

Teaching Abstract Physics Concepts  
to Elementary Students

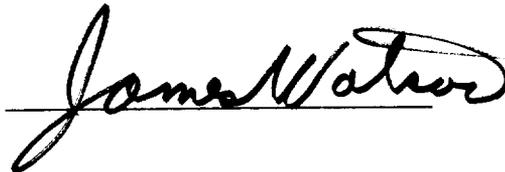
An Honors Thesis (HONORS499)

by

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A handwritten signature in black ink that reads "James Watson". The signature is written in a cursive style and is positioned above a horizontal line.

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### STATEMENT OF PURPOSE

In this project, I am attempting to explain physics concepts in every day language. The language will be understood by non-physics majors. I am placing emphasis on comprehension, and not on computation. Complex math skills are not necessary to understanding the basic concepts of physics.

The most basic key to comprehension is the mastery of vocabulary and fundamental concepts. Too many educators are guilty of not teaching physics, because they do not understand the vocabulary or the concepts themselves.

This paper presents understandable information for teachers. If more in depth information is wanted, start by examining a high school text book.

The concepts covered in this project are as follows:

Gravity / Why does the moon stay up?

Pressure

Density

Mass vs. Weight

I hope that this information will aid educators and students alike. We must understand the rules that govern our lives if we are to live happy and successful lives.

### INFORMATION TO TEACHERS

#### **Kepler's planetary motion**

The planets of the solar system are simply falling constantly around the sun. Their paths are ellipses. They do not travel at a uniform speed, but move faster when they are nearer the sun, and slower when they are farther away. They do this in a way that equal areas are covered in an equal time.

Gravity is the name that science gives to the force of attraction between objects. Although science has given a name to this force, it does not fully understand this force. What is understood is how gravity affects things such as projectiles, satellites, and the solar system of planets. It is also known that gravity extends throughout the universe; it accounts for such things as the shapes of galaxies.

Point out to students that gravitational effects are not dependent on the presence of an atmosphere. You would weigh the same on earth with or without an atmosphere.

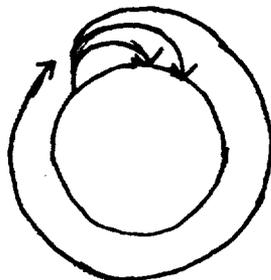
Sir Isaac Newton is credited with the discovery that gravity is universal. According to a popular legend, Newton was sitting under an apple tree when an apple fell on his head. Looking up he began to question. He understood the concept of inertia. He knew that an object undergoes a change in speed or direction when acted on by an outside force. What was the force that had acted on the apple?

Newton had been studying the moon's path. The fact that the moon followed a curved path around the earth instead of a straight line path puzzled him. Circular motion is accelerated motion,

which requires a force. Newton had the insight to see that the force that pulls between the earth and the moon, is the exact same force which had pulled the apple off the tree. It was the same force that pulled between everything in our universe - the force of gravity.

### Why Does the Moon Stay Up?

The moon is falling as we speak. Newton was the first to realize that if the moon did not fall, it would move in a straight line and leave its earth orbit. He hypothesized that the moon was a projectile circling the earth due to the attraction of gravity. The moon is actually falling around the earth. When a satellite is launched it is fired high enough that as it falls it will miss the earth. Its course down will have a parabolic shape, and as it misses the earth it will become a circle, and thus begin to orbit the earth.



This sideways motion, or tangential velocity, causes the movement around the earth rather than into it. The moon "falls" around the earth indefinitely, as long as there is no resistance to reduce its speed.

Review Newton's first law: An object in motion (moon) will remain in motion unless acted upon by an outside unbalanced force (gravitational attraction).

Depending on the maturity of the student, a more in depth study of tangential velocity can begin at this time.

Newton generalized his moon findings to all objects in his law of universal gravitation. It says that every object in the universe attracts each other.

Allow students to discuss this law. They will most likely ask this question:

Q. Since the moon is gravitationally attracted to the earth, why does it not simply crash into the earth?

A. The moon would crash if its tangential velocity were reduced to zero, but because of its tangential velocity, the moon falls around the earth rather than into it.

At this point a more in depth view of the numerical force of gravity may be started.

Newton discovered that gravity is universal, he did not discover gravity.

The symbol of gravity is  $G$ . It is the weakest of the four fundamental forces of nature. We have a sense of gravity only when huge masses like planets are involved.

Point out that the weight of an object is the force of attraction between its mass and the earth's mass.

At the top of a huge cliff, your mass is the same, but your weight is slightly less due to your distance from the center of the earth.

**BULLETIN BOARDS:**

1. Why the Moon Stays up: Make a picture of the earth and the moon. Show the moon orbiting the earth. Also picture satellites being launched. Use yarn to show the paths of the falling objects.

**LEARNING CENTERS:**

Set up the following experiments or demonstrations.

1. Put a coin on a paper hoop on a glass. Pull the hoop out quickly. Inertia leaves the coin in midair. Gravity then pulls the coin down into the glass.
2. Spin raw and hardboiled eggs. Record your data. The raw egg will stop sooner because the loose material inside has more friction.

