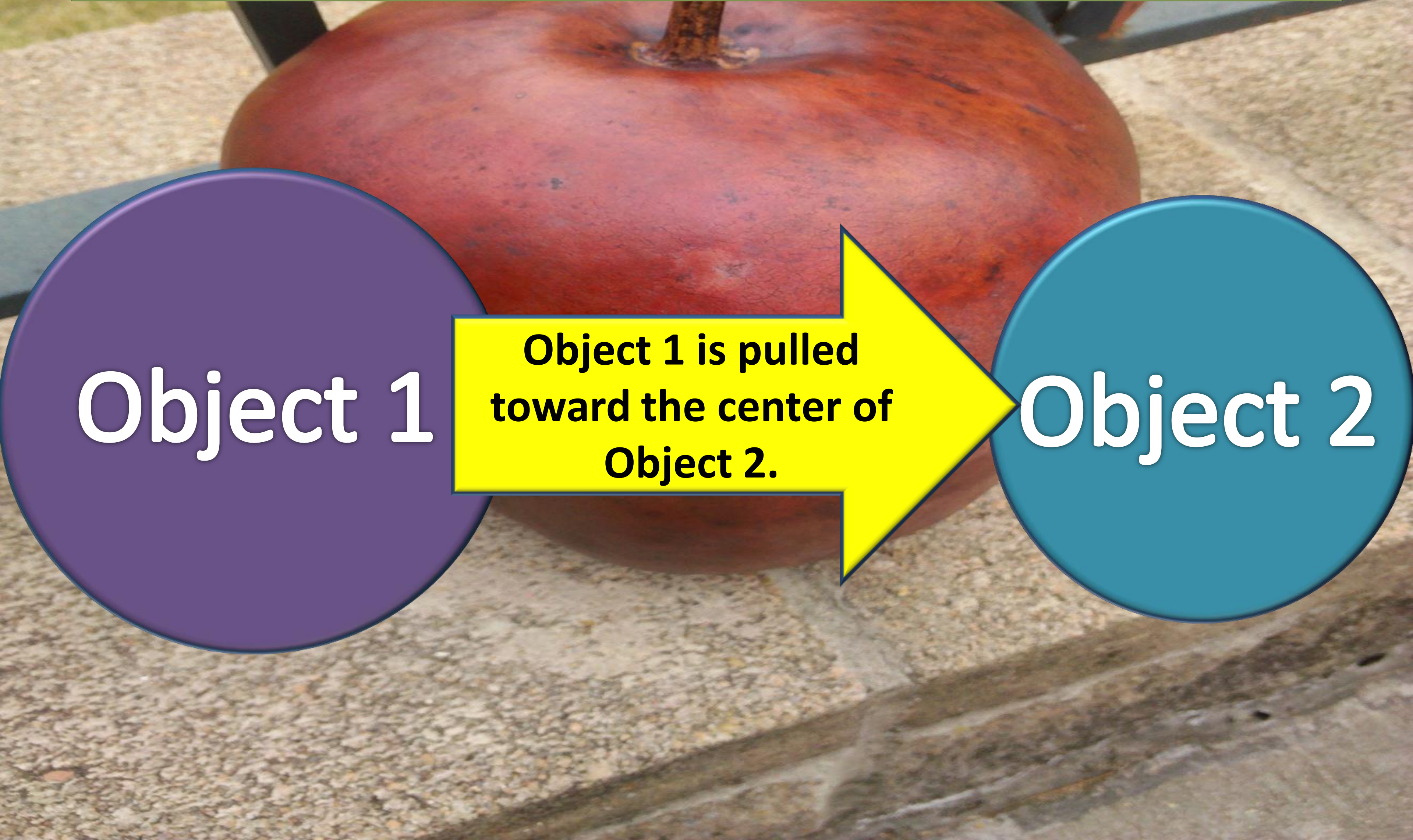
- In Newton's Law of Universal Gravitation, ***G*** is just a constant, called the Gravitational Constant.

