Forces in Motion
<table>
<thead>
<tr>
<th>Anticipation</th>
<th>Statement</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>T / F</td>
<td>1. If you drop a marble and a bowling ball at the same time, they will both land on the ground at the same time.</td>
<td>T / F</td>
</tr>
<tr>
<td>T / F</td>
<td>2. Galileo proved that the mass of an object does not affect the rate at which an object falls.</td>
<td>T / F</td>
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<tr>
<td>T / F</td>
<td>4. A flat sheet of paper will fall at a slower rate than a crumpled ball of paper due to air resistance.</td>
<td>T / F</td>
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<tr>
<td>T / F</td>
<td>5. The shape of an object has no effect on the amount of air resistance.</td>
<td>T / F</td>
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<tr>
<td>T / F</td>
<td>6. Free fall occurs when there is no air resistance acting on an object.</td>
<td>T / F</td>
</tr>
<tr>
<td>T / F</td>
<td>7. When forward motion and air resistance occur together, it causes orbiting.</td>
<td>T / F</td>
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Testing Galileo’s theory on the moon!
1. All Objects Fall with the Same Acceleration (on Earth)

- Galileo proved that the **mass** of an object does NOT affect the **rate** at which it falls. The mass does not affect the rate of **acceleration**.
- Objects fall to the ground at the **same** rate because the acceleration due to gravity is the same for all objects.
- The rate of acceleration due to gravity is **9.8 m/s/s**.
  - This means that for every second it falls, it’s downward velocity increases by 9.8 m/s. It starts of slow, then goes faster and faster!
When objects begin to fall, they gain speed (accelerate).

- 1 second: $v = 0 \text{ m/s}$
- 2 seconds: $v = 9.8 \text{ m/s}$
- 3 seconds: $v = 19.6 \text{ m/s}$
- 4 seconds: $v = 29.4 \text{ m/s}$
Testing it in a vacuum chamber - bowling ball vs feather.
MATH BREAK: VELOCITY OF FALLING OBJECTS

Formula: $\Delta v = g \times t$ and $g = 9.8 \text{ m/s/s}$

What does $\Delta$ mean?
We call this sign “delta” (it’s Greek). It means CHANGE.
The formula $\Delta v = g \times t$ means...

A change in velocity = acceleration due to gravity multiplied by time.

LET’S PRACTICE!

1. A penny at rest is dropped from the top of a tall stairwell. What is the penny’s velocity after it has fallen for 2 seconds?

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2. A boy standing on a high cliff drops a ball and it strikes the water after 6 seconds. What is the ball’s velocity when it hits the water?

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2. Air Resistance Slows Down Acceleration

a) Air Resistance - a **fluid friction** that opposes the motion of objects through the **air**.

b) Air resistance acts in the **opposite** direction of gravity.

c) Amount of air resistance depends on the **size** and **shape** of an object.

d) For example, a sheet of paper has **more** air resistance than a ball of crumpled paper.
e) The force of air resistance keeps **increasing** as the object **accelerates**.
f) At a certain point, the force of air resistance will equal the force of gravity and the net force will be zero.

- This is called **terminal velocity** and the object no longer accelerates as it falls.

- It is the constant velocity of a falling object when the size of the **upward** force of air resistance matches the size of the **downward** force of gravity.
Physics of Sky Diving
3. Orbiting Objects are in Free Fall

a) Free fall occurs (happens) when there is **no** air resistance (in a vacuum or outer space). **Gravity** is the only force acting on the object.

b) Two motions combine to form orbiting, **forward** motion and **free fall**.

c) The shuttle is in free fall because the only force acting on it is **gravity**.

d) The horizontal motion came from the rocket’s engine that makes it want to go in a straight line.

e) The shuttle and the astronaut are continually falling in a **curved** path following the surface of the Earth!
f) If the shuttle started moving **faster**, it would go straight and fall out of orbit.

**Too fast**

g) If the shuttle started moving **slower**, it would begin to hit the Earth.

**Too slow**

Therefore, **GRAVITY** provides the **unbalanced** force that keeps **planets** in **centripetal motion**.
Free Fall and Projectile Motion
4. Projectile Motion

a) **Projectile motion** is the **curved** path an object follows near the Earth’s **surface**.

b) Two components combine to form projectile motion - constant **horizontal** motion and vertical **free fall** (acceleration due to gravity).

c) **SUMMARY**: PROJECTILE MOTION = VERTICAL + HORIZONTAL MOTION

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**More Examples:**
NFL - Projectile Motion

Image of a football with labeled axes $V_1$, $V_2$, and "speed".
That’s all for the notes!

Go to the substitute teacher to pick up a GIZMO Worksheet: “SHOOT THE MONKEY”
Understanding Car Crashes: It’s Basic Physics