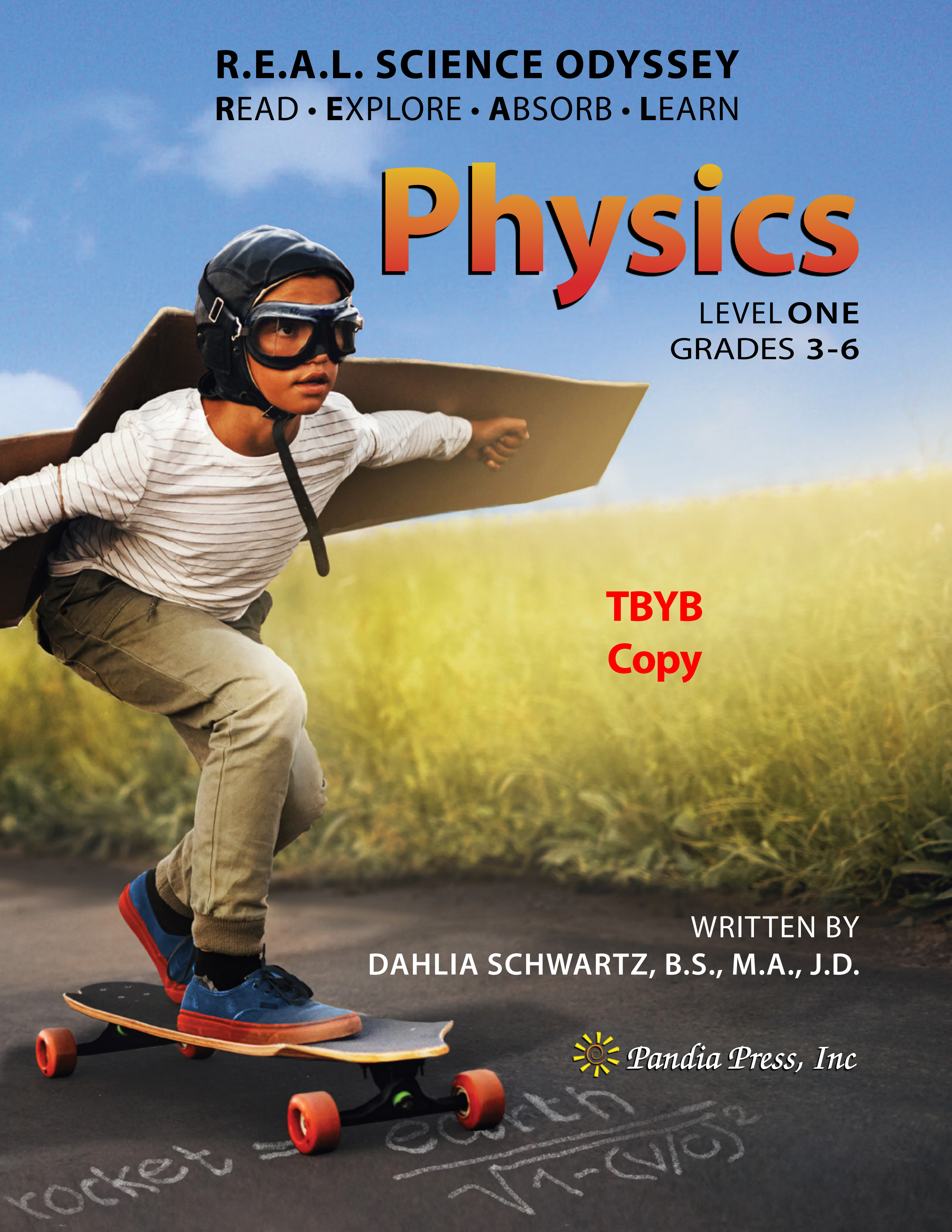

R.E.A.L. SCIENCE ODYSSEY

READ • **E**XPLORE • **A**BSORB • **L**EARN

Physics

LEVEL **ONE**

GRADES **3-6**

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WRITTEN BY
DAHLIA SCHWARTZ, B.S., M.A., J.D.

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REAL Science Odyssey
Physics Level One
Preview

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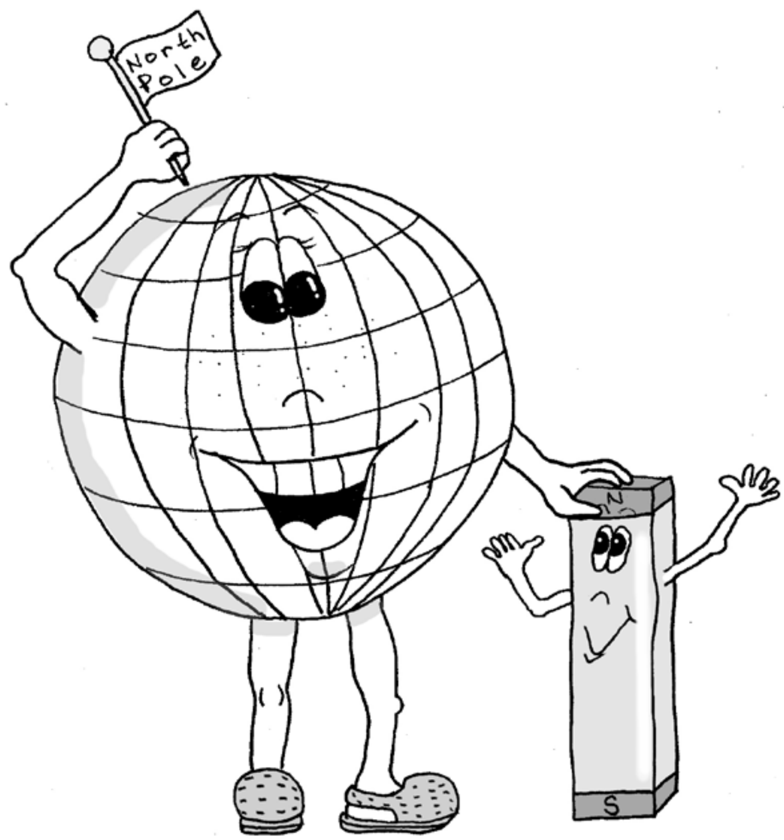

RSO Physics

(level one)

for grades 3-6

Written by Dahlia Schwartz BS, MA, JD

The publisher and author have made every attempt to state precautions and ensure that all activities and labs described in this book are safe when conducted as instructed, but we assume no responsibility for any damage to property or person caused or sustained while performing labs and activities in this or in any RSO course. Parents and teachers should supervise all lab activities and take all necessary precautions to keep themselves, their children, and their students safe.

Written by Dahlia Schwartz
Illustrated by Terri Williams

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WHAT'S INSIDE THIS BOOK?

*Denotes lab or activity

About the Author and Dedications

Dahlia Schwartz has been interested in physics since her family acquired a cheap telescope when she was a child. She graduated from Michigan State University with a Bachelor's Degree in Electrical Engineering and Computer Science and worked for the Space & Communications group at Hughes Aircraft Company for five years. A few degrees, decades, and careers later, Dahlia started homeschooling her two children. She now helps to run a homeschool co-op where she has had a wonderful time developing science classes that encourage kids to think outside the usual box, such as a world-building class in which students create their own planet, from the big bang to the development of language, culture, and technology, learning about subjects such as physics, chemistry, biology, linguistics, and anthropology. Dahlia lives in Michigan and enjoys teaching, reading, complex origami, playing guitar and, when the Michigan weather permits, taking out her newer, bigger telescope to marvel at the universe.

This book is dedicated to every child who has been curious about the world around us, and especially to my children, Aliana and Itamar, who taught me that even young children are capable of comprehending precise and complex scientific ideas. Thanks to them, I have discovered that true wonder and excitement about science spring from being exposed to the deep questions that science asks and to the ideas that are often, mistakenly I believe, reserved for advanced science classes. This book is also dedicated to my spouse, who patiently endured not only my many hours spent writing, but also lived with various science experiments inhabiting our shared office space during the last few years.
—Dahlia Schwartz, BS, MA, JD

Introduction to RSO Physics

Almost everyone who has ever spent any time with a baby has played “the gravity game.” The rules go something like this: The baby seems bored. You hand her an interesting object. She promptly drops it. So, you pick it up and hand it to her again. She promptly drops it. Repeat indefinitely. It seems babies could play this game for hours, certainly for longer than most adults continue to enjoy it.

We know that the baby is actually actively learning and studying—learning about cause and effect, studying how the people around her behave and internalizing some of the deepest concepts in physics without even being aware of it. Without language or math, we learn when we are quite young how the physical world behaves—that some force pulls things toward the ground, that balls arc when we throw them, that it is harder to push heavy objects than lighter objects, that, overall, objects behave in fairly predictable ways.

Yet, by the time we get to high school, only about 30% of us study physics—the very science that fascinates us as babies. Our lack of engagement with physics as we get older is not because most of us think it is just too easy, but rather, because for some reason we have been led to believe that it is really quite difficult, too difficult in fact. This is unfortunate because physics is not only incredibly fascinating, but an understanding of physics also allows us to look at everything in the world around us in new and deeper ways.

I have given a lot of thought to how and when and why to teach physics, and more generally science to elementary and middle-school-aged students. Many science programs I have seen and tried either turn the learning of science into something like learning a foreign language—memorize these words, these rules, these formulae—or focus on unconnected, flashy, and interesting experiments at the expense of depth, consistency, and true understanding. In both cases, children never gain the exposure they need and deserve from the essence of real science—wonder, exploration, problem-solving, understanding, and application to the world they live in.

It is this sense of wonder and exploration that I have striven to incorporate into every lesson of RSO physics. Students will not only learn Newton’s three laws of motion but they also will experiment with them and develop simple models of real-world applications such as automobile safety and rocket engines. In studying simple machines, the emphasis is placed on building each type of machine with common household objects, experimenting with how the machines make work easier for people, and discovering that, after careful observation and experimentation, it is possible to predict how these machines will behave in new situations.

Science is a precise academic discipline, but it is also a story—a story of discovery, of mistakes that seem ridiculous to us now but that halted scientific development for centuries, of great intuitive leaps that opened doors to entirely new realms inside the atom or out in the depths of space. Therefore, I have also striven to incorporate a sense of the history of physics into this course—through stories of scientists such as Archimedes, Aristotle, Newton, Goddard, and Einstein.

I have heard it said that one cannot really learn or appreciate physics without knowing calculus. It is true that some of the beauty of science lies in the amazing fact of being able to describe the physical world with formulas and numbers, and I hope that many of the students who take this course will someday go on to learn calculus and college physics and experience that beauty. But even young students with basic arithmetic skills can appreciate that with a simple formula such as “weight = mass x gravity,” they can figure out how much they, or their sister, or their family car, would weigh on any planet in the solar system. Therefore, formulas are introduced, but primarily as a way to show the power of describing physical laws through mathematics.

One of the most important ideas that young people should take away from studying science is that our understanding of the world and of the universe is still incomplete. How exactly are protons, which should repel each other, held together inside the nucleus of an atom? Can a magnet be made so small that it has only one pole? Can we reimagine some of the simple machines to invent new ways to generate energy or do work without polluting our planet? I hope, most of all, that studying physics inspires your students to think about the world around them in new ways and instills in them the belief that they can experiment, create, and improve the world.

A Note About Grade Level: The target grade level for this course is 4th (approximately 9- to 10-year-olds). However, with some minor adaptations, this course may be successfully utilized with children as young as 3rd grade, and as old as 6th grade. For younger children, you might need to eliminate some of the math (or do the calculations yourself). Don't worry about a few of the more abstract concepts like those found in the study of quantum physics. Focus on the main concepts, the "Big Ideas," with younger children.

Older students should grasp all the main concepts and details of each lesson, the "Big Idea" and "Small Stuff" list that starts on page 9. For older students, I also recommend requiring at least three formal lab reports while completing the course. There is a reproducible lab report form on page 485. Older students should also complete several of the "More Lab Fun" ideas found on the instructor pages. Many of these activities elicit higher-level thinking and delve deeper into science concepts. Finally, for older students, I suggest you assign research outside the course for at least one topic (or scientist) of the student's choosing, and require a written report.

THE UNIQUE PAGES IN THIS BOOK

For My Notebook Pages

1. All the student pages have a boxed outline around the material presented. That way it is easy to identify what is for the child and what is for the parent or teacher.
2. The For My Notebook (FMN) pages are the lesson pages that present the majority of new material to the student. They are intended to be read aloud. Some students, who are good readers, may want to read the FMN pages aloud themselves to the parent or class. However orchestrated, these pages are intended to be read aloud and not silently, to encourage discussion and questions.
3. New vocabulary words are underlined. You will notice that many of the vocabulary words are not presented with a classic dictionary definition. Instead, the explanation is given in context, so it is "felt" rather than memorized. Formal definitions for the vocabulary words are offered in the back of the book.
4. If you wish, FMN pages can be removed along the perforated binding, three-hole punched, and then placed in a three-ring binder along with completed Lab Sheets and Notebooking pages to create a Physics Notebook.

