

Lecture 5: Part 1

Gravity: A Force of Attraction

Chapter 5.4

24. Eureka! Gravity

It all starts with an apple...

- One beautiful spring day in 1655, a man named Isaac Newton was sitting under an apple tree in his garden, enjoying a glass of tea.
- Suddenly, one of the apples fell and crashed on his head.

Disclaimer: This last part has been fictionalized, most believe that the apple did not actually hit Newton on the head, but rather fell nearby and caught his attention.

A story about an apple

- That got Newton thinking (once the bump had gone down of course).
- "Why did the apple fall towards the Earth?"
- "Why did it not "shoot upwards" when it came away from the branch?"
- And, "why did I plant that stupid apple tree anyway?!!!"



A story about an apple

- Newton knew that unbalanced forces are necessary to move or change the motion of objects.
- So, he came up with the idea that the Earth must attract the apple towards it with some "unseen force".
- He named this force gravity.



G

- Gravity is a force of attraction between objects.
- We're not talking about finding someone really cute and adorable.
- We mean when the molecules of one object pull on the molecules of another object.
- It's like the Earth pulling on you and keeping you on the ground.
- That pull is gravity at work.

All matter is affected by gravity

- Do you remember the definition of matter?
- Matter is anything that has mass and volume.
- Since all matter has mass, all matter is affected by gravity.
- Gravity (aka: **gravitational force**) **pulls objects towards each other.**
- It acts on anything with mass.

Ok, then why don't we see objects being pulled towards one another?

- This is because the mass of most objects is too small to cause an attraction large enough to cause the objects to move towards each other.
- Even though gravity is "pulling" the pencil you're holding, its mass is so small that it's not really moving.
- There is, however, one object that is big enough to cause a noticeable attraction...

Gravity on Earth

- That's right, the Earth!
- Earth has an enormous mass and thus an enormous gravitational force.
- When the Earth spins and gravity pulls on the clouds, weather can be affected.
- The Earth's gravity even holds the atmosphere close to our surface.



- And, for a little BrainPop review:

■ BrainPop: Gravity

- Log is: MMS308 Password: marshall

The Law of Universal Gravitation

- Now that we know what gravity is, let's go back to Newton.
- He generalized his observation in something called **the Law of Universal Gravitation.**
- This law states: **All objects in the universe attract each other through gravitational force.**

The Law of Universal Gravitation

The size of the gravitational force depends on two things:

1. **Mass** of the objects
2. **Distance** between the objects

The law of universal gravitation

Basically, there are two major parts to this law that you need to know:

1. Gravitational force increases as mass increases
2. Gravitational force decreases as distance increases

(please underline these 2 sentences)

The Law of Universal Gravitation

a Gravitational force is small between objects with small masses.



b Gravitational force is larger between objects with larger masses.



c If the distance between two objects is increased, the gravitational force pulling them together is reduced.



What is weight?

Hey! Good Question!

- Weight is a measure of the gravitational force exerted on an object.
- Most of the time, when we're talking about weight, we're referring to the *Earth's* gravitational force on an object.
- Since gravity is a force and weight is a measure of gravity, weight is expressed in newtons (N).
- On Earth, a 100 gram object would weigh 1 N.

What is mass?

- Mass is the amount of matter in an object.
- This does not change... ever!
- Whereas weight changes when gravity changes, mass always remains the same.
- Remember, mass is measured with a balance, where the mass of one object is *compared* to another object.
- On Earth, mass and weight are both constant since gravity is a constant force, which is why they seem like the same thing to us.

Weight and Mass Are Different

The astronaut's weight and mass on Earth are shown on the spring scale and balance.

Weight is measured with a spring scale.

Mass is measured with a balance.

The astronaut has the same mass on the moon, but his weight is one-sixth of his weight on Earth. This is because the moon's gravitational force is one-sixth that of Earth's.