$$G = 6.67 \times 10^{-11} N * m^2 / kg^2$$

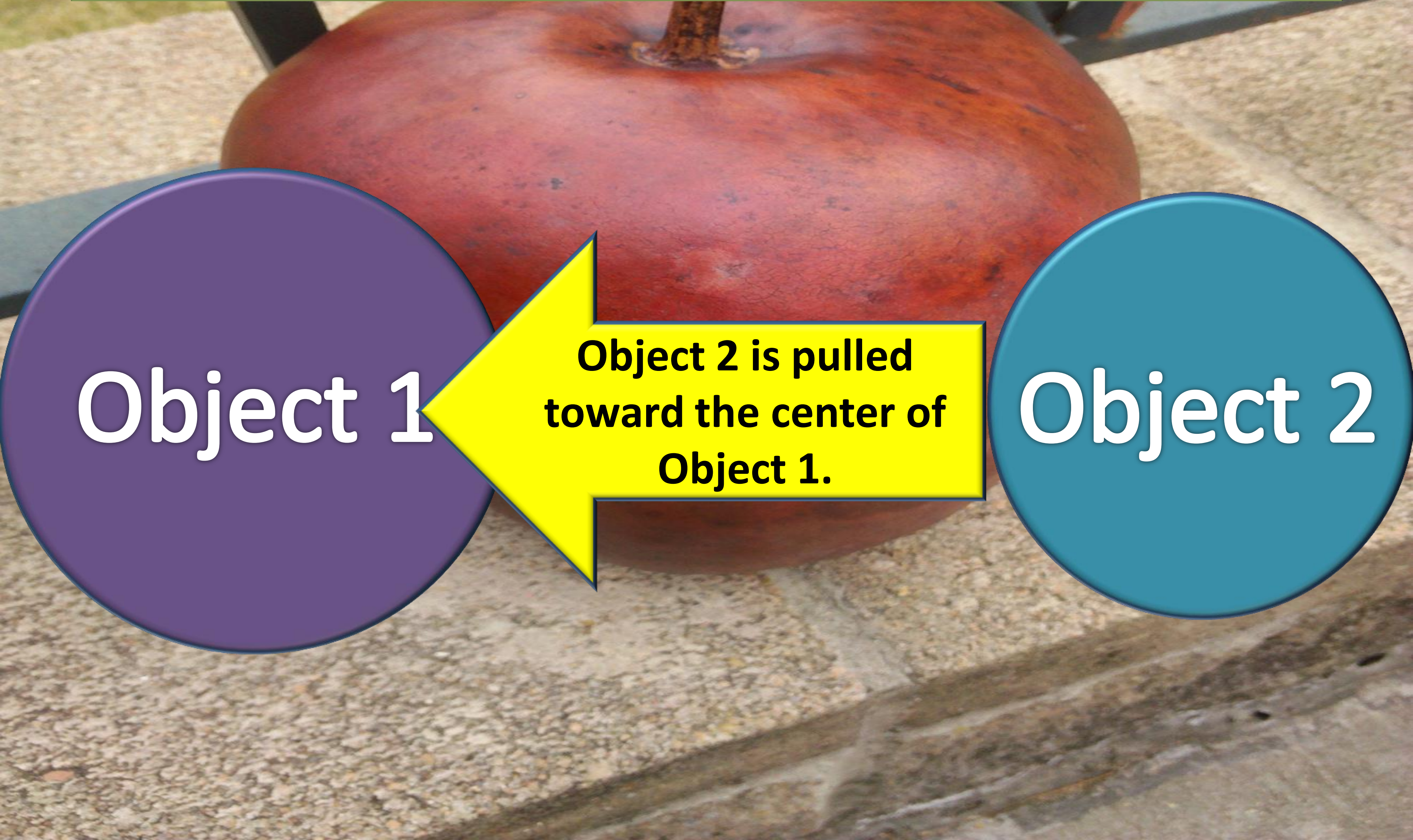
- Notice, ***G*** is a tiny number.
- Isaac Newton first came up with ***G*** using experimentation.

Click HERE to read an article with some relatively new information about *G*.

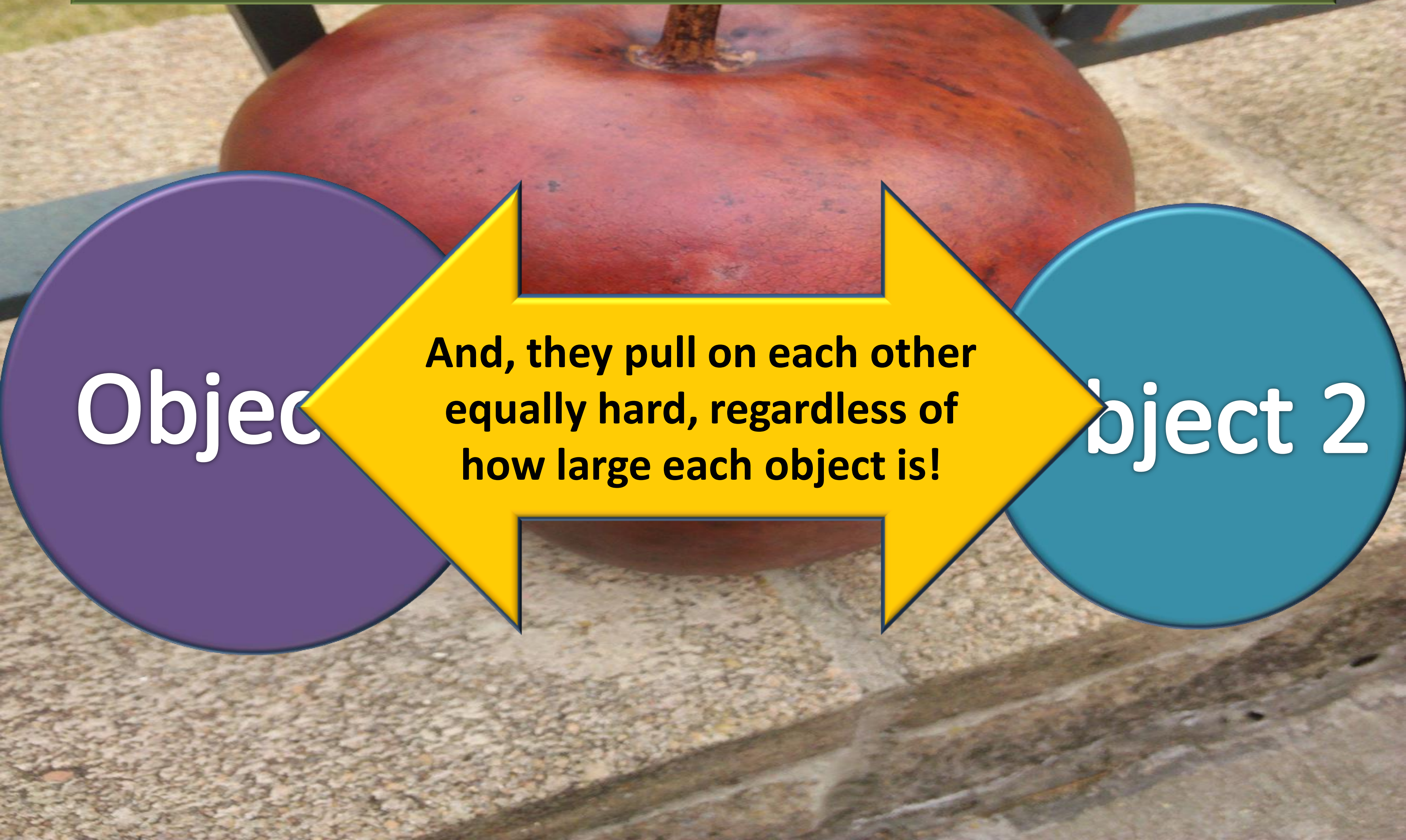
Mathematical Statement of Newton's Law of Universal Gravitation