**INTRO ACTIVITIES:**

1. Put a marble in a bowl. Make the marble roll along the upper rim of the bowl by moving the bowl in circles. Inertia of the marble keeps the marble from falling to the bottom.
2. Stack up a pile of checkers. Flip one checker to hit the bottom checker out of the stack. The bottom checker flies out and the remaining drop down. The bottom checker has inertia. The motion of the first checker is transferred. Gravity pulls the rest of the checkers down.

**EXPERIMENTS:**

1. Experiment with a balloon. Put different amounts of pressure into a balloon. Chart the distance or time each stays up.
2. Experiment with spring launched objects. Change the force and chart their descent and altitude.

INFORMATION TO TEACHERS

**Pressure** is the force per area on which it acts.

$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$

Make sure that you distinguish between force and pressure. Both of these blocks are of equal weight; therefore, they exert the same force on the surface. The upright block exerts a greater pressure due to the smaller area. The pressure a block exerts against a table is simply the weight of the block divided by its area of contact. The pressure that a liquid exerts against the bottom of a container is the weight of the liquid divided by the area of the container bottom.

The pressure and weight of a liquid depends on its density. Consider two identical containers, one filled with mercury and the other filled with water. The denser liquid exerts the greater pressure. Mercury is 13.6 times as dense as water; therefore, the the weight and pressure are 13.6 times as dense. For liquids of equal density, the pressure will be greater at the bottom of the deeper liquid.

The pressure of a liquid at rest depends only on the density and the depth of the liquid. Liquids are practically incompressible, which they can not be compressed or made smaller. Explain that incompressibility means that water is not like a sponge that can be squeezed into a smaller volume. This is on reason that water balloons explode. The water inside does not compress upon impact as is commonly believed.

Pressure can on an ear underwater. The deeper one swims, the greater the pressure is on the ear. The weight of the water pushes down on the swimmer. Liquid pressure depends on depth. **Liquid pressure = weight density x depth**. Pressure does not depend on the amount of matter.

Liquid pressure is exerted equally in all directions. Due to the fact that a liquid can flow, the pressure is not only downward. When liquid presses against a surface, there is a net force perpendicular to the surface. If there is a hole, water spurts out at right angles before curving down due to gravity

#### **SURFACE TENSION**

Surface tension accounts for the spherical shape of liquid droplets. A sphere is the shape having the least surface. Surface tension results from the contraction of liquids. Water has a greater tension than other common liquids. This concept can be explored by the brighter students.

#### **PASCAL'S PRINCIPLE**

Pascal's principle describes the changes in pressure at any point in an enclosed fluid at rest are transmitted undiminished to all points in the fluid and act in all directions.

#### **ACTIVITIES**

1. Float an egg in water. Then dissolve salt in the water until the egg floats. How does the density of an egg compare to that of the tap water.
2. Punch a hole in the top of a juice can. Pour the juice. Now punch another hole in the can. How does this affect the pouring of the juice when two holes are punches?

Ask these questions to monitor progress to this point.

1. Is there more pressure at the bottom of a bathtub of water 30 cm deep or at the bottom of a pitcher of water 35 cm deep?
  - A. There is more pressure at the bottom of the pitcher, because the water is deeper in it. The fact that there is more water in the bathtub does not matter.
2. A brick mason wishes to mark the back of a building at the exact height of bricks already layed at the front of the building. How can he measure the same height using only a transparent garden hose and water?
  - B. To measure the same height, the brick mason can extend a garden hose from the front to the back of the house, and fill it with water until the water level reaches the height of bricks in the front. Since water seeks its own level, the level of water in the other end of the hose will be the same.

**BULLETIN BOARD:**

1. Under the Sea: Label different objects at different depths. Indicate the different pressures on each object.
2. Put your foot down: Make several different feet and their shoes. Label the different pressures on each foot.

**INTRO ACTIVITIES:**

1. Gather various aerosol cans. Have the children read the warnings. What does that mean? After the unit ask the same question, and compare the answers.
2. Show two rectangular blocks, one on its end and one on its side. Which exerts a greater pressure on the table? The upright, because the force is in a smaller area.
3. The can crushing experiment. Get a pint or quart can with a screw cap. Heat about a half cup of water in the can. Let the water boil for about a minute. Shut off the heat and cap. Carry it to the sink and pour cold water over it. The steam changed back to water, leaving less air pressure inside. The greater outside air pressure crushes the can.

**EXPERIMENTS:**

1. Dip a matchstick in various substances and record each effect on surface tension. Some will allow the match to float on top of a glass of water, and some will not.
2. Cover a glass of water with waxed paper. Crease along the sides. Turn upside down or sideways. The outside air pressure keeps the water from falling out.

INFORMATION TO TEACHERS

Density is a property of matter, it is a property shared by solids, liquids, and gases. Density is the measure of compactness of the matter. The most common view of density is one of "lightness" or "heaviness". It is actually a measure of how much matter is present in a given space. It is the amount of mass per unit volume.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Density is a very difficult concept, because students have very little experience with mass and unit volume.