Lab Sheets

1. The lab sheets are those pages that the student writes on. They also have a boxed outline because they are intended for the student, not the parent/teacher, to complete.
2. The lab sheets not only reinforce the material presented in the FMN pages, but they are also the vehicle through which this course reinforces and formalizes scientific method. On the lab sheets, students will be making hypotheses based on questions formed during the lesson. Students record observations and lab results, and make conclusions based on those results. They will also practice sketching details of their lab experiences, an important process that reinforces observation skills.
3. If you are working with a student who isn't writing yet, have him dictate the information to be written on the lab sheets. If your student is unable to draw (meaning physically incapable; I'm not referring to artistic

abilities), then have him describe in detail his observations as you create them on the lab sheet.

4. If you wish, Lab Sheets can be removed along the perforated binding, three-hole punched, and then placed in a three-ring binder along with completed FMN pages and Notebooking Pages.

The Instructor Pages

1. The instructor pages contain the supply lists for the labs or activities and procedure instructions.
2. These pages are written for the parent/teacher, but the procedure is often written as if for the student. For example, "Complete the hypothesis portion of the lab sheet," is instruction for the student, not the parent.
3. Most instruction pages include a prompt to read aloud to students. A great deal of course instruction is found in these prompts. If you dislike prompts, then be sure to present the information in your own words.

Notebooking Pages and Creating a Physics Notebook

As an optional addition to the course, Notebooking Pages have been added. Notebooking is a method of organizing coursework (FMN pages and completed lab sheets) along with notes, drawings, photographs, questions, independent research, and projects on a particular subject, all in one binder. Notebooking tends to involve more creative and visual elements than traditional "taking notes" on a course, and a student's notebook on a subject can become a keepsake to revisit over the years. For a good introduction to notebooking, just look at the first results from an Internet search on that term.

Blackline masters of the Notebooking Pages are provided in the Appendix of this book. This means that you are free to make as many copies of these pages as you need for your child. These pages are essentially templates such as Venn Diagrams and Definition Pages, and suggestions are given in many of the units for using the templates or for open-ended notebooking assignments. When students build simple machines or perform other experiments, you might consider taking pictures of the work completed and pasting them on sheets of paper. You will also find a lab report form on page 485 for optional use with more advanced students.

When the course is complete, students can assemble the many pages they have completed in one large three-ring binder to create their own Physics Notebook. There is a cover sheet on page 475 that may be cut out, colored, glued to a sheet of construction paper, and then used as the front cover for a Physics Notebook. Encourage students to share their Notebook with family and friends. Showing others their work and teaching others are excellent ways for students to review the material and further reinforce the science concepts studied. Many families choose to have the pages bound into a book at a copy shop.

What's The Big Idea?

Whenever you study a subject, there are main ideas and details to learn. It's true, that in science, there is a lot of new material to discover. If you are using a classical education approach to teaching, you will cover every subject three times throughout your child's education. Because of this, don't sweat the small stuff. This outline gives you the big ideas that your child should get from each unit, and the small stuff is an added bonus. If you and your child are timid scientists, just have fun as you try to learn the big ideas. If you and your child have a strong science background, work on learning the small stuff as well as the big ideas. There are many challenging words in this course that are used because they are the right words, and after hearing them over and over, they will "sink in." They are not here for your child to memorize the first time around. Use difficult words and science concepts gently, not with force, and your child will enjoy his science experience.

BI = BIG IDEA **SS = SMALL STUFF**

UNIT 1: WHAT IS PHYSICS?

<u>PHYSICISTS USE SCIENTIFIC METHOD</u>

BI = Everything around us is made of matter.

Physicists are scientists who study how matter behaves using the scientific method.

The scientific method is a cycle—observe, record, analyze, hypothesize, experiment, and start over again.

SS = Matter has characteristics that help us to describe it.

<u>PHYSICISTS, IT TAKES ALL SORTS</u>

BI = There are many types of physicists.

A thought experiment is one in which you imagine what would happen if you did an experiment.

SS = Experimental physicists tend to spend their time performing experiments.

Theoretical physicists tend to spend their time coming up with ideas.

Albert Einstein is famous for his thought experiments about the nature of time and space.

UNIT 2: WHAT MATTERS

<u>MASS: IT REALLY MATTERS</u>

BI = Mass is a measure of how much matter is in an object.

Weight is a measure of the strength of gravity pulling on an object.

SS = The mass of an object is the same everywhere—Earth, the moon, Jupiter.

The mass of an object will change only if you add something to or take something away from an object.

Weight = gravity x mass

<u>WHAT FLOATS YOUR PLANET?</u>

BI = One characteristic of matter involves whether it floats in water or not.

Sometimes, larger, heavier objects float while smaller, lighter objects sink.

Density is one of the most important characteristics in determining whether an object will float.

Density is a description of how much matter is packed into the space, or volume, that the object takes up.

SS = Saturn would float in water, but Earth would not.

The characteristics of matter that determine whether it will float include: volume, density, and volume of water displaced.

Density = Mass ÷ Volume

An object will float if the volume of water it displaces weighs more than the object weighs.

UNIT 3: NEWTON'S LAWS

A FORCEFUL INTRODUCTION

BI = A force is any push or pull on an object.

Gravity is a force that pulls all objects toward the center of the earth.

When an object isn't moving, it is at rest. For an object to be at rest, all the forces acting on it must be in equilibrium.

SS = A contact force is any force that requires touching an object.

An action-at-a-distance force is a force that pushes or pulls without touching an object, such as gravity or magnetism.

MOVING WITH NEWTON

BI = Isaac Newton was a mathematician and scientist who lived in the 1600s in England.

Newton figured out that the gravity that caused objects to fall to the ground is the same force that causes the moon to orbit Earth.

A scientific law describes what always happens given certain conditions.

SS = Newton invented a form of mathematics called calculus that he used to describe the effects of gravity on an object both on Earth and in space.

Newton used math to develop his laws of motion: these laws predict how matter behaves when at rest and in motion.

Newton's laws do not work under all conditions. They fail to predict what will happen at speeds close to the speed of light and at sizes smaller than an atom.

NEWTON'S LAWS: THE FIRST LAW OF MOTION—INERTIA

BI = The first law of motion has two parts:

An object at rest tends to remain at rest unless an extra force is applied to it.

An object in motion tends to remain in motion unless an extra force is applied to it.

An object's mass determines how much force is needed to change whether it is at rest or in motion.

SS = This law was hard to figure out because on Earth there are many extra forces that we don't see, such as gravity and friction.

The tendency of an object to stay at rest or in motion is called inertia, which even affects how your body behaves.

NEWTON'S SECOND LAW—FROM ARISTOTLE TO NEWTON

BI = Velocity is the scientific term for the speed of an object in a particular direction.

Newton's second law describes how forces change the speed or direction of an object.

Aristotle incorrectly believed that for an object to keep moving at a constant velocity, one had to apply a constant force to the object.

SS = Acceleration is the scientific term for a change in velocity.

NEWTON'S SECOND LAW: MOMENTOUS MOMENTUM

BI = There are three parts to Newton's second law:

1) An object will move in the direction it is pushed.

2) The harder you push an object, the faster it will go.

3) The more mass an object has, the harder it is to push.

We say that a moving object has a lot of momentum if it is hard to change its speed or direction.

Momentum depends on an object's mass and speed and can be transferred from one object to another.

SS = Momentum is the tendency of an object to keep moving in the same direction.

Momentum even affects objects in zero-gravity environments.

NEWTON'S THIRD LAW: LIFT-OFF!

BI = Newton's third law states: every action has an opposite, but equal, reaction.

Rocket ships work because of Newton's third law.

SS = When you stand on the earth, the action is your shoe pushing down on the earth from the force of gravity. The reaction is the force of the earth pushing back.

Vectors are arrows that physicists use to illustrate forces. Vectors have both quantities (size) and direction to show how much force is being applied and in what direction.

UNIT 4: FRICTION

FRICTION—IT CAN RUB YOU THE WRONG WAY

BI = Friction is caused when irregularities in two surfaces rub against each other.

Friction is a contact force that resists motion and always involves two pieces of matter rubbing against each other.

Without friction, it would be impossible to walk or to get cars to move.

SS = It is almost impossible on Earth to make a perfectly smooth surface.

Friction can be caused by liquids, gases, or solids. For example, air molecules cause friction when objects move through the air.

A tribologist is a scientist who studies friction.

The coefficient of friction is a number representing how much friction exists between two particular surfaces.

FRICTION IN REAL LIFE: AUTO SAFETY

BI = The science of physics goes into the design of the treads on car tires in order to maximize friction in slippery conditions.

Friction generates heat.

SS = Tire treads are designed to help prevent hydroplaning, which can occur if a thin layer of water forms between a wheel and a road.

Motor oil helps prevent too much friction in automobile engines.

UNIT 5: WORK: PLANE AND SIMPLE MACHINES

WORKING HARD AND HARDLY WORKING

BI = Work is done when an object is moved by a force from one place to another.

Energy is the capacity to do work.

Kinetic energy is the energy of a moving object.

Potential energy is the energy stored up by an object when you move it against a force like gravity.

SS = Work is accomplished even when a force-at-a-distance such as gravity moves an object.

SIMPLE MACHINES: PLANES & WEDGES

BI = Simple machines are devices used to make work "easier," either because a machine changes the direction of force needed or because it changes the amount of force needed.

In physics, there is always a trade-off. If less force is needed, that force probably needs to be applied over a longer distance.

One group of simple machines is made of planes—or flat surfaces. These include: ramps (inclined planes), wedges, and screws.

SS = Archimedes described how simple machines work mathematically and helped people to understand and use simple machines.

Great things can be accomplished with simple machines. The pyramids and the Parthenon were constructed using primarily simple machines.

A ramp or inclined plane is a plane that is at an angle. A wedge is a ramp that moves.

WHAT DO STAIRS AND SCREWS HAVE IN COMMON?

BI = Stairs are a sort of ramp. They make work easier than lifting ourselves straight up, but we have to travel farther.

A screw is like an inclined plane, or staircase, wrapped around a cylinder.

SS = Threads are the grooves on a screw. More threads mean less force is needed, but the screw needs to be turned more times.

LEVERS: HOW TO MOVE THE PLANET WITH A REALLY LONG STICK

BI = Levers make it easier to lift objects. A lever is a stick or board placed on a fulcrum.

The fulcrum is the rock or object it rests on.

The load is what you are trying to move.

The effort is the amount of force you push with to move the object.

SI = Archimedes claimed that he could move the planet with a large enough lever.

LUGGING LOADS WITH LOTS OF LEVERS

BI = The fulcrum's location relative to the load and effort determines whether a lever is a first-, second-, or third-class lever.

The load arm is the length from the load to the fulcrum.

The effort arm is the length from the effort to the fulcrum.

SS = In a first-class lever the fulcrum is between the load and the effort, such as in a teeter-totter.

In a second-class lever the load is between the fulcrum and the effort, such as in a wheelbarrow

In a third-class lever, the effort is between the fulcrum and the load, such as in a broom.

LAWFUL LEVERS

BI = Archimedes described a mathematical formula that predicts how levers behave.

The formula tells us that: for all classes of levers, if you increase the load on the lever, you will have to either increase the distance you move the lever or the amount of force you apply to move that load.

SS = Archimedes's formula is called "The Law of the Lever." The formula is: (size of effort arm) x (amount of force applied at effort) = (size of load arm) x (weight of load).

DIZZY LEVERS: WHEELS & AXLES

BI = An axle is a stick to which a wheel has been attached such that when the wheel turns, the stick turns, and vice-versa.

Axles make work easier either by decreasing the amount of force needed (e.g., a truck winch) or increasing the distance moved (e.g., automobile wheels).

SS = A wheel and axle is actually a type of a lever.

PULLEYS

BI = A pulley is a wheel with a groove in it for a rope or chain.

Fixed pulleys do not move and help do work by changing the direction of force.

Moveable pulleys help do work by changing the amount of force.

SS = A block and tackle or compound pulley system is a group of pulleys working together. These machines can multiply the advantages and disadvantages of using a single pulley.

UNIT 6: AERODYNAMICS

AN INTRODUCTION TO THE INVISIBLE

BI = Air is a gas made up of molecules which are constantly in motion.

Like any gas, air is made of matter, and therefore it has mass and takes up space.

SS = Two objects cannot occupy the same space at the same time. This means, for example, that to get water into a cup, the air has to be pushed out of the way.

IF HOT AIR WERE A SUPERHERO

BI = Heat is a form of energy which causes molecules in a gas like air to move more quickly.

Hot air rises because it has less mass than cool air.

SS = Hot air has less mass than cool air because its molecules are moving more quickly, leaving fewer molecules in any given space.

The interaction of air with different temperatures is one of the main causes of weather.

STANDING UP UNDER PRESSURE

BI = The atmosphere is the air surrounding a planet.

The atmosphere is made of matter and therefore presses down on us with a lot of pressure.

SS = Heat and cold increase and decrease air pressure in a closed space.