Mathematical Statement of Newton's Law of Universal Gravitation



Mathematical Statement of Newton’s Law of Universal Gravitation



The Inverse Square Law

Newton's Law of Universal Gravitation follows the Inverse Square Law.

Click HERE to watch a great demonstration of the Inverse Square Law.

According to the **Inverse Square Law,** if the distance between two objects increases, the gravitational force between the two objects decreases as the square of the distance between the two objects' centers.

Click HERE to watch some short videos demonstrating the Inverse Square Law.

How Changing Mass Affects Gravitational Force

- According to Newton's Law of Universal Gravitation, if you increase the sizes of the two objects, the gravitational force between the two increases, also.
- If you decrease the masses of the two objects, the gravitational force between them decreases.

Let's See What You Know

If the distance between two objects is tripled, what happens to the gravitational force between those two objects? Go to the next page to see the correct answer.

The gravitational force is tripled.

The gravitational force is decreased to 1/3 what it was when the objects were closer.

The gravitational force is increased to 9 times what it was when the objects were closer.

The gravitational force is decreased to 1/9 what it was when the objects were closer.

Let’s See What You Know

$$\vec{F}_g = G\frac{m_1 \times m_2}{d^2}$$

If you triple d, the gravitational force will decrease by a factor of 9 (or 3^2).

closer.

when the objects were closer.

Let's See What You Know

If the **distance** between two objects is halved, what happens to the gravitational force between those two objects? Go to the next page to see the correct answer.

The gravitational force is halved.

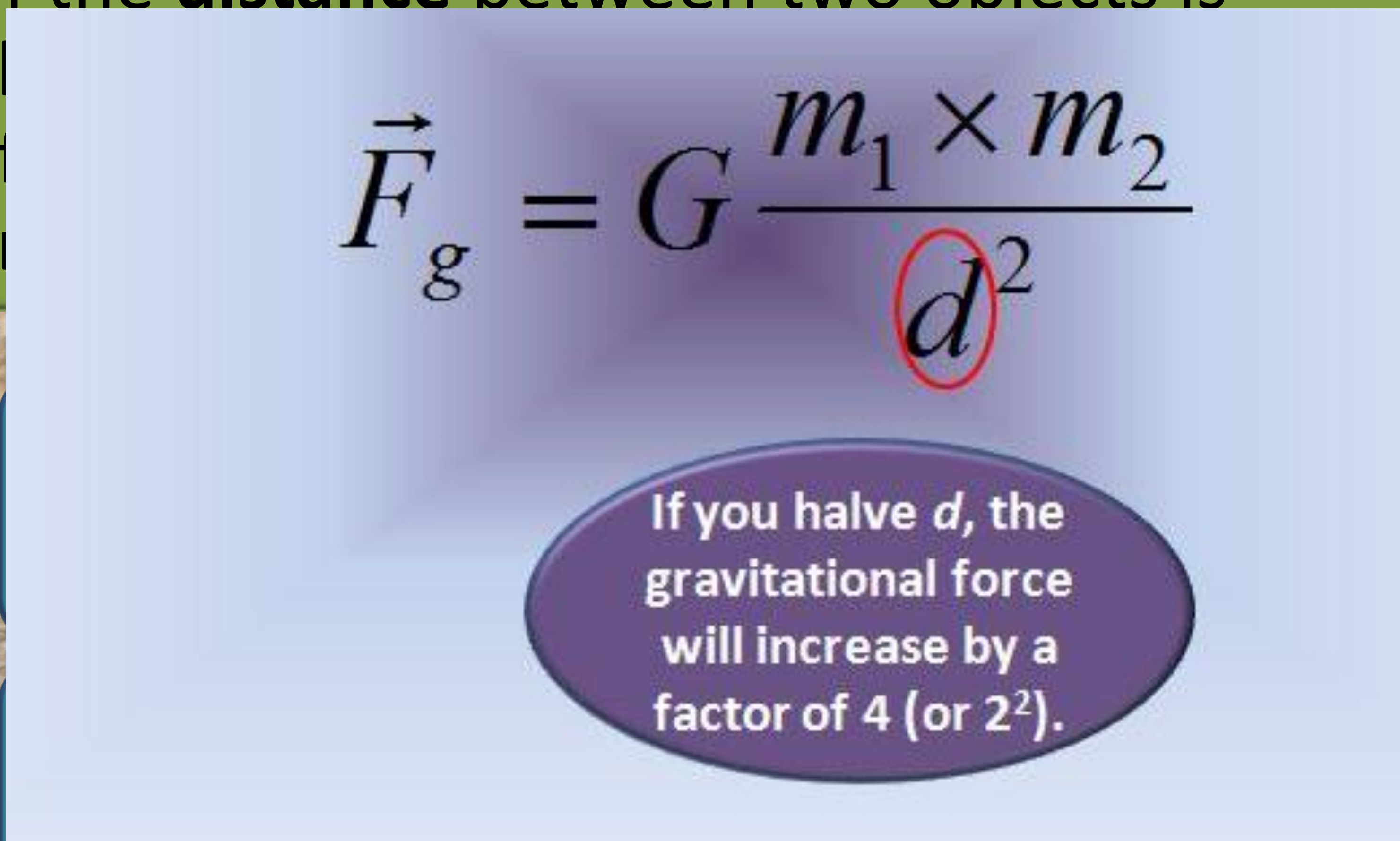
The gravitational force is doubled.