Density is neither mass nor volume, it is a ratio. A cake that is cut in half still has the same density, but less mass and volume. A pure iron nail has the same density as a pure iron pot.

Both the masses of atoms and the spacing between atoms determines density. The densest material on earth is osmium, a bluish-white metallic element.

**Demonstration:** Cut out a piece of styrofoam that has a slightly greater mass than a nail. Pass both around, and ask the students which has the greater mass. Most will say the nail. Place both on a balance to prove that the styrofoam has a greater mass, even though it is less dense.

**Questions:**

1. Which has the greater density? 1kg of water or 10kg of water? **A.** They are equal. The density of water is 1.00g/cm<sup>3</sup>
2. Which has the greater density? 5kg of lead or 10kg of aluminum? **A.** Lead has the greater density. The amount is irrelevant.

3. Which has the greater density? 1 kg of uranium or the whole earth? A. Uranium has the greater density  $19.0\text{g/cm}^3$ . The earth's density is  $5.5\text{g/cm}^3$ .

### Density of Submerged Objects

**Demonstration:** Add colored water to a jar containing oil. The water sinks because it is more dense. Add oil to colored water. The oil floats on the water because it is less dense.

I would deal with liquid density with more advanced students. Buoyant force is compared to the object's weight to determine if it sinks or floats.

**BULLETIN BOARDS:**

1. How do things stack up?: Make a diagram of different liquids which are stacked on each other. You may also picture various objects suspended in each layer. You could have the children guess at these and use it as an introduction activity.

**EXPERIMENTS:**

1. Experiment with stacking different liquids. Record your results.
2. Try putting different objects in each layer of liquid.

**LEARNING CENTER:**

1. Provide different materials and a balance. Let students predict the densities, and test their guesses. Make this self checking.

### INFORMATION TO TEACHERS

Mass is related to our measure of weight. However, weight is due to the force of gravity, and mass is independent of gravity. This is one of the hardest facts for students to understand. Mass is the measure of how much matter something has. The greater the mass of an object, the greater its inertia. Mass is a measure of the inertia of an object. Inertia is the tendency of things to resist changes in motion.

**Newton's Law 1:** Every material object continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it.

For example, if a glass is sitting on a table, it will remain sitting on the table until an outside force acts upon it to knock it off of the table. A swinging hand would be considered an outside force.

Mass is more basic than weight. For example, if you are trying to determine which of two objects is heavier you would balance them back and forth in your hands. By doing this, you are judging which object is more difficult to move. You are actually making a decision about the inertia of an object. Mass and weight are often confused, due to the fact that they are directly proportional.

**Mass:** The quantity of matter in a material object. More specifically, it is the measurement of the inertial or sluggishness that an object exhibits in response to any effort made to start it, stop it, or change in any way its state of motion.

**Weight:** The force upon an object due to gravity.

In the United States, matter has been described by its weight, in terms of pounds. The rest of the world uses the kilogram for a mass unit.

On the moon, where the gravitational influence is less, an object would weigh less, but would have the same mass. For example, a 1 kilogram brick would weigh less, but it would still have the same resistance to speeding up or slowing down.

It is also easy to confuse mass and size-**volume**. A voluminous object occupies a great deal of space; however, it doesn't have to be more massive.

1. Which has a greater mass, 10kg of feathers, or 10kg of lead?

The answer is neither, both have a mass of 10kg. The feathers have more volume. You can squeeze a loaf of bread and change its volume, but its mass will stay the same. Mass is neither weight nor volume.

Balances measure mass. Spring scales measure weight. No scales work in space, because there is not enough gravitational force. Balances can be used in space.

- \* Make sure the vocabulary is understood. This is the primary cause for confusion in this subject.
- \* Which one measures mass or weight? A balance can be used anywhere as long as some type of gravity.

**EXPERIMENTS:****I. Pendulums**

A yo-yo works well as a pendulum. What are the variables and their relationships of a pendulum. Investigate the effect of mass on period.

1. Half of the lab groups triple the mass by adding clay.
2. The other half doubles the mass.
3. Find the period.
4. Graph the class data.
5. Is period a function of mass?

**I.**

- A. For younger children have them triple and double the mass. Make a large class graph. Discuss what happened when they added to the mass. Why do they think this happened.

**II. Inertia Experiments**

Explain inertia as it relates to mass and weight.

1. Put a glass on a piece of paper. Pull the paper out from under the glass. The glass should not move.
- 2.

**LEARNING CENTER:**

Provide a balance and a spring scale. Provide different objects to weigh and mass. Let the children estimate the mass and or weight, then they investigate. Make self check area with answer key, so that they know if they are correct.

**BULLETIN BOARDS:**

1. Diagram of a balance and a spring scale. Label all parts and which each is used for.
2. Picture of a man going into space and his weight and mass changing as he ascends into space.
3. Different items pictured. Ask which has more mass/weight. Make this self checking.

**INTRO ACTIVITIES:**

Discuss:

1. Which has more mass 10 kg of lead, or 10 kg of feathers? Why? explain.
2. Discuss the metric systems and conversions.
3. Have the children mass and weigh different objects.
4. How do spring scales and balances work?

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