Differences in air pressure can create dramatic results, such as crushing a plastic bottle or creating a water fountain.

AIR FORCES WITHOUT UNIFORMS

BI = Aerodynamics is the study of what happens when objects move through air.

The four basic forces that push or pull on objects in the air are: weight, drag, thrust, and lift.

SS = Drag resists movement through air and is largely dependent on the shape of an object.

Bernoulli's principle is a partial description of how an airplane's wing shape, thrust, and lift interact to create a difference in air pressure and get planes off the ground.

UNIT 7: ENERGY AND WAVES

LET'S CATCH A WAVE, DUDE

BI = A wave is energy carried from one location to another in the form of a distortion through a medium, such as the energy carried in a wave in the ocean.

SS = The parts of a wave are the crest and the trough.

IT'S SOUND. IT'S A WAVE. IT'S A SOUND WAVE!

BI = Sound waves consist of energy traveling through the medium of air molecules.

The amplitude, or height, of a sound wave determines how loud it is.

SS = When sound travels through the air, it is energy that goes from one place to another, not air molecules.

THE SPEEDS OF SOUND

BI = The distance between one wave and the next wave is called the wave's "wavelength."

When waves seem close together, we say that they have a higher frequency than waves that are farther apart.

SS = Sound travels through different mediums at different speeds.

The speed with which a wave travels through a medium is different than the wave's frequency.

Higher-pitched sounds are created from waves with a higher frequency.

AMPLIFICATION: CAN YOU HEAR ME NOW?

BI = Amplification means increasing the amplitude, or loudness, of a sound wave.

To increase amplification, one must increase the amount of energy in a wave.

Amplifiers such as stethoscopes or megaphones increase amplitude by focusing a lot of energy into a small space.

SS = René Laennec invented the stethoscope when he realized that listening to a patient's heartbeat through a rolled-up piece of paper amplified the heartbeat's sounds.

UNIT 8: MAGNETISM

INTRODUCING MAGNETISM

BI = In physics, a “field” is an area in which a force exists.

A magnet is a substance that produces a magnetic field. An object is magnetic if it can be attracted by a magnet.

Some magnets are stronger than others.

SS = All magnetic objects have metal in them, but not all metals are magnetic.

Magnetism is an action-at-a-distance force.

Quantitative observations are those that involve measuring with numbers—such as temperature or distance. Qualitative observations involve describing something’s qualities—such as whether or not it is magnetic.

MAGNETS AND POLES

BI = All magnets have two “poles”—north and south. Like poles always repel one another, and unlike poles always attract one another.

SS = Physicists believe that magnetism is ultimately caused by how electrons in different substances behave.

MAGNETS: SMALL, SMALLER, AND SMALLEST

BI = When a magnet is cut in half, it creates two magnets, each with two poles.

Ferromagnetic materials are attracted by magnets and can be magnetized temporarily.

SS = Magnetic domains are regions in a material in which the magnetic fields of the atoms making up the substance are aligned in one direction.

OH NO! I THOUGHT THIS WAS THE NORTH POLE!

BI = The planet Earth behaves like there is a giant magnet running through the center of the planet.

Scientists believe the magnetic field around the earth is caused by molten iron spinning within the earth’s outer core.

SS = In reality, the magnetic poles of the earth move around quite a bit—on the order of hundreds of miles per century.

The North Pole is actually the south pole of the earth’s magnetic field. We call it the North Pole because the north poles of our magnets point to it.

UNIT 9: ELECTRICITY

LET’S START INSIDE THE ATOM

BI = Atoms are composed of protons, neutrons, and electrons. Protons have an electrical charge of +1, electrons have an electrical charge of -1, and neutrons have no electrical charge.

Electrons exist in an orbit around the nucleus of the atom, which contains the protons and neutrons.

SS = Normally positive charges repel each other. It is the strong nuclear force which holds the protons together in the nucleus of the atom and is immensely stronger than the force of gravity.

Scientists sometimes use models when they can’t study something directly.

STATIC: IT'S ELECTRIFYING

BI = A static electrical charge is created by a "pool" of electrons—a bunch of electrons that are not flowing through a substance.

An electrical current is created by flowing electrons.

SS = Sometimes, electrons are transferred between atoms and molecules. For example, when you rub a balloon on a wool sweater, electrons are transferred from the wool and "pool" on the balloon.

An electroscope is a device used to detect static electricity.

ELECTRICITY RULES: PLAYING IT SAFE

BI = Always follow the safety rules when experimenting with electricity.

ELECTRICAL CURRENT: GOING WITH THE FLOW

BI = Electrical current is caused by electrons flowing through empty spaces in atoms' electron shells.

Conductors are materials that allow electrons to flow freely. Insulators are materials in which electrons have a very hard time flowing.

An electrical circuit is a loop through which electricity flows.

SI = Batteries get current flowing through wires by creating a difference in a type of potential energy—electrical potential—between one end of the battery and the other.

There are many types of electrical components—such as wires, batteries, switches, and light bulbs.

POWERING UP!

BI = When electrical components are connected in series, they are connected one after the other.

When electrical components are connected in parallel, there are two or more components connected to the same component.

SI = Electricity is measured in power (wattage), amount of electrical charge (amperes), and electrical potential (voltage).

ELECTROMAGNETISM

BI = Both electricity and magnetism are created by the motion of electrons and create fields of force around this motion. Because of this, electrical fields affect magnetism and magnetic fields affect electric current.

SS = Electric motors transform electrical energy into motion. Magnets can be used in electrical generators to transform the motion of the magnet into electric current.

Ferromagnetic materials can be made into magnets by running an electrical current around them.

UNIT 10: NEW WORLDS TO EXPLORE

EVERYTHING IS RELATIVE

BI = Motion is relative. If you are in a car moving at 10 miles per hour and there is another car traveling next to you at the same speed and in the same direction, it will appear as if the other car is not moving relative to your car. The observation of speed and direction of an object will depend on—be relative to—the speed and the direction of the observer.

Einstein imagined traveling with a beam of light and realized that the speed of light is not relative. It is constant regardless of whether an observer is moving. This realization led to Einstein's theory of special relativity.

Einstein also imagined various thought experiments involving acceleration and gravity. He realized that an observer experiences both acceleration and gravity the same way. This realization led to Einstein's theory of general relativity.

SS = Objects (and people) traveling close to the speed of light experience time more slowly than observers not traveling close to the speed of light.

Objects traveling close to the speed of light contract, or get smaller, in the direction in which they are traveling.

These two effects are necessary for the speed of light to remain constant to all observers.

LIGHT: WHEN DOING THE WAVE JUST WON'T WORK

BI = Isaac Newton theorized that light was composed of particles. Thomas Young theorized that light was composed of waves of energy. Both theories were supported by experimental evidence and everyday observations.

Albert Einstein wrote a paper about the photoelectric effect demonstrating that light behaves more like particles. This was an important step toward understanding that light exhibits both wave- and particle-like behavior.

SS = Quantum physics is the study of the behavior of matter on the extremely small scale of subatomic particles.

Thomas Young demonstrated the wave nature of light by shining a focused light through small slits to create a wave-like pattern on the wall.

The photoelectric effect occurs when certain metals eject electrons from their surface when exposed to light of different wavelengths.

QUANTUM WEIRDNESS

BI = Thomas Young used a light beam in his double-slit experiment. When scientists tried the experiment with electrons, rather than light, the results were startling. These experiments suggested that electrons, which are made of matter, behave like waves under certain circumstances, and like particles under other circumstances.

Ultimately, scientists concluded that light and electrons have a dual nature—they exhibit both wave- and particle-like behavior.

Scientists were amazed to discover that the act of measuring and detecting the results of their experiments changed the results of those experiments—forcing the electrons to behave like particles.

SS = Physicists hypothesize that when an electron is fired toward double slits, the electron exists in a state of superposition: It exists as a set of possible outcomes such as going through the left slit, going through the right slit, or going through neither slit.

Schrodinger devised his famous cat experiment to demonstrate how absurd these quantum effects would seem if they occurred in the everyday world that we perceive. Rather than disproving quantum weirdness, Schrodinger's thought experiment became the basis for different interpretations of how measuring quantum behavior affects the outcome of experiments.

Lab Supply List (see page 2 regarding RSO supply kits from Home Science Tools)

Items are listed by unit in the order in which they are first needed. + means an item will be needed for later labs also. The amounts listed are totals for the entire course. Most items are common household items.
* means the item requires some explanation. Ordering hints and explanations are given on page 21.

UNIT	EQUIPMENT / MATERIAL	AMOUNT
1	Similar, not identical, toys	2
1+	Colored pencils	pack
2+	Calculator	1
2	Bathroom scale	1
2+	Kitchen scale	1
2	Low- and high-density objects	6 each
2+	Wide, short, clear glass	1
2	Dry-erase marker	1
2+	Polymer Clay	1 pack
2+	Glass of water	1
2+	Teaspoon and tablespoon	1
3+	Drawing materials (e.g. markers)	pack
3+	Toy with wheels (small, flat top)	1
3	Toy figure (small)	1
3	Cardboard (small, rectangular)	1
3+	Masking tape	1 roll
3+	Flat, smooth surface	
3+	Paper cup	2
3+	Permanent marker	1
3	Toy with wheels (medium-size)	1
3+	String	2 rolls
3+	Marbles (2 sizes)	at least 5
3	Cardboard from paper towel roll	1
3	Basketball	1
3	Tennis ball	1
3	Outdoor paved space	
3	Straws	3
3+	Balloons (round and long ones)	16+

UNIT	EQUIPMENT / MATERIAL	AMOUNT
3+	Ruler/tape measure	1
3	Clothespin (optional)	1
4	Book with dust jacket	1
4	Heavy book	1
4+	Stiff foam board	1 @ 4′ x 2′
4+	Meter stick	1
4	Aluminum foil	1 roll
4+	Magnifying lens	1
5+	Rubber bands	5
5	Flour	1 cup
5+	Spoon	1
5	Paper plate	1
5	Box of tissues	1
5+	Spring scale*	1
5	Door wedge	1
5	Large building blocks	2
5+	Large sheet of paper	3
5+	Corrugated cardboard, 12″ square	3 sheets
5	Sharpened pencil with eraser	1
5+	Scissors	1
5	Variety of screws	few
5	Bolts w/ different threading	2+
5	Stiff ruler	1
5	Pennies	50
5	Internet access (optional)	
5	Car owner's manual (optional)	1
5	Hole puncher	1
5	Shoebox	1

UNIT	EQUIPMENT / MATERIAL	AMOUNT
5	Whisk broom	1
5	Heavy object (e.g. jug of water)	1
5	Lighter object (e.g. empty jug)	1
5	Household objects that are levers (e.g. tweezers, pliers, rake)	10+
5	Stiff foam board or cardboard	1 @ 30″ x 10″
5	Duct tape	1 roll
5	Drawing compass	1
5	Thin wooden dowels	4 @ 12-18″ 2+ @ 3-4″
5	Straw that will fit over dowel	1
5	Household objects that are wheel & axle simple machines (e.g. screwdriver, doorknob, pencil sharpener, fan, etc.)	5
5	Wooden clothes hanger and place to hang it	1
5	Bendable metal wire	12″
5	Wire cutter	1
5+	Glue	1 bottle
5	1-liter bottle of soda or water	1
6+	Paper towels	1 roll
6+	Sink or plastic tub	1
6	Empty plastic 2-liter bottle	1
6	Heat source (e.g. light bulb or burner)	1
6	Sheet of newspaper	1
6+	Table surface	1
6	Empty plastic water bottle with cap	2
6	Freezer access	
6+	Large index card	2
6+	Sheets of copy paper	15+
6	High place from where to drop things (e.g. staircase, ladder, chair)	
6	Empty soda cans	2
6+	Paper clips (optional)	few

UNIT	EQUIPMENT / MATERIAL	AMOUNT
6	Stopwatch (or watch w/ second hand)	1
6	Wide-open space to fly paper airplanes	
7	Metal Slinky (or Mardi Gras beads)	1
7	Plastic, round food container	1
7	Rubber band that will fit over plastic, round food container	1
7	Plastic wrap	1 roll
7	Fine sugar or salt	pinch
7	Construction paper	8 sheets
8	Magnets (at least 2 bar-type, 1 disk-shaped, and 1 horseshoe-shaped)	5+
8	Household objects- magnetic and nonmagnetic	10-15
8+	Metal paper clips (that are magnetic)	5+
8	Colored tape	2 colors
8	Iron fillings*	
8	Iron or steel nail	1
8	Cork (e.g. wine bottle cork)	1
8	Needle (that is magnetic)	1
9	Self-hardening or polymer clay	2 colors, small packs
9	Glass jar	1
9	Piece of wool (or wool clothing)	1
9	Insulated wire	5-6 feet
9	Wire cutters	1
9	D-cell battery	2
9	D-cell battery holder*	2
9	Miniature light bulb*	1
9	Miniature light bulb receptacle or socket*	1
9	Card stock	5″ x 1″
9	3″ to 4″ nail or screw that is attracted by a magnet	1
9	Needle-nosed pliers	1

UNIT	EQUIPMENT / MATERIAL	AMOUNT
10	Pencil lead for mechanical pencil	3 sticks
10	Laser light	1
10	Dark room with clear wall space	

***Ordering Hints and Explanations:**

Spring Scale: You don't need to spend a lot of money on a spring scale (a $4-$10 one is all you need). These are readily available online at Amazon and from science supply companies. Look for one that has a 5-10 lb (about 2 kg-5 kg) capacity.