The gravitational force is decreased to ¼ of what it was when the objects were farther apart.

The gravitational force is quadrupled.

Let’s See What You Know

If the **distance** between two objects is



farther apart.

Definition of Weight

- When we learned about various forces, we learned that the weight of an object is defined as the gravitational force acting on that object.
- In addition, we learned that the formula for weight is just

$$\vec{F}_g = mg \downarrow$$

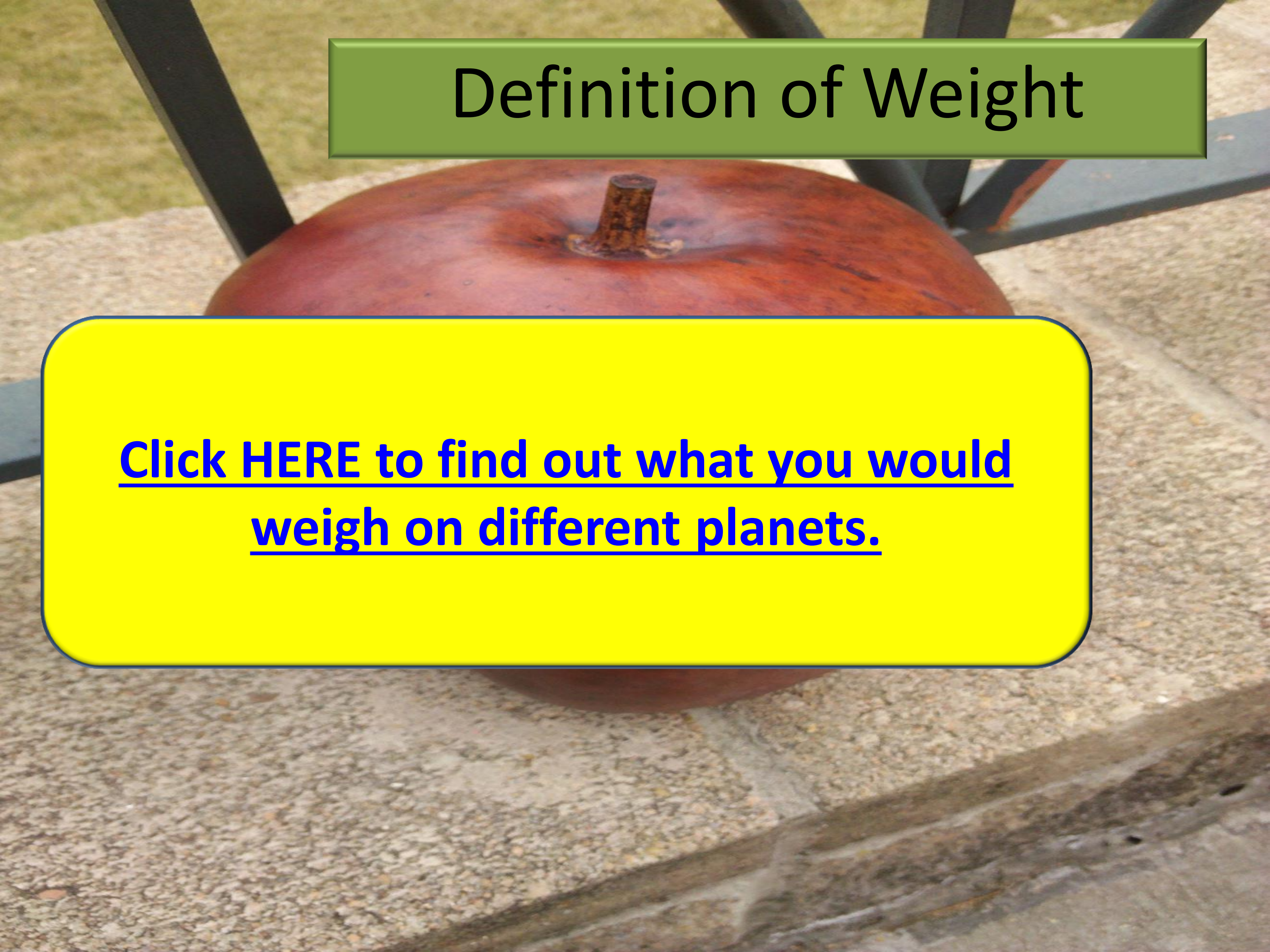
Definition of Weight

Same Thing!

$$\vec{F}_g = mg\downarrow \qquad F_g = G\frac{m_1 \times m_2}{d^2}$$

This is the same thing as WEIGHT!

