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**Available Physics Demonstrations**

# 1 Size Scale of Planets

The principles of physics are universal: these principles apply throughout the universe. We show photos of the planets with accurate relative sizes and discuss that physics applies even in worlds much different from our everyday experience.

# 2 Free Fall

The Earth's atmosphere affects everything around us including the motion of falling objects. We demonstrate that without air friction all objects, independent of mass, accelerate at the same rate under the influence of gravity. This was shown in 1972 by Apollo 15 astronauts dropping a hammer and feather on the Moon (download video clip at: www.schwellenbach.com/casper09). On the surface of the Moon there is no air and the acceleration of gravity is $\frac{1}{6}$ the value at the Earth's surface.

# 3 Projectile Motion – Vectors

At the instant the paint ball leaves the barrel, a light beam is interrupted and the target is released. The paint ball hits the target because both objects fall at the same rate independent of their initial motion. Similarly, the Moon is orbiting the Earth with an average speed of over 2,000 MPH. Like the paint-ball, gravity pulls the Moon perpendicular to its motion, changing its direction but not its orbital speed.

# 4 Mass and Inertia – Newton's First Law

*Objects at rest remain at rest unless acted on by a net force.* The glasses stay in place when the tablecloth is pulled due to their inertia. If the glasses were empty they would be more likely to move since they would have less mass and therefore less inertia.

# 5 "Newton's Eggs" – Newton's $1^{st}$ Law

*Objects at rest remain at rest unless acted on by a net force.*

The eggs have enough mass (and therefore inertia) to have no noticeable motion in the horizontal direction. Actually, friction with the moving plastic plate provides a very small horizontal force on the eggs, and they will experience a very small horizontal acceleration that can be neglected.

# 6 Centripetal Force – Newton's First Law

*Objects in motion will continue to move in a straight line unless acted upon by a force.* The water in the bucket tends to move in a straight line. We must apply a force (centripetal force) to keep it moving in a circle. In the case of orbits (satellites, the Moon, planets) the centripetal force is provided by gravity.

# 7 Newton's Second Law (F=ma)

*Force = mass x acceleration.* The firecrackers apply the same force to both cans but the less massive can has a greater acceleration, reaches a greater speed, and therefore flies to a greater height than the more massive can. The less massive can is physically bigger pointing out the importance of having complete information before making predictions.

# 8 Action/Reaction – Newton's Third Law

*For every action there is an equal and opposite reaction.* The pressure in the tank (approx. 800 psi) forces the $CO_2$ out of the modified fire extinguisher, the reaction is an equal but opposite force accelerating the passenger. The same principle explains the thrust provided by rockets for use in the atmosphere or in space. (Conservation of momentum can also be used to describe this demonstration.)

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## 9 Conservation of Momentum

The air track provides a nearly frictionless system so the momentum remains constant before and after the explosions. Newtons's 3rd law can explain why the lighter cart moves away faster–conservation of momentum provides the most straight-forward explanation of why the two carts come to rest again after they stick together.

## 10 Pressure (= Force ÷ Area)

Pressure and force are related but it is important to understand the distinction. A person can lie on a bed of nails because their weight (the force of gravity pulling them down) is distributed over a large enough area; the pressure is low enough that the skin is not damaged.

## 11 Weight of Air

One cubic foot of air weighs only about .075 lbs (engineeringtoolbox.com) at the surface of the Earth, or the mass of 1 liter of air in one of the flasks is about 1 gram. Two 1 liter flasks are on a sensitive balance initially both at atmospheric pressure. A vacuum pump is used to pump the air out of one flask and the movement of the balance clearly shows that air has mass.

## 12 Atmospheric Pressure

Adding up the contribution of the weight of the entire atmosphere (greater than 50 miles in height) leads to a substantial total weight which we measure as atmospheric pressure. Atmospheric pressure is 14.7 psi at sea level.The volume of a balloon or of shaving cream changes dramatically as the surrounding pressure is reduced.

## 13 Bernoulli Effect

Make a screwdriver "float" in front of class. Just like an airplane wing, the pressure is lower above the screwdriver because the air is moving faster.

## 14 Pressure and Temperature

As the gas is cooled the pressure in the flask is reduced. The force exerted by atmospheric pressure pushes the egg into the flask.

## 15 Boiling Point

The boiling point of water is a function of temperature and pressure. As the flask cools the a partial vacuum is created above the water and the water and gas are in equilibrium. When the gas is cooled slightly by an ice cube, the pressure is reduced so room temperature is hot enough to boil water.