Iron Fillings: readily found in education supply stores, and even some toy stores in the "science" section. These can also be ordered online from many companies, including Amazon. Enter "iron fillings" in your search engine and you will find iron filings for sale in little shaker bottles like the type spices come in.

Electricity Supplies: D-cell battery holder, miniature light bulb**, and miniature light bulb receptacle: These items can be found at your local home improvement store or electronics store, such as Radio Shack. They are also readily available from online companies like Amazon. In lieu of purchasing all these items individually, you could purchase one or two basic electricity kits, such as those found in toy stores. Make sure you have at least 2 battery holders, a light bulb, and a bulb holder. These kits generally use AA batteries instead of D-cell, and they are more flimsy than one you could put together yourself, but they are still a possible alternative.

**Which miniature bulb should I buy? Students are going to be making circuits to illuminate a flashlight bulb. A decade ago, this was a simple proposition, as there was really only one type of flashlight bulb available, an incandescent bulb. Now, because of environmental concerns, incandescent bulbs are no longer being produced, and LED and other bulbs such as halogen, xenon, and krypton bulbs are replacing them. Halogen, xenon, and krypton bulbs look and function similarly to the old incandescent bulbs. The best bulb to use for this experiment is the bulb out of an old flashlight. The only bulb that absolutely won't work well is an LED bulb because the voltage requirements for LED bulbs are so low that one needs to use an extra component, a resistor, with regular batteries. You may have to experiment with one or two bulbs, but the worst that will happen is that you will burn out a flashlight bulb, or the exposed ends of the wires might become hot.

Suggested Weekly Schedule

The following schedule is suggested for those wishing to complete this course in a 36-week school year, teaching science twice a week. General supplies needed for each week are listed. Refer to the lesson or supply list for specifics on supplies including quantities. * **indicates a lab or activity**

Week	Day	Lesson / Lab	Supplies Needed for the Week	Dates / Notes
1	Day 1	Physicists Use Scientific Method *Acting Like a Physicist	Similar toys (2), Colored pencils	Unit 1
	Day 2	Physicists, It Takes All Sorts *Thinking about Drinking Water		
2	Day 1	Mass: It Really Matters *Weighing in Around the Solar System	Calculator, Bathroom scale, Kitchen scale, Low- and high-density objects (6 each)	Unit 2
	Day 2	What Floats Your Planet? *Density: All Objects, Large and Small		
3	Day 1	*Water Displacement: It'll Float Your Boat!	Wide, short, clear glass; Dry erase marker; Polymer Clay; Glass of water; Teaspoon or tablespoon	Unit 2
	Day 2	A Story about Density: Archimedes and the Crown		
4	Day 1	A Forceful Introduction *An Object in Equilibrium	Glass of water, Drawing materials	Unit 3
	Day 2	Moving with Newton		
5	Day 1	Newton's Laws: The First Law of Motion—Inertia	Drawing materials, Toy with wheels, Small toy figure, Cardboard, Tape, Flat surface	Unit 3
	Day 2	*Inertia and You!		
6	Day 1	Physics in Action: Preventing Injuries in Car Accidents *Inertia Can Be Dizzying!	Paper cup, Permanent marker, Toy with wheels, String, Flat area	Unit 3
	Day 2	Newton's Second Law—From Aristotle to Newton *You've Got to Keep It Moving		
7	Day 1	Newton's Second Law: Momentous Momentum	Marbles, Cardboard from paper towel roll, Magic marker, Basketball, Tennis ball, Flat surface, Tape, Outdoor paved space	Unit 3
	Day 2	*Giving the Gift of Momentum		
8	Day 1	Newton's Third Law: Lift-Off! *Rocket Science Newton's Brain Teasers	String, Straws, Balloons, Ruler or tape measurer, Strong tape, Marker, Clothespin (optional)	Unit 3
	Day 2	Newton's Laws of Motion: A Summary		
9	Day 1	Friction - It Can Rub You the Wrong Way	Drawing materials	Unit 4
	Day 2	*Activity: Slip Sliding Away		
10	Day 1	*How Much Is Enough?	Book with dust jacket, Heavy book, Stiff foam board, Toy vehicle, Meterstick or yardstick, Aluminum foil, Magnifying lens, Tape, Calculator	Unit 4
	Day 2	Friction in Real Life: Auto Safety Friction: A Summary		
11	Day 1	Working Hard or Hardly Working? *Working It Out	Rubber bands, Marbles, Paper plate, Flour, Spoon, Ruler	Unit 5
	Day 2	*You've Got a Lot of Potential!		

Week	Day	Lesson / Lab	Supplies Needed for the Week	Dates / Notes
12	Day 1	Simple Machines: Planes & Wedges *It's Plainly a Plane!	Box of tissues, Spring scale, Ruler, Foam board, Colored pencils, Door wedge, Large building blocks, Sheet of paper, Corrugated cardboard, Pencil w/ eraser, Magnifying lens (optional)	Unit 5 See p. 21 re. spring scale
	Day 2	*All Wedged In *More Wedges		
13	Day 1	*Those Screwy Planes	Sharpened pencil, Sheets of paper, Scissors, Inches ruler, Screw(s), Bolts and fitting nuts, Permanent marker, String	Unit 5
	Day 2	What Do Stairs & Screws Have in Common? *The Nuts & Bolts of Screws		
14	Day 1	Levers: How to Move the Planet . . . *Large, Little, and Long Levers	Stiff 12" ruler, Pencil, Pennies, Tape, Internet or car owner's manual (optional), Calculator	Unit 5
	Day 2	Lugging Loads with Lots of Levers *First-Class Levers—Large, Larger & Largest		
15	Day 1	*Second-Class Levers: Wheeling It In	Stiff 12" ruler, Paper cup, Hole puncher, String, Pennies, Shoebox, Whisk broom, Heavy object (e.g. jug of water), Lighter object (e.g. empty jug), Masking tape, Tape measurer	Unit 5
	Day 2	*Third-Class Levers: It's a Clean Sweep!		
16	Day 1	Lawful Levers *Lever Detector	Household objects that are levers (e.g. tweezers, pliers, rake), Foam board, Scissors, Wooden dowels, Duct tape, Drawing compass, Magic marker, Ruler	Unit 5
	Day 2	Dizzy Levers: Wheels & Axles *Going in Circles		
17	Day 1	*A Dizzy First-Class Lever	String, Roll of packing or duct tape, Straw, Scissors, Helper, Tape, Ruler, Household objects that are wheel & axle simple machines (e.g. screwdriver, doorknob, pencil sharpener, fan, etc.)	Unit 5
	Day 2	*Going in Circles in the Real World *Wheel & Axle Wrap-up		
18	Day 1	Pulleys *Fixed Pulleys- Which Way Did It Go? (begin)	Wooden clothes hanger and place to hang it, Bendable metal wire, Wire cutter, Corrugated cardboard, Drawing compass, Scissors, Wooden dowels, String, Glue, Pencil, 1-liter bottle of soda or water, Spring scale, Ruler	Unit 5
	Day 2	*Fixed Pulleys- Which Way Did It Go? (complete)		
19	Day 1	*Moveable Pulley- How Does It Do That?	Spring scale, Ruler	Unit 5
	Day 2	*It's a Block! It's a Tackle! It's a Block & Tackle! Simple Machines: They're Simply Fantastic!		
20	Day 1	An Introduction to the Invisible *It Can't Be Nothing if It Weighs Something	Balloons, String, Rubber bands, Meterstick or yardstick, Glass cup, Sink or plastic tub, Paper towels	Unit 6
	Day 2	*Is the Glass Half Empty or Half Full?		
21	Day 1	If Hot Air Was a Superhero *Hot Air Is Cool!	Empty plastic 2-liter bottle, balloons, Access to hot and cold water, Tape, Colored pencils, String, Scissors, Heat source (e.g. light bulb or burner)	Unit 6
	Day 2	*Taking Hot Air for a Spin		
22	Day 1	*Are You Stronger than a Piece of Paper? *Differences Matter *The Magic of Pressure *A Water Fountain That Defies Gravity!	Newspaper, Stiff ruler, Table surface, Empty plastic water bottle with cap, Access to a freezer, Glass of water, Large index card, Sink or basin, Straw, Water, Clay	Unit 6
	Day 2	(Complete anything unfinished from the Quartet of Quick Experiments on Day 1)		
23	Day 1	Air Forces without Uniforms *Dropping Stuff Is a Drag	Sheets of copy paper, High place from where to drop things (e.g. staircase, ladder, chair), Scissors, Empty soda cans, Tape measure, Paper clips (optional), Stopwatch or watch w/ second hand, Wide open space	Unit 6
	Day 2	How Do Planes Fly? *Hey, Bernoulli, Can You Give Me a Lift? *Take Off!		

Week	Day	Lesson / Lab	Supplies Needed for the Week	Dates / Notes
24	Day 1	Let's Catch a Wave, Dude! *Doing the Wave	Metal Slinky (or Mardi Gras beads); Large hard surface; Plastic, round food container; Plastic wrap: Large rubber band; Fine sugar or salt	Unit 7
	Day 2	It's Sound. It's a Wave. It's a Sound Wave! *Making Big Waves		
25	Day 1	The Speeds of Sound *Hitting the High Notes	Construction paper, Tape, Scissors, Crayons or markers (optional)	Unit 7
	Day 2	Amplification: Can You Hear Me Now? *Can You Hear Me Now?		
26	Day 1	Introducing Magnetism *Tracking Attraction	Magnets, Household objects- magnetic and nonmagnetic, Metal paper clips, Ruler, Flat surface, Tape	Unit 8
	Day 2	*The Measure of a Magnet		
27	Day 1	Magnets and Poles	Magnets, Colored tape (2), Iron Fillings, String	Unit 8 See p. 21 re. iron fillings
	Day 2	*Searching for Poles		
28	Day 1	Magnets: Small, Smaller, and Smallest *Is It a Magnet or Isn't It?	Magnets, Metal paper clips, Iron or steel nail, Cork, Bowl of water, Metal needle	Unit 8
	Day 2	Finding the North Pole *Oh No! I Thought This Was the North Pole!		
29	Day 1	Let's Start inside the Atom *Atomic Super Models (begin)	Self-hardening or polymer clay (2 colors), Colored pencils	Unit 9
	Day 2	*Atomic Super Models (complete)		
30	Day 1	Static: It's Electrifying	Aluminum foil, Scissors, Glass jar, Large Index card, Tape, Balloon, Piece of wool (or wool clothing), Hole puncher (optional)	Unit 9
	Day 2	*Static Detector		
31	Day 1	Electricity Rules: Playing It Safe Electrical Current: Going with the Flow	Insulated wire, Wire cutters, D-cell battery, D-cell battery holder, Miniature light bulb, Miniature light bulb receptacle or socket	Unit 9 See p. 21 re. electrical supplies
	Day 2	*Going with the Flow		
32	Day 1	*Switch It On	Insulated wire, Wire cutters, Metal paper clips, Tape, Card stock, D-cell batteries, D-cell battery holders, Miniature light bulb, Miniature light bulb receptacle or socket	Unit 9
	Day 2	Powering Up! *Power Up!		
33	Day 1	Electromagnetism *Creating a Force Field	Nail or screw that is attracted by a magnet, Insulated wire, Wire cutters, D-cell batteries, D-cell battery holders, Paper clips, Magnet, Tape, Needle-nosed pliers, Cardboard	Unit 9
	Day 2	*That's Right, I Made an Electric Motor! (begin)		
34	Day 1	*That's Right, I Made an Electric Motor! (complete)	Insulated wire, Wire cutters, D-cell batteries, D-cell battery holders, Paper clips, Magnet, Tape, Needle-nosed pliers, Cardboard	Units 9 and 10
	Day 2	Everything Is Relative *Dropping Rocks Around the Universe		
35	Day 1	Light: When Doing the Wave Just Won't Work * Quantum Experiments	Pencil lead for mechanical pencil, Laser light, Dark room with clear wall space	Unit 10
	Day 2	Quantum Weirdness * Schrodinger's Cat		
36	Day 1	Final Thoughts Begin Assembly of Your Physics Notebook	Completed Lab sheets, FMN pages, Photos from class, 3-hole punch, 3-ring notebook, Craft supplies: colored pencils, glue, scissors, etc.	See Introduction for info on creating a Physics Notebook
	Day 2	Complete Assembly of Your Physics Notebook and Show It off!		

Further Reading and Exploring

The following are suggestions for those who want to explore further. Most public libraries will have a children's section about physics which includes picture books about particular subjects, such as "gravity" or "pulleys." Almost all of these are good, solid books. The resources listed below are those that are exceptional or stand out in some way for each of the subjects covered. I have also included a few books for adults who would like an overview of physics.