Definition of Weight



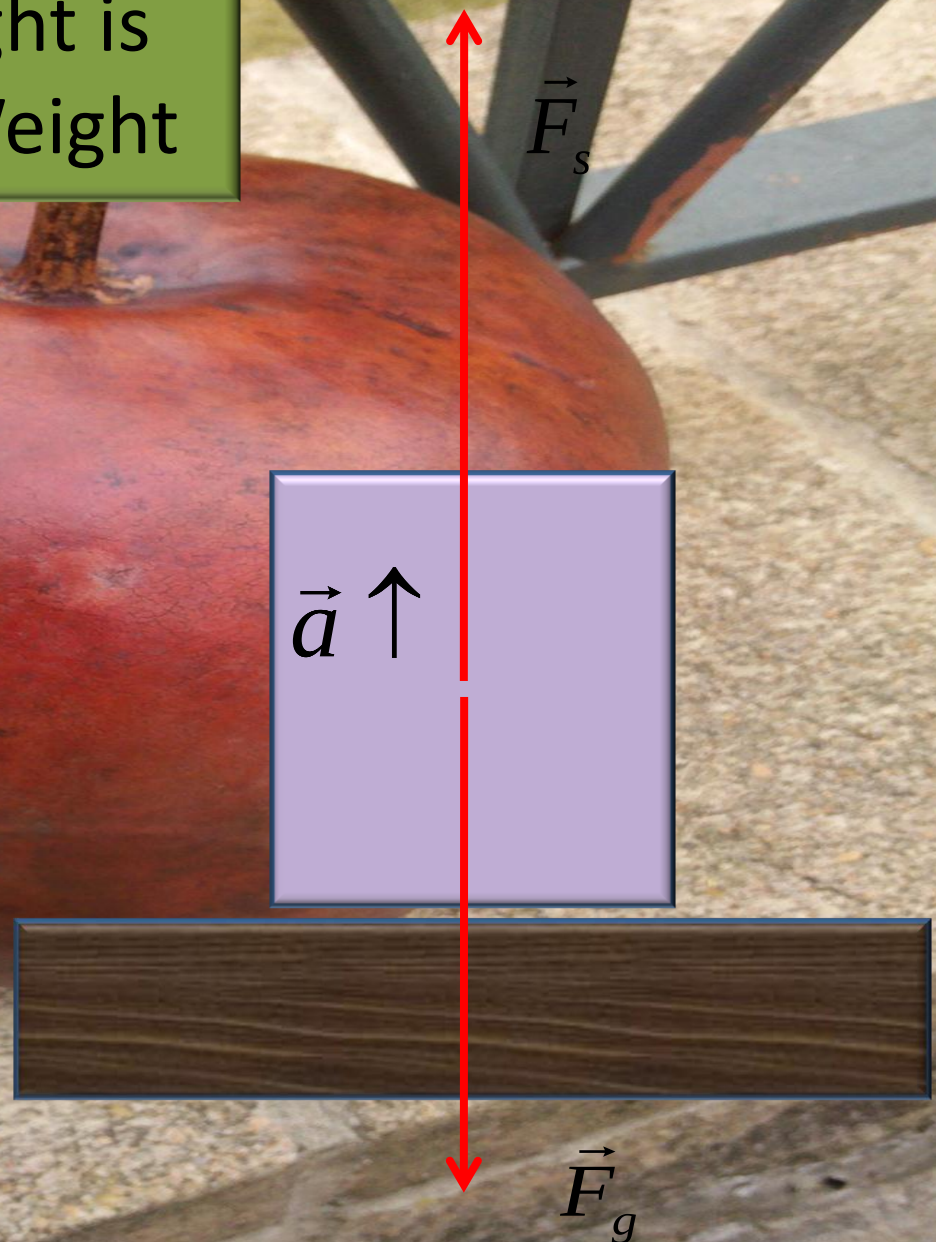
[Click HERE to find out what you would weigh on different planets.]

Definition of Apparent Weight

- The **apparent weight** of an object is not exactly the force due to gravity acting on that object, but it is the **SUPPORT FORCE** acting on that object.
- Remember: for an object at rest on a horizontal surface, support force and the force due to gravity are equal in magnitude.
- In other words, if an object is at rest on a horizontal surface, its apparent weight and its actual weight are essentially the same.

When Apparent Weight is Greater than Actual Weight

- When support force is greater in magnitude than the force due to gravity, then apparent weight is greater than actual weight.
- This happens when an object is ACCELERATING upward.