Write this formula at the bottom of the page:

The law of universal gravitation

The formula for this law is:

$$F = G \times \frac{m_1 \times m_2}{r^2}$$

F = force

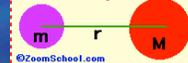
G = $6.673 \times 10^{-11} \text{ Nm}^2/\text{kg}^2$ - gravitational constant always an uppercase G, do not confuse with g, which is for gravity

M = objects' mass

R = distance between objects

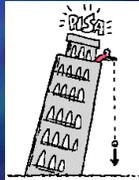
Newton's Law of Gravitation

$$F = \frac{GmM}{r^2}$$



Part 2 Gravity & Motion

Chapter 6.1

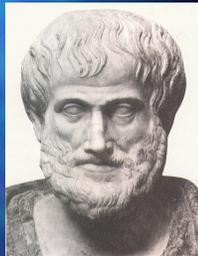


25. And now a little music!



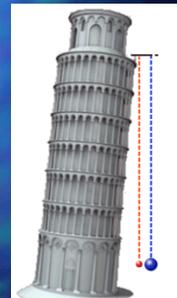
Actually, it all started with a cannonball...

- Well, and before the cannonball, it started with a philosopher & scientist named **Aristotle**.
- In ancient Greece around 400 BC, he proposed that the rate at which an object falls depends on its mass.
- In other words, Aristotle believed that the heavier the object, the faster it falls.



A story about a cannonball

- In the late 1500s, an Italian scientist named **Galileo** Galilei decided to prove Aristotle wrong.
- Galileo theorized that all objects will land at the same time when they are dropped from the same height.
- To prove this to his critics, he set up a little experiment.



A story about a cannonball

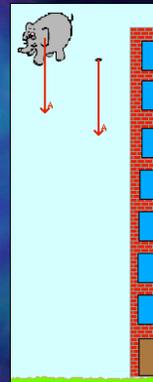
- Galileo carried a cannonball and a wooden ball up the 300 steps of the Leaning Tower of Pisa.
- Dropping the two different balls at exactly the same time, the crowd was amazed with what they saw...
- The two balls, with extremely different masses, landed at the exact same time!

Disclaimer: this story may or may not be true, but a similar and well-documented experiment was performed by Benedetti Giambattista in 1553.

Elephants & feathers

a similar type of comparison

- What did Galileo prove?
- Objects fall to the ground at the same rate because **acceleration due to gravity is the same for all objects**.
- For example, an elephant and a feather fall with the **same acceleration** even though they have **different masses**.

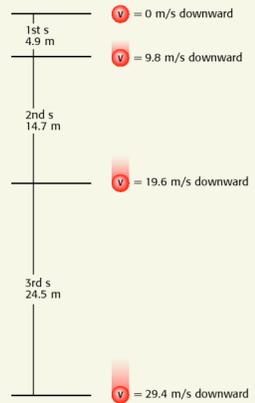


26. Feather in Vacuum



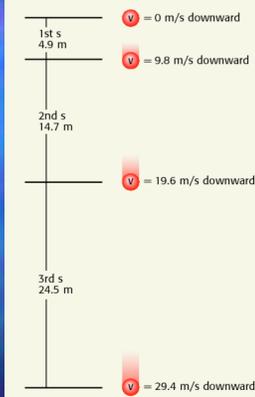
Gravity & Acceleration

- The rate at which objects accelerate towards Earth is **9.8 m/s/s**.
- This acceleration is the same for all objects, regardless of their mass.
- In other words, **falling objects accelerate at a constant rate of 9.8 m/s²**.
- Gravity = $g = 9.8 \text{ m/s}^2$



Gravity & Acceleration

- Notice, the ball isn't traveling at 9.8 m/s^2 , it's **accelerating** at 9.8 m/s^2 .
- It's velocity is continually increasing.
- Only the acceleration remains constant.
- Each picture was taken 1 second apart, but notice how the ball travels a greater distance between each second.