Unit 1 - WHAT IS PHYSICS? (AND GENERAL PHYSICS)

What's Physics All About, by Kate Davies

Junk Drawer Physics: 50 Awesome Experiments That Don't Cost a Thing, by Bobby Mercer

A Brief History of Time, by Stephen Hawkings (for adults)

Mr Tomkins in Paperback, by George Gamow (for adults--an older, classic book explaining post-Einstein physics to lay people)

Unit 2 - WHAT MATTERS

Audio recording: *Jim Weiss: Galileo and the Stargazers* (includes the story of "Archimedes & the Crown")

The Magic School Bus: Lost in the Solar System, by Joanna Cole

Archimedes and the Door of Science, by Jeanne Bendick

Unit 3 - NEWTON'S LAWS & UNIT 4: FRICTION

Car Science, by Richard Hammond

Isaac Newton and Physics for Kids: His Life and Ideas with 21 Activities, by Carrie Logan Hollihan

Forces Make Things Move, by Kimberly Brubaker Bradley

Unit 5 - WORK: PLANE & SIMPLE MACHINES

The New Way Things Work, by David Macaulay & Neil Ardley

The Best of Rube Goldberg, by Ruben Lucius Goldberg

Websites: On Wikipedia, look up "Hero of Alexandria," and look into the inventions on this page. Hero invented the first vending machine, steam engine, and hydraulic water fountain—2000 years ago!

For kids who are into video games, this one provides a series of puzzles that require you to design various contraptions: http://www.fantasticcontraption.net/

Unit 6 - THE INVISIBLE WORLD OF AIR

The Flying Machine Book: Build and Launch 35 Rockets, Gliders, Helicopters, Boomerangs, and More, by Bobby Mercer

The World Record Paper Airplane Book, by Ken Blackburn

Flight! Make It Work!, by Andrew Haslam

Unit 7 - SOUND AND WAVES

Rubber Band Banjos and a Java Jive Bass: Projects and Activities on the Science of Music & Sound, by Alex Sabbeth

Unit 8 - MAGNETISM and Unit 9 - ELECTRICITY

Electricity! Make it Work!, by Andrew Haslam

Batteries, Bulbs, and Wires, by David Glover (covers similar material as this text, but in a bit more detail)

Awesome Experiments in Electricity and Magnetism, by Michael DiSpezio

Hands-on: Snap Circuits toys and kits are easy ways for kids to build electronic devices as complex as radio receivers

Website: http://deciwatt.global: This is the site of the GravityLight—a clever device which uses gravity and the principles of electromagnetism to power lamps in areas without electrical power.

Unit 10 - NEW WORLDS TO EXPLORE

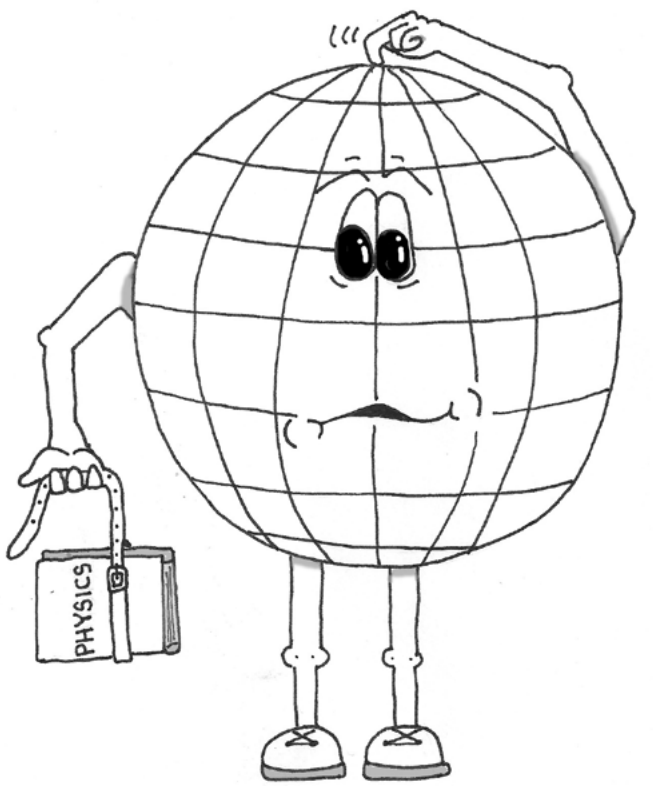
Website: Dr. Quantum's video on quantum effects is fabulous: https://www.youtube.com/watch?v=DfPeprQ7oGc

Albert Einstein and Relativity for Kids, by Jerome Pohlen

For older students & parents who are really intrigued by these ideas, I suggest reading any of Michio Kaku's books

Unit 1

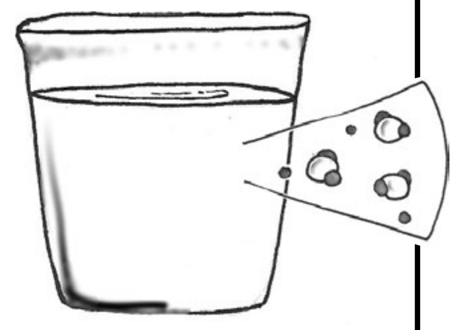
What Is Physics?



NAME ______________________________ DATE ___________________

For my notebook

Physicists Use Scientific Method



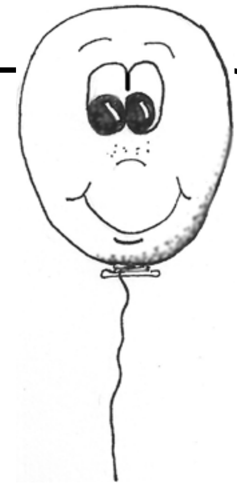
Look around you. You probably already know that everything around you, that almost everything in the universe, is made of atoms and molecules. This piece of paper, your body, whatever you're sitting on—all these things are made of atoms and molecules. Even things you can't see, like the air you breathe, or things you can't touch, like the clouds in the sky, are made of atoms and molecules. You might even know that there are a few things made of particles that are smaller than atoms and molecules.

Scientists call any thing that exists, any thing that is made of any sized particle at all, matter. You are made of matter. The sun and other stars are made of matter. The food you eat and the liquids you drink are made of matter.

Physicists are scientists who try to understand why different forms of matter behave in certain ways. Physicists try to figure out why things fall when you drop them, why different objects move at different speeds when you push them, why magnets pull and push things, how electricity moves through a wire, and countless other questions. The science of physics is the study of matter and the forces and energy that affect matter.

There are many different types of physicists and many different ways that physicists study matter and its behavior. All physicists, though, use the scientific method. This means that they carefully observe the world around them. They examine things not only with their senses, but also with equipment that can measure different qualities of matter such as electrical current, brightness, speed, and weight. Then, they record their observations by writing them down in a lab book, just like you will when you do the experiments in this book.

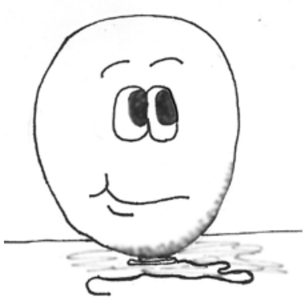
For my notebook - page 2



Once physicists have made observations and recorded their observations, they can analyze these observations—the data. They think about what they have seen and compare it with what they already know about how the world works. They think of questions that they might want to answer about what they've observed.

For example, a physicist might observe that a helium balloon slowly floats upward when she lets go of it. Then, she might compare this observation to the knowledge that almost everything else in the world falls toward the ground when you let go of it. She might wonder why the balloon rises. Is it because it is tied to a string? Is it because of the helium gas inside the balloon? Is it because of the substance the balloon is made from?

The physicist will come up with an idea about what is most likely the cause for the observation. Perhaps the physicist will develop an idea—a hypothesis—that the balloon rises because of the helium inside of it. The physicist will then develop experiments to test this hypothesis. The physicist might observe what happens if a balloon is filled with gases other than helium. Or, the physicist might experiment with filling objects other than balloons with helium. Eventually, the physicist will make additional observations and reach a conclusion about the hypothesis. Perhaps in our example the conclusion will be that helium causes the balloon to rise. Even if the conclusion is that the hypothesis was wrong, the scientist has still learned something valuable and can develop more experiments to understand more about the world.



In the next activity, you're going to practice the most valuable skill a scientist can have—the ability to observe the world around you carefully and precisely.

What Is Physics? Lab #1: Acting Like a Physicist - instructions

Materials:
- Lab sheet, pencil
- Two similar, but not identical, toys. For example: two toy cars, two alphabet blocks, two dolls

Aloud: All matter has characteristics. A characteristic is some feature of an object that helps us to describe that object. For example, some characteristics of an apple are: it is round; it is red; it is composed of cells; and, it is healthy to eat. Can you think of other characteristics of an apple?

Physicists and other scientists use characteristics to help them compare different types of matter to each other. They might observe, for instance, that a magnet attracts iron but not wood. Scientists also use characteristics to describe what happens to a single type of matter in different situations. For example, water at room temperature has the characteristic of being a liquid. But when you boil it, it becomes a gas.

Two important skills scientists have are being able to notice details and being able to describe what they notice. Take a minute to look closely at one of your toys. What color is it? Is it big or small? Is it heavy or light? Would it travel a long way if you pushed it on a flat surface? Would it bounce or break if you dropped it? Now, fill in your lab sheet.

Procedure:
1. Lay the objects on a table or the floor where everyone can see them.
2. Fill in the lab sheet.
3. Conclusion / Discussion:
4. Talk about which of the characteristics are the most important in telling one toy from another. For example, with something like marbles, color and size are probably more important than shape.
5. Are these characteristics different from ones that help you know what to do with a toy? For example, if you compare two cars, you would notice that they both have wheels and can roll. These characteristics wouldn't help you to distinguish between the two cars, but they would help you to determine what to do with the toy cars.
6. Are these characteristics any different from the characteristics that tell you how a toy would behave? Which characteristics tell you things like whether a toy bounces; whether it rolls; whether it is sturdy or delicate?

More Lab Fun:
Here's a game you can play with characteristics: Have one player think of an object in the room. Don't tell the other player what it is. The second player should ask questions about what the object is, based only on its characteristics, such as: What is its color? Is it heavy or light? This is like 20 questions, but focuses on observations you can make about objects.

[continued]

What Is Physics? Lab #1: Acting Like a Physicist - instructions page 2

Notebooking Ideas:

Reproducible notebooking pages are found in the Appendix.

1. Use a Venn Diagram page to diagram the characteristics of two people you know well. One circle should be labeled "Characteristics of ____________" (the first person); the second should be labeled "Characteristics of ____________" (the second person). The intersection is the characteristics these two people share.
2. Use a definition page to define any of the following words:

   Matter
   Physicist
   Scientific Method
   Data
   Hypothesis

NAME ______________________________ **DATE** __________________

Acting Like a Physicist

The two toys that I observed are:

____ and

____.

Fill in the chart. Add whatever characteristics you'd like to the list. You should be able to come up with at least 10.

Characteristic	Toy 1	Toy 2
Color		
Bounces?		
Rolls?		

Circle the characteristics that would help you to distinguish one of your toys from the other.

NAME ______________________________ DATE __________________

For my notebook

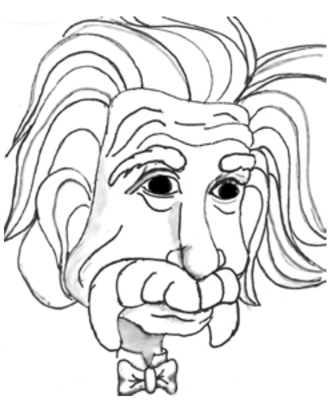
Physicists, It Takes All Sorts

All physicists work with some or all of the parts of the scientific method. Some spend their time focusing on making observations. They might observe the universe by looking through telescopes, by tracking the motions of objects in the sky, or by listening to radio waves from objects in space. Or, they might observe what happens when they smash atoms together at very high speeds in order to find out what atoms are made of.

There are physicists who perform lots of experiments. Some of the astronauts who perform experiments in space are physicists. Some physicists might try to figure out how to speed up atoms when they smash them together. Other physicists might devise experiments that use electricity and magnets to help us understand more about how the world works.

There are also physicists who do none of these things. A <u>theoretical physicist</u> could work by sitting in an office all day long looking at mathematical equations that describe how matter behaves. He develops ideas based on previous observations and experiments and based on the ideas of other physicists. A theoretical physicist tries to develop a hypothesis that experimental physicists can test, using experiments.