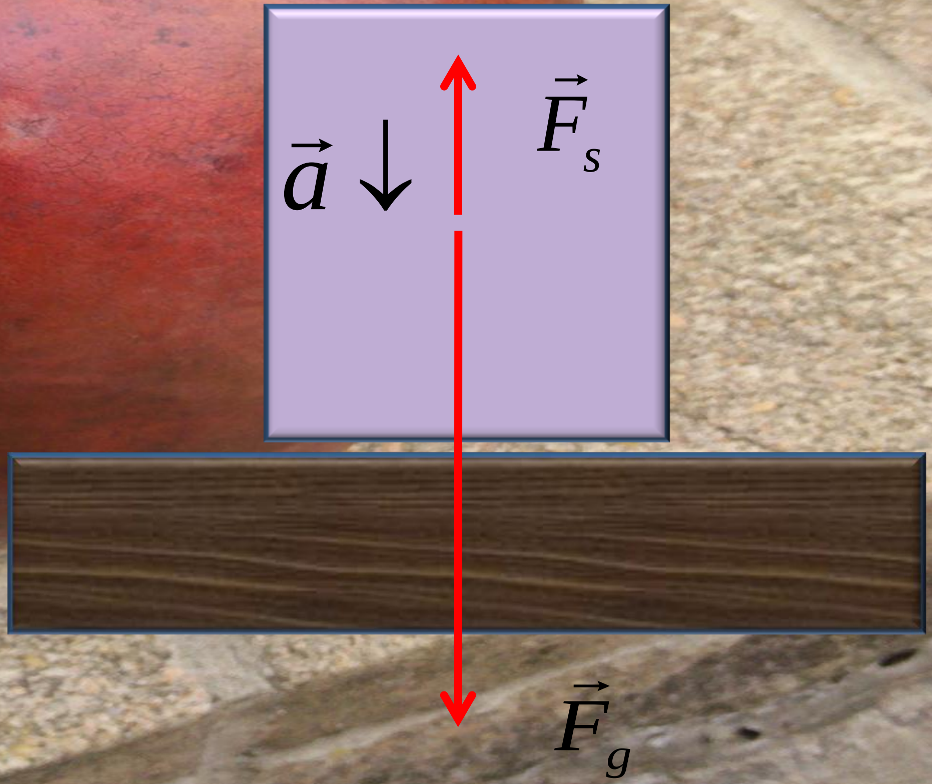


When Apparent Weight is Greater than Actual Weight

- Example: Apparent weight is greater than actual weight in an elevator which is ACCELERATING upward.

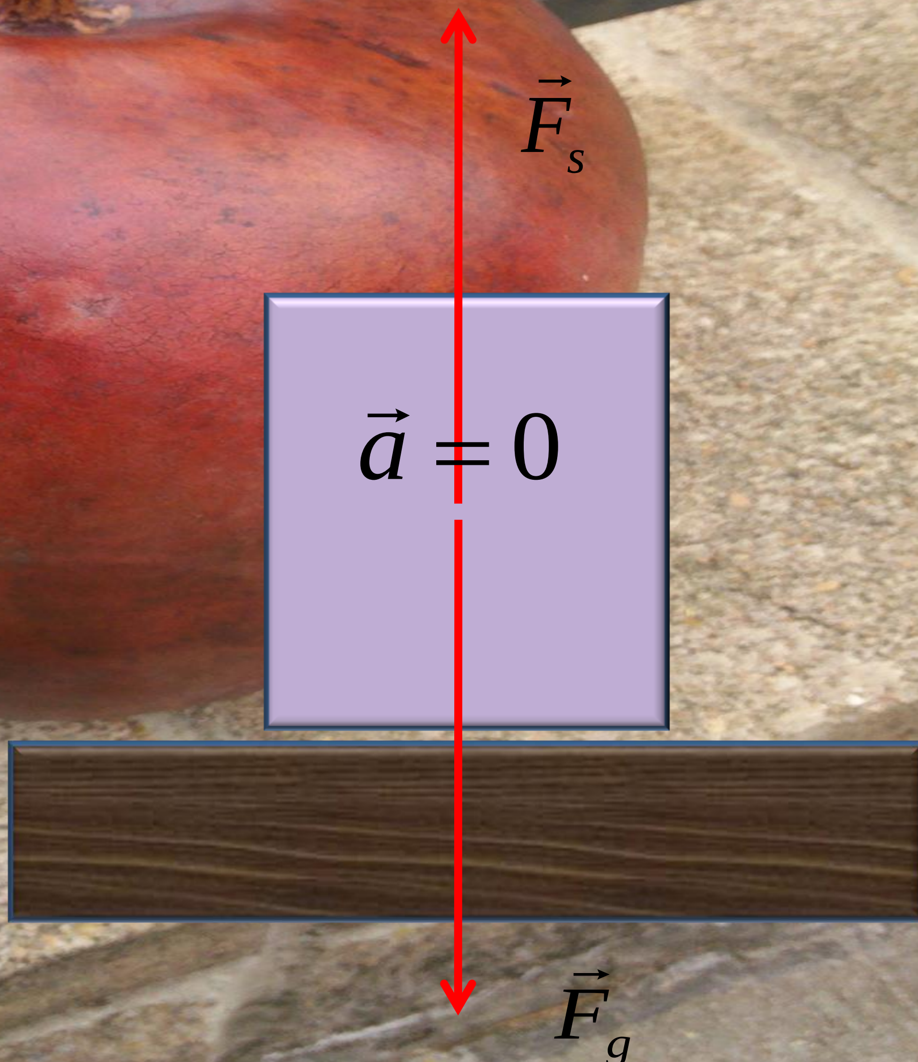
When Apparent Weight is Less than Actual Weight

- When support force is smaller in magnitude than the force due to gravity, then apparent weight is less than actual weight.
- This happens when an object is ACCELERATING downward.



