STUDYING THE FORCE OF GRAVITY

The Motion of Falling Objects
Every object exerts a force on every other object. This force is called.....

Gravity
The Effects of Gravity on Matter

**Gravity:** a force of attraction between objects that is due to their masses.
Sir Isaac Newton and the Study of Gravity

- Observation: an apple falling from a tree
- Conclusion 1: an unbalanced force on the apple made the apple fall
- Conclusion 2: an unbalanced force on the moon keeps the moon moving around the Earth.
- 1665: proposed that these two forces are actually the same force—gravity.
NEWTON AND THE STUDY OF GRAVITY

Law of Universal Gravitation: This law states that every object in the universe attracts every other object. It depends upon:

- Mass
- Distance
**Gravitational Force Depends on Mass**

The gravitational force between objects increases as the masses of the objects increase. The arrows indicate the gravitational force between two objects. The length of the arrows indicates the strength of the force.

- **a** Gravitational force is small between objects that have small masses.

- **b** Gravitational force is large when the mass of one or both objects is large.

**Gravitational Force Depends on Distance**

The gravitational force between objects decreases as the distance between the objects increases. The length of the arrows indicates the strength of the gravitational force between two objects.

- **a** Gravitational force is strong when the distance between two objects is small.

- **b** If the distance between two objects increases, the gravitational force pulling them together decreases rapidly.
PROJECTILE MOTION

Curved path an object follows when it is thrown or propelled near the surface of the earth
Examples

- A frog leaping
- A swimmer diving
- Balls being juggled
- Water sprayed by a sprinkler
- An arrow shot by an archer
Two Components of Projectile Motion

Horizontal Component
• parallel to ground
• Velocity is constant

Vertical Component
• Acts perpendicular to the ground
• Gravity pulls at acceleration of 9.8m/sec²
• Downward acceleration of a thrown object and a falling object are the same
The place in a system or body where the weight is evenly dispersed and all sides are in balance.

It is as if the force of attraction between the Earth and the object were acting at this one point alone.
Regardless of the size and shape of an object

Its weight seems to be concentrated at one point.
This point is called...

Center of Gravity
Gravity causes objects to accelerate downward, whereas air resistance acts in the direction opposite to the motion and reduces acceleration.
Galileo

- 1564 – 1642
- Most famous for invention of the telescope.
- Discovered the moons of Jupiter and the rings of Saturn

Galileo’s work on the motion of objects and their acceleration due to gravity paved the way for Isaac Newton’s theories.
Galileo proved his theory by rolling balls of different masses down an inclined plane.
Galileo’s Experiments proved that gravity causes objects to accelerate.
ACCELERATION

• Acceleration: the rate at which velocity changes over time

• an object \textit{accelerates} if its speed, or direction, or both change.

• positive acceleration: an increase in velocity

• negative acceleration, or deceleration: decrease in velocity
All falling objects accelerate at the same rate regardless of their mass.
Galileo was able to determine the correct mathematical law for acceleration due to gravity.

On Earth, falling objects accelerate at a rate of $9.8 \text{ m/s}^2$ or $32 \text{ f/s/s}$.
This means each second it falls, it will be traveling 9.8 meters per second faster.
If something is dropped from The Empire State Building (443.00 meters up) it will hit the ground in 9.51 seconds. It will be traveling at 93.18 meters per second when it hits the ground. 93.18 meters per second is 208.44 miles per hour (mph).

\[9.8 \text{ m/s} \times 9.51 \text{ s} = 93.18 \text{ m/s/s}\]
So… the speed of a falling object depends on…. 

**HOW LONG IT FALLS!**
To determine acceleration due to gravity…

\[
\text{Acceleration} = \frac{\text{Velocity}_{(F)} - \text{Velocity}_{(I)}}{\text{Time}}
\]
Velocity: Direction Matters

- Velocity: speed of an object in a particular direction

- An object’s velocity is constant only if its speed and direction don’t change.
FREE FALL

The movement of an object towards the earth because of gravity.
Let’s compare and contrast friction and gravity by completing this table.

<table>
<thead>
<tr>
<th></th>
<th>Friction</th>
<th>Gravity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Effect on motion</strong></td>
<td>Opposes motion</td>
<td>Pulls objects toward one another</td>
</tr>
<tr>
<td><strong>Depends on</strong></td>
<td>Types of surfaces involved, how hard the surfaces push together</td>
<td>Mass and distance</td>
</tr>
<tr>
<td><strong>Measured in</strong></td>
<td>Newtons</td>
<td>Newtons</td>
</tr>
</tbody>
</table>
On Earth, falling objects are affected by air resistance.

This opposes downward motion.
**AIR RESISTANCE**

- Falling objects with a greater surface area experience more air resistance.
As a body falls, air resistance increases. And the speed of the falling body increases at a slower rate.
A point is reached where acceleration stops. The highest speed reached by a falling object is called….

**Terminal Velocity**
The object continues to fall at a constant speed.
Air resistance increases as the speed increases. Eventually, the force $R$ of air resistance becomes equal to the force exerted by the earth, and the object reaches equilibrium.
At Terminal Velocity
Net Force = 0
Free Fall

- **Drawing Conclusions:**

  - Suppose another object of the same size but with a greater mass was dropped instead. How would the speed values change?

  - The speed values would not change.
Free Fall

- Predicting:

- What will the speed of the object be at 6 seconds?

Q.  

- $58.8 \text{ m/s}$
• Acceleration can be shown on a graph of velocity versus time.
Free Fall

• **Interpreting Graphs:**

  – What variable is on the horizontal axis? The vertical axis?

  – Time is on the horizontal axis, and speed is on the vertical axis.
Free Fall

• Calculating:

– Calculate the slope of the graph. What does the slope tell you about the object’s motion?

– The slope is 9.8. The speed increases by 9.8 m/s each second.