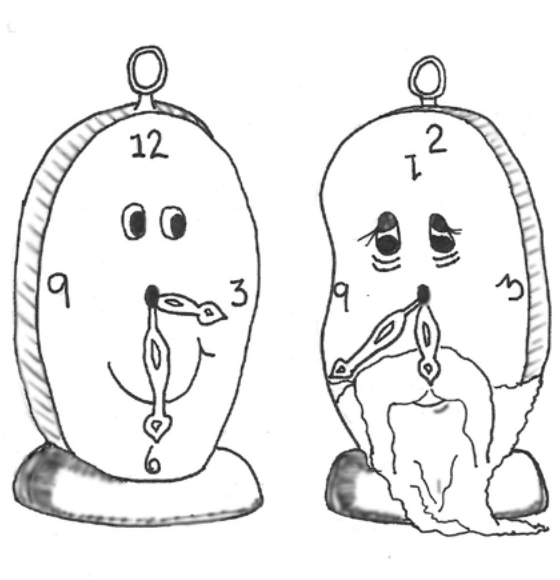
One very famous theoretical physicist was **Albert Einstein**. He thought about what would happen if we could perform experiments that just weren't possible to perform at the time. In one of these thought experiments, he tried to figure out what would happen if one of two twin brothers were sent off into space and traveled at a speed that was close to the speed of light. He hypothesized that the brother who traveled into space would experience time more slowly than the brother who stayed on Earth—that when the traveler returned, he would be younger than his twin brother!



Albert Einstein

For my notebook - page 2

Scientists were shocked by Einstein's hypotheses. Many of his thought experiments were even more surprising than this one. So, experimental physicists figured out ways to test some of Einstein's ideas. Instead of sending a person into space, they put a very precise clock into an airplane that traveled at a very high speed. They kept an identical clock on the ground. When the plane landed, they compared the two clocks. Time actually had slowed down for the clock that was on the plane, just as Einstein's thought experiment predicted. All sorts of physicists were needed to demonstrate that many of Einstein's ideas were correct.



In the next activity, we're going to learn a little bit about how to conduct thought experiments of our own—just as Einstein did. Later in this course, we'll get to devise an experiment to test the ideas that we develop in this thought experiment.

What Is Physics? Lab #2: Thinking about Drinking Water - instructions

Materials:

- Lab sheets, pencil
- Colored pencils
- Imagination

Aloud: Albert Einstein used thought experiments as a way to help him think about what would happen if he could do things that were impossible—things like traveling at very high speeds in a rocket, or flying close to a very heavy object like the sun. Another reason that physicists use thought experiments is to help them think through a problem. By thinking about a scientific question before rushing to do a real experiment, physicists can make intelligent guesses about which experiments will be most helpful. This is the kind of thought experiment we're going to do today.

Here's the thought experiment: What happens when you drink through a straw? Sounds pretty simple, right? But, as a scientist, you would have to think about why each step happens the way it does. When you pour liquid into the glass, why does it stay there? Why does it take on the shape of the glass? When you put the straw into the glass, how much liquid fills the straw? What else is in the straw? Try to draw each step and label what you think is happening and what types of matter (air, water, glass) are involved. Try to do all this without actually having a glass of water and a straw in front of you. In another lesson, we'll do an experiment to see if the ideas from your thought experiment turn out to be correct.

Procedure:

Fill in the lab sheet

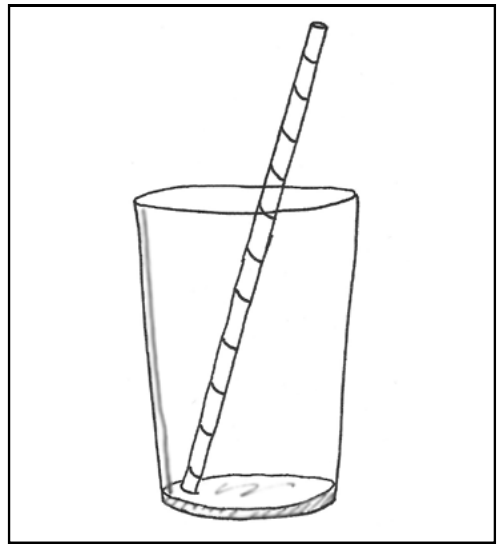
Note to Parents and Teachers:

It is helpful to have a toy block on hand when starting the next unit, What Matters.

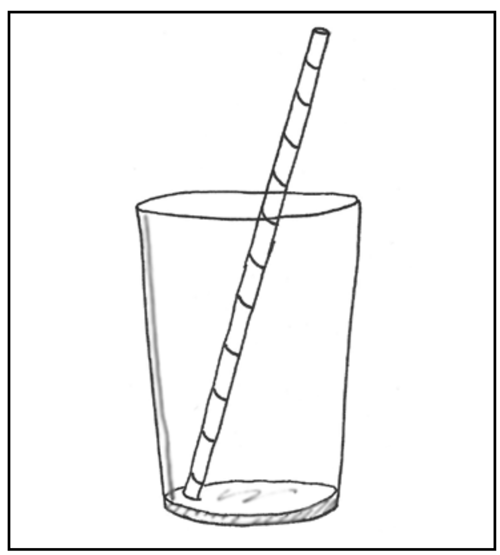
NAME ______________________________ DATE __________________

Thinking about Drinking Water

If I were to put a straw into a cup filled part way with water, this is what I think I would observe: (Show where you think water will be. Where will air be? Can you explain why matter might behave this way?)

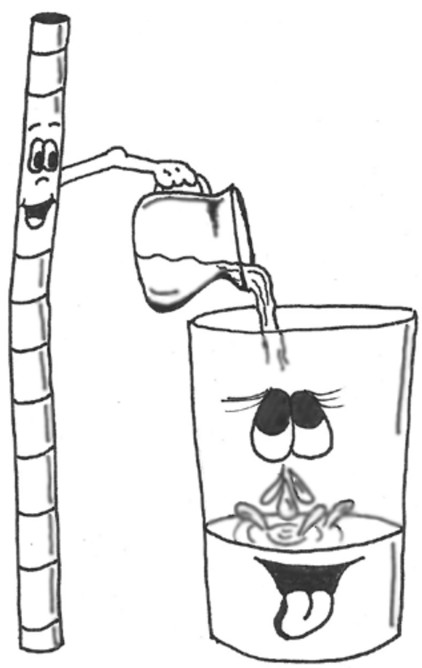


If I were to suck through the straw, this is what I imagine would happen. And, here's a description of why I think it would happen that way.



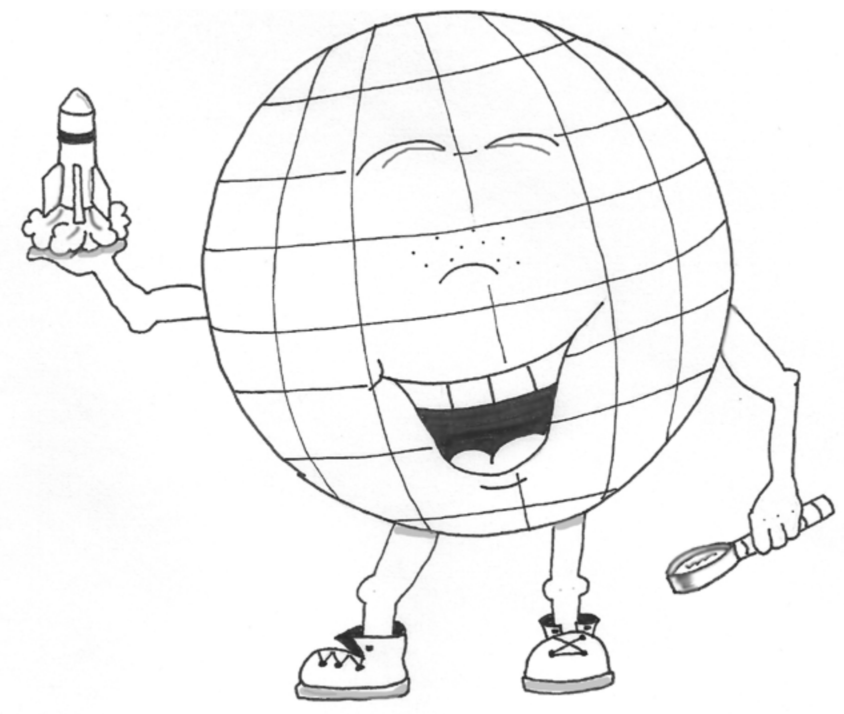
Thinking about Drinking Water - page 2

Describe an experiment that might test your ideas:



Unit 2

What Matters



NAME ______________________________ DATE ___________________

For my notebook

Mass: It Really Matters

It is helpful to have a toy block available for this lesson.

Pick up a toy block and hold it in your hand. It might feel heavy or light, but it definitely weighs something. It feels like something is pulling it down toward the earth. In fact, if you weren't holding onto the block, it would fall down. As you probably know, Earth's gravity pulls all objects. In which direction does gravity pull objects? I think that most people would answer, "down." Physicists have a slightly more precise way to answer this question. They say that gravity on Earth pulls all objects toward the center of the planet.

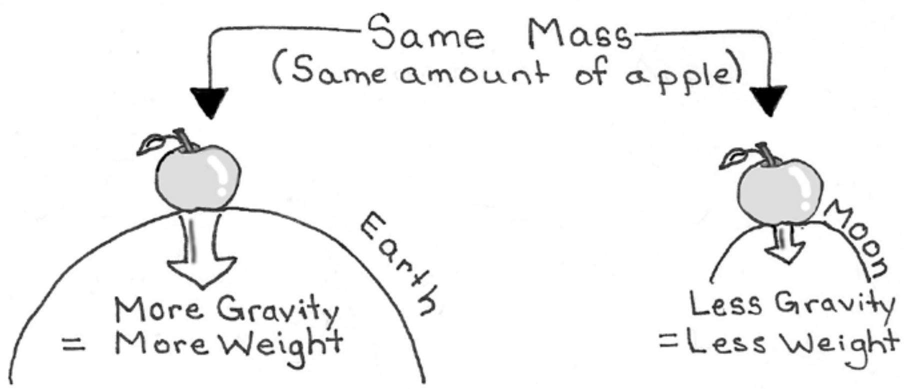
Let's look at your toy block. You can see that it contains a certain amount of matter—either wood, plastic, foam, or whatever it is made out of. You can *feel* the weight (the matter) in your hand. What would it feel like in outer space, though? Here's an experiment you might try: Catch a ride on the space shuttle and take the block into space with you. Wait. That could be a bit difficult. Let's try this as a thought experiment instead: *Imagine* catching a ride on the space shuttle with your toy block. You escape from Earth's gravity, and everything is floating. You take hold of the block: Does it feel like it weighs anything?

If you've ever seen videos of astronauts in space, you probably answered, "No. It feels weightless." If that's what you thought, you're correct. But now, let's say you look at the block. It still contains the same amount of matter as it did on Earth. No pieces of it have disappeared. You've just demonstrated the difference between mass and weight.

An object's mass is the amount of matter it is made of. The mass of an object doesn't change unless you actually add something to the object or take it away from the object. Your block's mass would be the same on Earth, out in space, or even under the very heavy gravity of Jupiter!

For my notebook - page 2

This is very different from an object's weight. The weight of an object is actually a way to measure how much gravity is pulling on the object. The weight of an object changes whenever the force of gravity changes. The weight of an apple would be less on the moon than it is here on Earth. But, where gravity is stronger, like on Jupiter, the weight of the apple would be greater than it is on Earth.



The difference between mass and weight is very important for physicists. Mass is an essential characteristic of matter. How objects behave when they are pushed and pulled depends on their mass. Weight, for physicists, is not really a characteristic of matter. Weight, instead, is just another force pulling on an object—the force of gravity. Physicists use a mathematical equation to describe how mass and weight relate to each other. Here is the equation:

$$\text{weight} = \text{mass} \times \text{gravity} \quad (w = m \times g)$$

Cool Science Fact!

Gravity decreases the farther you get from the center of an object. Because Earth bulges, or is fatter, near the equator, you're slightly farther away from the center of mass of the earth at the equator than at the North Pole. So, your weight would be slightly less at the equator than at the North Pole!

What Matters Lab #1: Weighing in Around the Solar System - instructions

Materials:

- Lab sheets, pencil
- Calculator
- Bathroom scale

Aloud: Imagine that you could take a scale and travel to the other planets in our solar system and to the moon and the sun. If you could land at all of these places, even the gas giants like Jupiter, Saturn, Uranus, and Neptune, what would happen if you stepped onto the scale and weighed yourself? Would your weight stay the same? Would it change? How would it change?

What if there were a way to measure your mass—how much matter you're made of? Would that change when you went to different planets? Would there suddenly be more or less of you just because you are on another planet? Of course not. Your weight might change as the gravity around you changes, but your mass will not.

Because you're learning physics, you can figure out what the scale would read wherever you imagine going. All you need to know is how much you weigh on Earth and how strong gravity is on other bodies in our solar system. Remember, we just learned that weight = mass x gravity. Here on Earth, we define gravity as being equal to one. Because any number multiplied by 1 is just that number, our weight on Earth is pretty much equal to our mass. Because we're stuck on Earth when we do experiments, we'll usually think of mass and weight as the same number.

But, on other planets where gravity is greater or lesser than that of Earth, weight and mass are not the same. In our next activity, we'll figure out how much you would weigh at different spots around the solar system. We can use the equation above to do this. You may need to use a calculator because a lot of the numbers have decimal points.