When Apparent Weight is the Same as Actual Weight

- When support force is equal in magnitude to the force due to gravity, then apparent weight is the same as actual weight.
- This happens when an object is neither ACCELERATING upward nor ACCELERATING downward.
- This does NOT mean that the object is not MOVING up or down; the object is just not ACCELERATING up or down.



Weightlessness

When there is no support force acting on an object, that object is **WEIGHTLESS**.

Click HERE to find out why astronauts in the space station are weightless.

Weightlessness

- When there is no support force acting on an object, that object is **WEIGHTLESS**.
- In other words, an object feels weightless when it is in FREE FALL.

Click HERE to see a great demonstration.

Projectile Motion

- When an object is moving under the influence of gravity, it is called a **PROJECTILE**.
- The motion of a projectile is called **PROJECTILE MOTION.**

Click HERE to open a projectile motion simulation.

The Two Components of a Projectile's Velocity

- When a projectile moves in two dimensions, its motion has two components:
  - A vertical component and
  - A horizontal component.
- Each component is independent of the other component.

The Vertical Component of a Projectiles' Velocity

- The vertical component of a projectile's velocity is affected by the force due to gravity.
- The force due to gravity on a projectile causes the vertical component of the projectile's velocity to have an acceleration of ***g***.

Click HERE to open another projectile motion simulation.

The Horizontal Component of a Projectiles' Velocity

- For an object in free fall (no wind resistance), the horizontal component of velocity does not have an acceleration because there is no force acting on a projectile in the HORIZONTAL direction.
- In other words, the horizontal component of a projectile's velocity DOES NOT CHANGE when wind resistance is neglected.

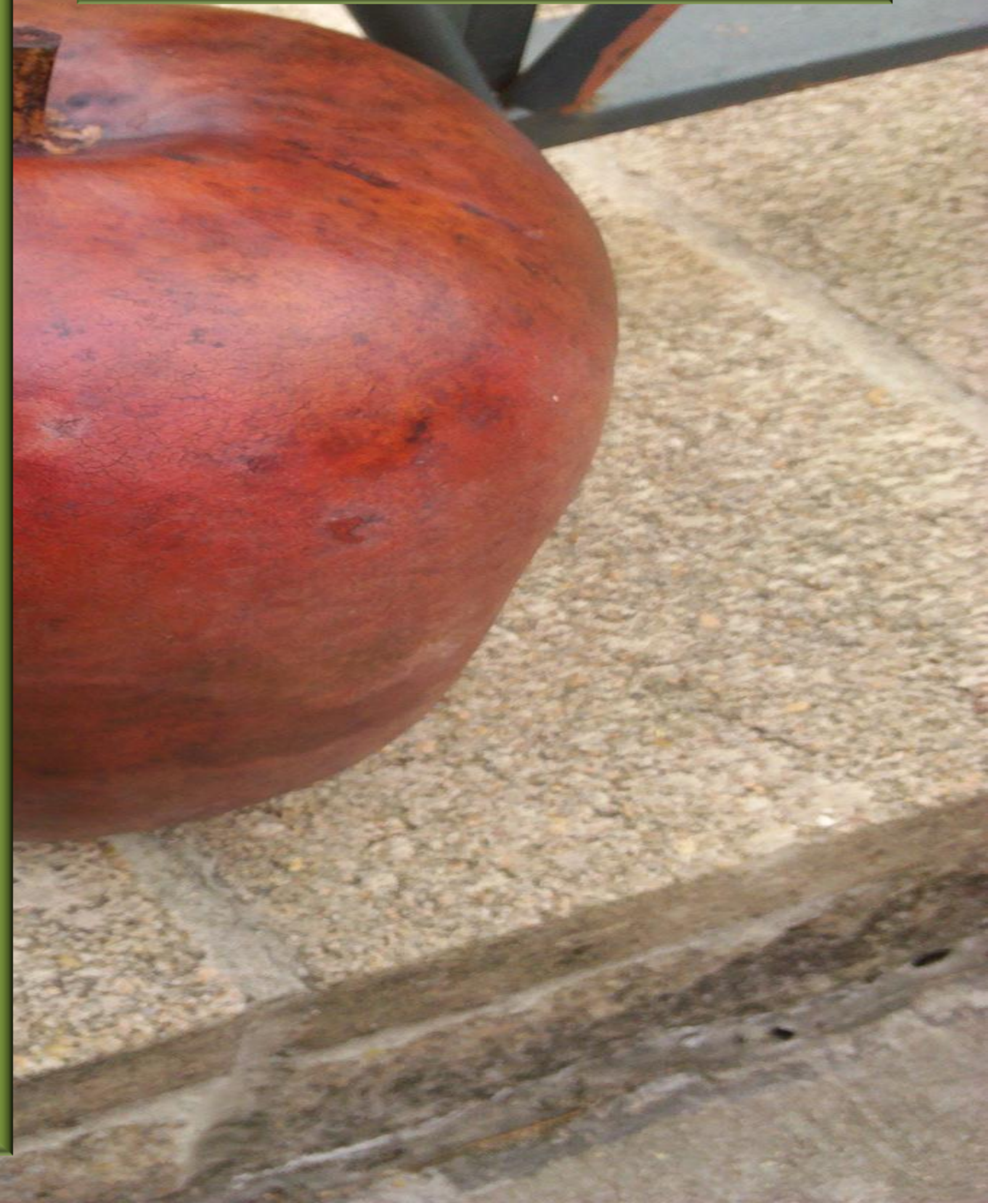
Satellite Motion

- A satellite is a projectile that falls around the earth.
- We say that a satellite has just enough ***tangential*** velocity that it does not ever hit the earth's surface when it falls.