## 16 Geysers

The model of a Geysers shows that a geyser requires a unique structure as well as a heat source. The restricted pipe upward prevents heat transfer through convection. The weight of the column of water increases the pressure at the bottom of the column increasing the boiling point of water. Once the water starts to boil, the hot steam moving upward lowers the pressure at the bottom since steam has a much lower density than water. With lower pressure, the boiling point falls and the water quickly evaporates creating the eruption. Evaporation cools the bulk of the water and the process starts again.

## 17 Collisions - Conservation of Momentum

The tennis ball cannon gives each tennis ball nearly the same speed and therefore the same momentum. In the inelastic collision (the ball is captured by the sled) the ball transfers its total momentum to the sled. In the elastic collision (ball bounces back) the ball transfers twice its original momentum to the sled. First the ball is stopped (just like the inelastic collision) but then the sled applies an additional force to accelerate the ball backwards.

## 18 Angular Momentum

Show that the effect of gravity on the motion of a gyroscope (spinning bicycle wheel) depends on the initial rotation. Gyroscopes are used to maintain stable orbits of spacecraft such as the International Space Station.

## 19 Conservation of Energy

Conservation of energy is shown using a pendulum made from a bowling ball suspended by a rope. The demonstrator's nose is safe from impact because energy is conserved; the bowling ball cannot return to a greater height than it started.

## 20 Electrostatics

Use the Van De Graff generator to show various aspects of electrostatics including making a person's hair stand out. (Opposite charges attract, like charges repel.) It is important to note that no charges are created, charges are only moved. Charge conservation says charge cannot be created or destroyed; as the sphere acquires a negative charge the base acquires an equal positive charge.

## 21 Lenses

Show how a lens forms an image by refracting, or bending, the light rays when the light goes from air (fast) to glass (slower). Discuss focal length and converging/diverging lenses.

## 22 Primary Colors

Even though white light consists of all colors of the rainbow (Red, Orange, Yellow, Green, Blue, Indigo, Violet), our eyes are sensitive independently to Red, Green, and Blue. Our eye interprets all colors as a mixture of various intensities (brightness) of these three colors. The three colors are projected and it is shown that the three can be "mixed' to give white light.

## 23 Total Internal Reflection

Demonstrate the concept of fiber optics work by observing a laser beam following a stream of water. Similar to the lens, the beam of light changes direction at the water/air interface. Due to the difference in the speed of light in air relative to water, all of the light energy is reflected back into the water.

## 24 Electromagnets

Show how electric current can be used to make a magnet and that the unique structure of iron enhances an applied magnetic field.

## 25 Transformers

A constant (DC) or changing (AC) electric current can create a magnetic field (an electromagnet). Similarly, changing magnetic fields can induce electric currents. The AC current in the coil under the table creates a changing magnetic field. Changes in the magnetic field through the coil on top of the table induce an electric current in the loop. The light bulb is connected in series with the loop so it lights when current flows.

## 26 Electric Circuits

Compare the brightness of light bulbs, and the current flowing in circuits connected in series and parallel.

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## 27 Jacob's Ladder – Plasma

The spark on Jacob's Ladder is created by a 15,000 volt transformer. The spark tends to move up as the air is heated, hotter air has a lower density so rises relative to cooler air. The electric current (flow of electrons) through the air adds energy to the air molecules creating a plasma. As this plasma loses energy to return to its stable state it gives off energy in the form of light, similar to a lightning bolt or the northern lights.

## 28 Index of Refraction

A broken beaker can be given the illusion of "gluing itself back together" by hiding an identical one in oil. The oil and Pyrex glass have nearly the same index of refraction.

## 29 Thermal Expansion

As the air in a balloon is cooled in liquid nitrogen it contracts and eventually turns to liquid because of the low temperature. The properties of materials change greatly at low temperatures. The temperature of liquid nitrogen is similar to the temperature near the surface of Jupiter or Saturn which shows one of the challenges of building spacecraft to withstand the hostile environment of space.

## 30 Geiger Counter

Discuss how a Geiger counter uses small changes in electric current to detect ionizing radiation. Show the properties of various radiation emitters, including: lantern mantles, a "Fiesta Ware" plate, inner working of a smoke detector, and dinosaur bones found near Medicine Bow, WY.

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