Procedure:

1. Weigh yourself in pounds. *(see notation on next page)
2. Use this knowledge to fill in the lab page. Circle the places where you would weigh the least and where you would weigh the most.
3. Complete the thought experiment page.

What Matters Lab #1: Weighing in Around the Solar System - instructions page 2

Possible Answers:

Below is how the chart would look for a person who weighed 80 pounds:

	Force of gravity compared to Earth's	Mass x Force of Gravity (use your weight on Earth as your mass for this exercise)	My weight would be:
Mercury	.38	80 x .38 =	30
Venus	.91	80 x .91 =	72.8
Earth	1	80 x 1 =	80
Mars	.38	80 x .38 =	30
Jupiter	2.54	80 x 2.54 =	203.2
Saturn	1.08	80 x 1.08 =	86.4
Uranus	.91	80 x .91 =	72.8
Neptune	1.19	80 x 1.19 =	95.2
Pluto (dwarf planet)	.06	80 x .06 =	4.8
Moon	.17	80 x .17 =	13.6
Sun	27.9	80 x 27.9 =	2232

Conclusion / Discussion:

1. Talk more about the difference between mass and weight. Can you think of any ways you might be able to change your mass? (Some ideas: eat a meal, breathe out, etc.). These actually change the amount of matter that makes up your body.
2. What would be the dangers of living somewhere with much greater gravity than Earth's? What would be the dangers of living somewhere with much less gravity than Earth's?

More Lab Fun:

1. If you're interested in what it's like to live with very little gravity, look online for information about it, and new videos of the astronauts on the International Space Station. Try to find out what these astronauts have to do to stay healthy in zero gravity. Are the dangers of low gravity what you thought they would be?
2. Look up the weight on Earth of something very heavy (like a blue whale) and something very light (like a head of lettuce). Figure out what they would weigh on the sun and on the moon.

Notebooking ideas:

1. Use a definition page to define: *mass* and *weight*.
2. Use a piece of lined paper to write about what astronauts need to do to overcome the effects of low gravity on the human body.
3. Use an Equation page to copy and explain the formula that relates mass to weight.

Note to Parents and Teachers:

*We aren't going to worry about the fact that pounds technically measure weight, and kilograms measure mass. The point here is that as gravity changes, so does weight.

NAME ______________________________ DATE __________________

Weighing in Around the Solar System

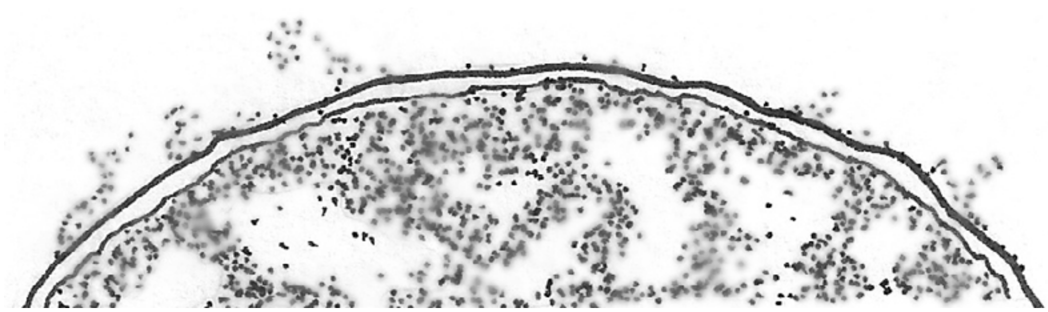
On Earth, I weigh: ________________ pounds

	Force of gravity compared to Earth's	Mass x Force of Gravity (use your weight on Earth as your mass for this exercise)	My weight would be:
Mercury	.38		
Venus	.91		
Earth	1		
Mars	.38		
Jupiter	2.54		
Saturn	1.08		
Uranus	.91		
Neptune	1.19		
Pluto (dwarf planet)	.06		
Moon	.17		
Sun	27.9		

Weighing in Around the Solar System - page 2

On the moon, I would weigh ____________________ pounds. I would be much lighter than I am now, and gravity's pull on me would be much less. This is what I imagine I could do on the moon:

On the sun, I would weigh ______________________ pounds. I would be really heavy. The force of gravity would pull down a lot on me. If the sun weren't so hot, this is what I imagine things would be like:

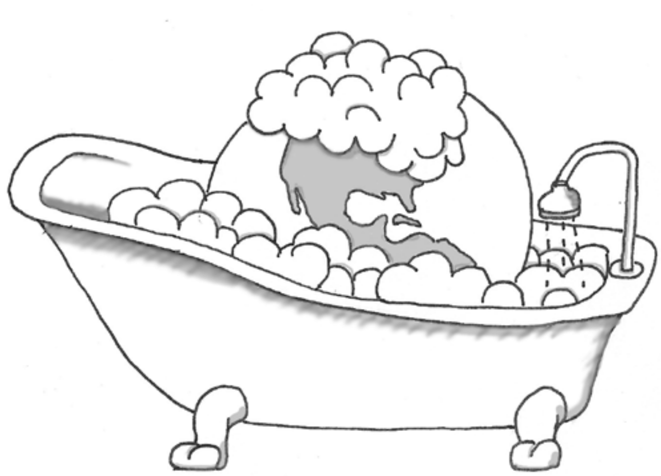


NAME ______________________________ DATE ___________________

For my notebook

What Floats Your Planet?

Here's an amusing thought experiment for you. You get a really big bathtub—one as large as the sun. Then, you fill it with water, lots and lots and lots of water. Next, you drop planet Earth into the bathtub. Other than a really big splash, what do you think would happen? Take a moment to imagine your answer. After you take Earth out of the bathtub and dry it off, you decide to throw Saturn in next. Now what do you think would happen?



Part of the answer may surprise you. Earth, as you may have guessed, will sink to the bottom of the bathtub, just as a stone sinks to the bottom of a bucket of water. Saturn, which is more than nine times as large as Earth, however, will float!

How can this be? Doesn't Saturn contain more matter, and therefore more mass, than Earth? Doesn't Saturn weigh more? These are good questions, and the answer to both of them is "Yes." To understand why Saturn would float in water but Earth wouldn't, let's bring our thought experiment down to Earth. Instead of planet Earth and planet Saturn, imagine that you have a model of Earth (a small rock) and a model of Saturn (an inflated beach ball). These are appropriate substitutes because, in reality, Earth is a solid and Saturn is made mostly of gases. Also, Saturn really is much larger than Earth.

For my notebook - page 2

If you put the rock into your bathtub, it's pretty obvious that it would sink. But, if you were to put the inflated beach ball into your bathtub, it would float. This would be true even if the overall weight (and mass) of the beach ball were greater than that of the stone. The question is: Why does the larger object float and the smaller object sink?

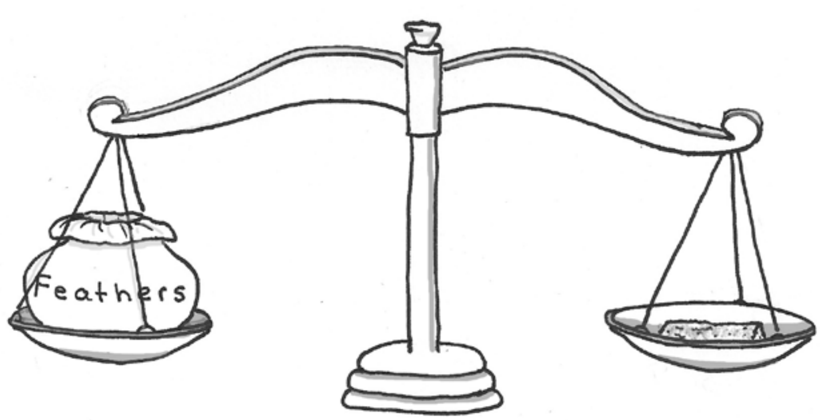
The answer to this question is complicated, and involves a number of different characteristics of matter. In the following labs, we're going to learn about these characteristics—volume, volume of water displaced, density, and buoyancy. When we're done, you'll be able to explain why Saturn would float in water, but Earth would not.

A Science Riddle!

Q: What weighs more, a pound of feathers or a pound of bricks?

A: They both weigh one pound, so they weigh exactly the same!

Think about it: Which would take up more space, though, a pound of feathers or a pound of bricks?



What Matters? Lab #2:
Density: All Objects, Large and Small - instructions

Materials:
- Lab sheet, pencil
- Balance or kitchen scale (or any type of sensitive precision scale that measures down to ounces and/or grams)
- At least 6 low-density and 6 high-density objects from around the house, as described below

Aloud: Scientists call an object's size (the amount of space that it takes up) its <u>volume</u>. Some objects seem to have a lot of mass for their volume—like heavy rocks. Other objects seem to be very light compared to the amount of space they take up—like inflated beach balls. This relationship between an object's mass and its volume is called an object's <u>density</u>. Scientists calculate an object's density by dividing its mass by its volume, like this:

DENSITY = MASS ÷ VOLUME

D = M / V

Because on Earth, mass is pretty much the same as weight, you could also think of it as:

DENSITY = WEIGHT ÷ VOLUME

Either way, a small rock is much more dense than an inflated beach ball. Its weight is large and its volume is small, so its density is pretty large. A beach ball takes up a lot of volume, but weighs very little. Therefore, its density will be pretty small.

Today, you're going to go on a scavenger hunt around your house. You'll be looking for small objects that you think are really dense—that are quite heavy for their size. And, you'll look for objects that you think have a low density—that are light for their size. The objects you find should all fit on your balance scale. I think that you'll discover that you already know quite a bit about the density of different objects.

Suggestions for objects if you're stumped:

High-density: small cup of water, coasters made of sandstone, filled up stapler, paperweight, roll of packing tape, ball bearings.

Low-density: Styrofoam cup, Styrofoam ball or packing materials, inflated balloon or beach ball, whiffle ball, loosely crumpled aluminum foil, an empty plastic container.

Procedure:
1. Try to guess which pairs of objects are such that a smaller object weighs more than a larger object. For example, a small cup of water might weigh more than a larger Styrofoam ball.
2. Fill in the lab sheet with your guesses. Then, use the scale or balance to test whether your ideas were correct.

Conclusion / Discussion:
1. Can you explain in your own words why some smaller objects are heavier than some larger objects? Does this give you a clue about why Saturn might float in water but Earth would not?
2. Make sure that students understand that density involves the relationship between the size and mass of an object. Large size, small mass = low density; and small size, large mass = high density.

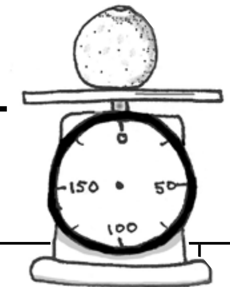
[continued]

What Matters? Lab #2: Density: All Objects, Large and Small - instructions page 2

More Lab Fun:
Take a survey of 10 to 20 people that you know. Ask them the riddle: "Which is heavier? A pound of feathers or a pound of bricks?" Mark down how many people answer "a pound of bricks" and how many answer that they weigh the same. Why do you think some people are confused about this? Place your results in your notebook.

Notebooking Ideas:
1. Use a definition page to define *density* and *volume*.
2. Use an Equation page to copy and explain the equation used to calculate the density of an object.

NAME ______________________________ **DATE** ____________________



Density: All Objects Large and Small

Larger object	Smaller object	The object I think will weigh more	The object that did weigh more

When a small object weighs more than a larger object, we know that the smaller object has a greater density than the larger object. You could summarize the results of your experiment by writing your conclusions in the following sentences:

1. I discovered that ____________________ has a greater density than

____________________ .

2. I discovered that ____________________ has a greater density than

____________________ .

3. I discovered that ____________________ has a greater density than

____________________ .

What Matters Lab #3:
Water Displacement: It'll Float Your Boat! - instructions page 1

Materials:
- Lab sheets, pencil
- A wide glass that you can see through, filled ¾ way with water
- A dry-erase marker or small piece of soap (you'll be writing on the glass with it)
- A small piece of polymer clay that makes about a 1-inch diameter ball. (Don't use one of the really lightweight clays like Model Magic. You need something that will sink.)
- An additional small cup of water
- A teaspoon or tablespoon

Aloud: You now know about three of the characteristics of matter that are important in figuring out whether (and why) an object floats: mass, volume, and the relationship between mass and volume—density. The next important characteristic for you to consider is called the <u>volume of water displaced</u>. This sounds pretty complicated, but it really isn't. We've already learned what <u>volume</u> means—it's the space an object takes up. I probably don't need to explain what water is. <u>Displaced</u> is a word that you can take apart to figure out what it means: "dis" means "apart," so displaced means to place apart or to move away. Let's put all these pieces together now.

If you drop an object into water, regardless of whether it sinks or floats, it will push some water out of the way, displacing that water. You've probably noticed, for example, that when you sit down in a bathtub, the water level seems higher than it was. That's because your body moved some water out of the way—water that took up a certain amount of space, or volume, and that water had to go somewhere else. The volume of water that is pushed out of the way is called the volume of water displaced.