If you can figure out what is physically wrong in the video below, post it in the discussion board.

Satellite Motion

- If an satellite stays the same distance from the center of its motion, it is said to be undergoing **uniform circular motion**.
- An object in uniform circular motion moves at a constant speed.
- However, an object undergoing uniform circular motion **is accelerating** because it is constantly changing direction.



Satellite Motion

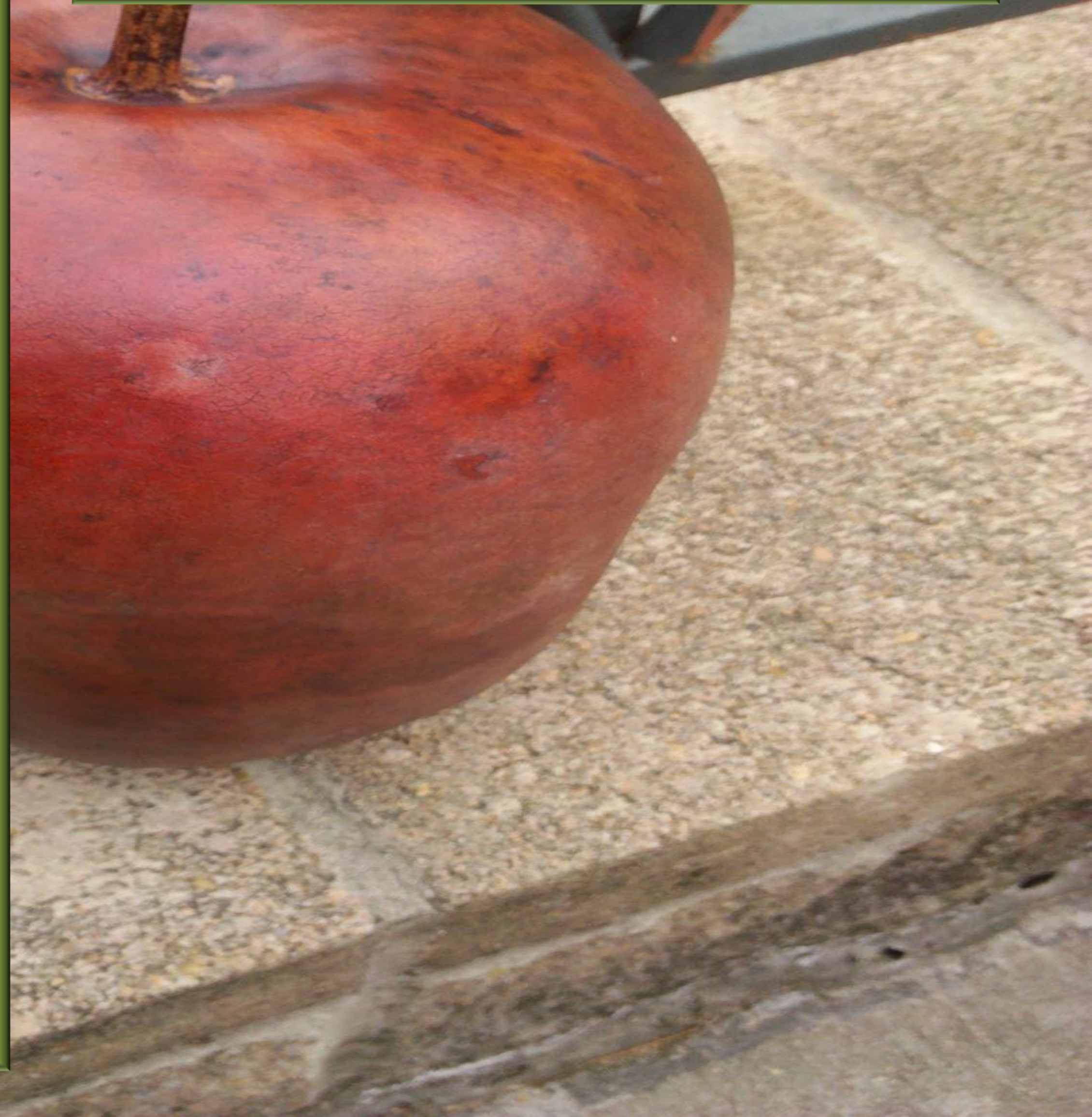
In order for an object to become an Earth satellite when it is at or near the surface of the earth, it must be traveling with a tangential velocity of about 8 km/s.

Energy is Conserved for Satellite Motion

- If we set up our system so that no external work is done on or by the system, then the total energy of the system is conserved.
- If we include the earth and a satellite in the system, we can say that the energy of the earth/satellite system is conserved.

Energy is Conserved for Satellite Motion

- If the energy of the earth/satellite system is conserved, then the sum of the kinetic and gravitational potential energies must stay the same, regardless of where the satellite is located in its orbit.
- If the satellite has a smaller gravitational potential energy (if it is closer to the earth), it must have a larger kinetic energy (it must be moving faster).



Escape Speed

- If an object is moving fast enough, it will escape from orbit.
- When an object has reached escape speed, it has escaped orbit, but it will never escape gravity.
- The force due to gravity extends infinitely far away from the source.

From the surface of the earth, escape speed is about 11.2 km/s.