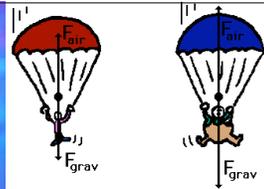


Air Resistance



- (Picture this!) I drop two pieces of paper, one crumpled in a tight ball and the other kept flat.
- What you see is that the crumpled paper has more velocity and hits the ground first, whereas the flat paper sashays slowly until it lands on the ground.
- You also know that air has friction & causes the objects to move more slowly.

Air Resistance



- The amount of air resistance depends on the size and shape of an object.
- Air resistance increases as an object's **speed** increases and its **surface area** (or cross-sectional) increases.
- While gravity pulls an object down, towards the Earth, the air resistance pushes an object up, or away from the Earth.

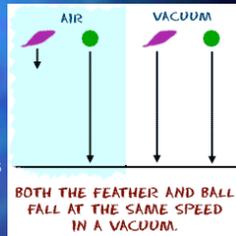
27. The physics of sky diving



DISCOVERY
EDUCATION

Free Fall

- When there is no air resistance, an object is in **free fall**.
- An object is in free fall only if **gravity is pulling it down and no other forces are acting on it**.
- Free fall can only occur where there is no air, such as in a **vacuum**.



Additional information

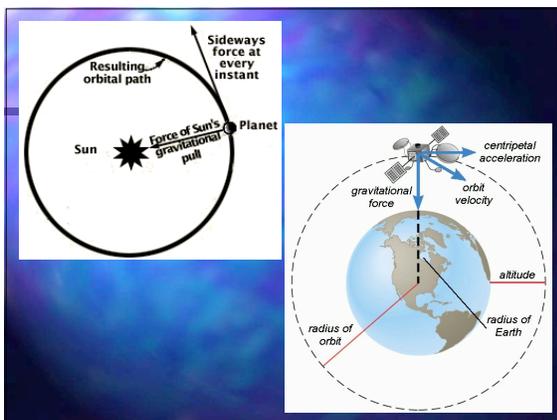
you may want to take some notes at the bottom of your page

The role of gravity in orbit

- In space, there is very little gravity.
- This is because the distances between you and other large objects are so vast, the force is minimal.
- You would still have mass, and because there is still a little bit of gravity, you would still have some weight.

The role of gravity in orbit

- We know that an object in orbit is traveling in a circular or near-circular path around another object.
- There are two forces that act on a spaceship in orbit.
- First, **gravity is pulling the spaceship back to Earth**, so technically, the shuttle is in **free fall**.
- Second, the shuttle is being propelled forward and is moving at a constant speed.
- As a result, the path of the orbit is a curved combination of the two forces.



Some additional info: Terminal Velocity, Acceleration & Air Resistance

- Watch as this sky-diver falls.
- Once the parachute opens, the upwards force of the air resistance begins to counter the downwards force of gravity.
- Eventually, his acceleration slows to 0 m/s².



$$a = \frac{F_{\text{net}}}{m}$$

$$a = \frac{1000 \text{ N}}{100 \text{ kg}}$$

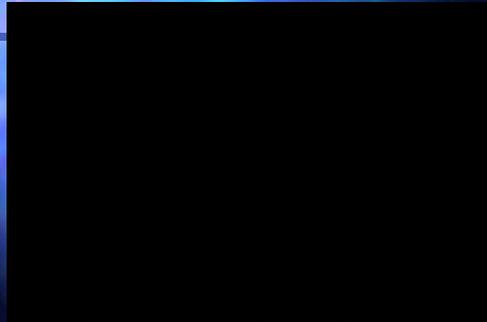
$$a = 10.0 \text{ m/s}^2$$

(down)

Terminal Velocity

- As an object falls, the air resistance is continually increasing.
- Eventually, the force of the air resistance will match the force of gravity pulling the object down.
- When this happens, the overall force is 0 N and the object stops accelerating.
- The object is now falling a constant velocity, which is called the terminal velocity.

28. Terminal Velocity



Summary

Be sure to answer the 3 questions

Summary Questions

- 1. What is gravity?
- 2. What is weight?
- 3. What is the difference between mass & weight?