There are several ways to measure the volume of water displaced by an object. You could fill a container to the very top with water and place the object into the water. Then, you could collect the water that overflows the container and measure it. This method can be a bit messy and imprecise without special equipment, so we're going to use a different method—marking the water level on a container with and without the object inside of it.

As you can probably guess, the amount of water an object will displace—or move out of the way—depends a little bit on characteristics you've already studied—mass, volume, and density. But, there's one more factor to consider, and that's what we're going to explore in this lab.

Procedure:
1. Pick up the piece of clay and roll it into a ball. Draw an outline of the ball about the same size as the ball in the first box on your lab sheet. Now, play with the clay and make it into three different shapes—a snake, a teddy bear, whatever you'd like. The only rule is that you need to use all of the clay each time. For each shape you make, draw a sketch of it on your lab sheet. Try to make your sketch the same size as the actual object; you can even trace it if you want.
2. Answer questions 1 & 2 on your lab sheet and fill in the HYPOTHESIS section.
3. Mark the water level on the glass. Make sure that you bend down so that your eye is at the level of the water. This is the most accurate way to mark the water level.

[continued]

What Matters Lab #3:
Water Displacement: It'll Float Your Boat! - instructions page 2

4. Roll the clay into a ball and fill in the first line of the chart on your lab sheet. You will notice that part of this has been done for you. When you are ready, gently place the ball of clay into the water, using a spoon so that you don't splash any water out of the glass. Mark the waterline now that the ball of clay is in the water. Record your observations on the chart.
5. Take the clay out of the water. If some water spilled and there's not enough water to reach your original waterline, add more water with a teaspoon until you have the same amount as you started with.
6. Make another shape with the clay—this time, the shape of a boat, like a canoe. Gently place the clay boat into the water. Fill in the next row on the chart. You don't need to mark the waterline; just observe whether it is higher or lower than it was when you placed the ball in the water. Repeat step 5.
7. Make another shape with the clay—this time, the shape of a flat boat, like a raft. Fill in the chart again. Repeat step 5. Make up a couple of shapes of your own to try. Record your observations on the chart.
8. Fill in the MY OBSERVATIONS section of the lab sheet.

Possible Answers:

#1: the same

#2: matter

My Observations:

all of these, different amounts, shape, more

One more thing:

sink

Analysis & Conclusions:

#1: air, water

#2: lighter

#3: air

Aloud: Something strange is happening here. How could whether an object floats depend on its shape rather than on its weight? How can a piece of clay that has the exact same amount of matter displace different amounts of water depending on its shape? Now you see that sometimes the experiments that scientists perform can lead to new questions and new experiments. We're going to perform one more short experiment to see if we can figure out what's going on with our piece of clay.

9. Wipe off the waterlines you've made on the cup. Refill it to about ¾ and make a new waterline.
10. Make a shape that will float and could hold water—something like a little canoe or rowboat. Test that it floats and also mark a line for the amount of water displaced by the clay while you do this.
11. Now, use a spoon to take water from a second cup and place it little by little into the clay shape that is floating. Observe what happens and record your observations under ONE MORE THING and ANALYSIS & CONCLUSIONS.

[continued]

What Matters Lab #3:
Water Displacement: It'll Float Your Boat! - instructions page 3

Conclusion / Discussion:

Aloud: You've discovered that you can make some shapes that float in water and some that don't—all with the same piece of clay. You now have all the pieces of a scientific puzzle: Why do some objects float while others sink? The answer has to do with all sorts of properties of matter: volume, mass, volume of water displaced, and density. There's a simple way to determine whether an object will float. Here it is: an object will float if the volume of water it displaces weighs more than the object weighs.

Let's think about this for a while. The clay weighed the same and had the same mass, no matter what we did to it. But when we floated it on water, it sometimes had lots of air taking up some of the space inside the clay sculpture (like when it was a boat) and sometimes no air at all (like when it was a ball). When there was air taking up space, as in the clay boat, the clay boat displaced more water and floated. When there was no air taking up space, such as when we shaped the clay like a ball, less water was displaced, and the boat sank. It's important to realize that the mass, volume, and density of the clay stayed the same no matter what we did. But, the overall mass, volume, and density of the boat and its contents changed.

Steel is very heavy and dense. Now that you understand why some objects float, can you explain why large steel cargo ships can float?

More Lab Fun:

1. Salt water is heavier than just plain water because it has the weight of the salt and the water together. You can experiment with what happens if you float your clay boats in water and then start adding salt. Does the waterline change? How?
2. Build a bigger clay boat and then try to load it with cargo, such as marbles. Does it still float? Can you make changes to the boat that allow it to float better and carry more cargo?

Notebooking Ideas:

1. Look up *buoyancy* in a dictionary and write its definition on a Definition page.
2. Design a ship that you think will float no matter how much load it carries. Draw a picture of your ship and explain why you think it will float.

NAME ______________________________ **DATE** __________________

Water Displacement: It'll Float Your Boat!

From my piece of clay, I made:

Circle or underline the word(s) to make the sentences correct:

1. When I made these clay sculptures, I always used **the same** / **different** amounts of clay.
2. This means that even if the sizes of the clay sculptures are different, the clay always had the same amount of **matter** / **shape**.

Hypothesis: I think that changing the shape of the clay **will** / **will not** affect whether the clay floats in water.

Water Displacement: It'll Float Your Boat! - page 2

Data:

Description of clay shape	Did I think this would float?	Did it float?	Did this displace more or less water than the clay shaped as a ball?
Ball			X
Canoe			
Raft			

My Observations: Some of the shapes made from the clay floated, but some of them sank. All of the shapes had the same amount of clay. This means that they all had the same **volume** / **mass** / **weight** / **density** / **all of these**. Different shapes displace **different amounts** / **the same amount** of water. This means that the amount of water displaced depends on the **shape** / **mass of the object**. The shapes that floated displaced **less** / **more** water than the shapes that sank.

One More Thing: When I added water to the clay boat, it began to **sink** / **float**.

Analysis and Conclusions:

1. When I added water to the clay boat, the clay boat itself stayed the same shape. Whether it floated or sank depended on what it was filled with. When it floated, it was filled with **air** / **water**. When it sank, it was filled with **air** / **water**.
2. Air is **heavier** / **lighter** than water. (If you're not sure, think of how much a blown-up balloon weighs compared to a water balloon.)
3. If I were to experiment further, filling different clay shapes with air and different clay shapes with water, I think that the ones filled with **air** / **water** would be more likely to float.

NAME ______________________________ DATE __________________

For my notebook

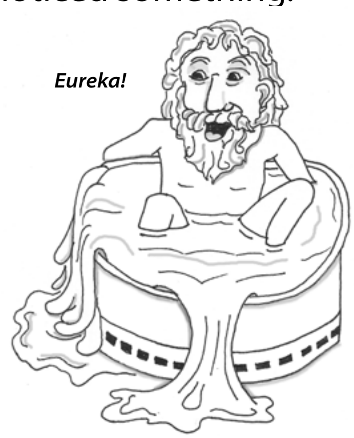
A Story about Density: Archimedes and the Crown

Archimedes was one of the greatest physicists ever. He lived in Syracuse more than 2,000 years ago (c. 287 BCE-212 BCE) and was a cousin to King Hiero II. There's a wonderful story about Archimedes, King Hiero II and, of all things, density! We don't know if the story really happened this way, but it's a great story nevertheless.

One day, King Hiero commissioned, which means he hired for pay, a goldsmith to make him a crown—a golden crown shaped like a wreath of laurel leaves. The goldsmith told King Hiero that the crown was crafted from the purest gold. Indeed, the crown was amazing: Even the tiniest veins in the laurel leaves had been carved into the gold.

King Hiero, however, had heard that the goldsmith was a thief. The king began to worry about his crown. Perhaps it wasn't really made of pure gold. Perhaps the goldsmith had substituted some other metal for some of the gold and kept some gold for himself. But, the only way to find out for certain would be to melt the crown into a lump of gold to see if it weighed the same amount as another lump of gold with the same volume. King Hiero couldn't bring himself to destroy the crown just to prove that it was, or was not, pure gold.

The king mentioned his problem to his cousin Archimedes, a great scientist, inventor, and mathematician. Archimedes said that he would think about the problem and get back to the king. Some time later, Archimedes went to take a bath. As he stepped into the bathtub, he noticed something. He noticed that the water level rose every time he lowered himself into the tub. And, the water level dropped every time he stood. You can try this in your own bathtub.



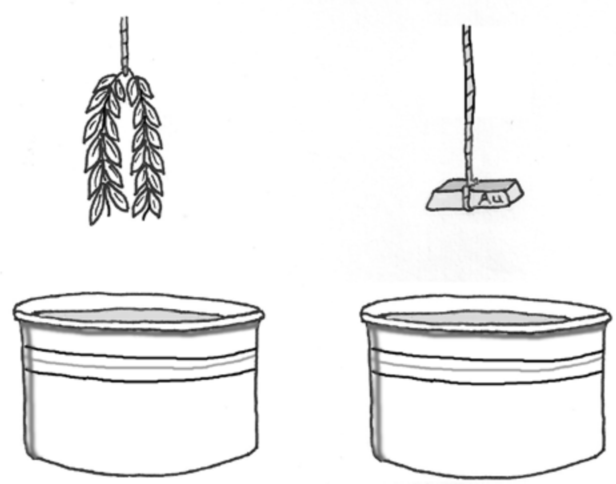
Archimedes shouted, "Eureka!" *Eureka* in Greek means "I have found it!" He was so excited that he ran out of the bathhouse without a stitch of clothing on. He ran straight to King Hiero, whom we hope gave him a

For my notebook - page 2

robe to wear. Then, Archimedes explained his discovery. He said something that went like this, “King Hiero, the problem with figuring out whether your crown is pure gold is that we need to know not only the weight of the crown, but also its volume. Does it weigh exactly the same as a lump of gold with the same volume? We thought that to figure out the volume of gold in the crown, we would have to melt the crown into a lump. I have discovered another way. All we need to do is fill a tub to the very brim with water. Then, we place the crown into the water slowly, until it sinks to the bottom. If we catch the amount of water that overflows the tub in a pan and measure the amount, that will tell us the exact volume of the crown.”

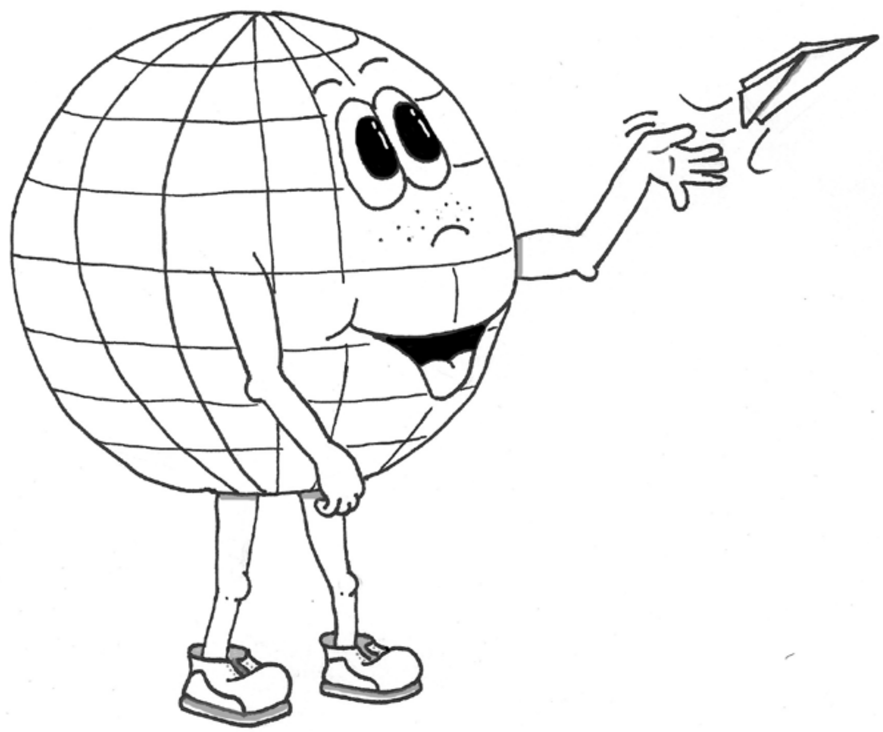
The king, who didn’t at all understand that density is the relationship between mass and volume, nodded politely. Archimedes performed his experiment and discovered that the crown was not, in fact, pure gold. The crown displaced a certain volume of water. Archimedes found a lump of pure gold that displaced exactly the same volume of water. This lump of gold, however, did not weigh the same as the crown. The volume of the crown and the volume of the lump of pure gold were the same, but their weights were different. In other words, the density of the crown was not equal to the density of pure gold.

We don’t know what happened to the goldsmith or to the crown. But, we’ll be hearing more about Archimedes, a man who discovered amazing things about physics just by observing the world around him. And, if you keep a history timeline, you might want to put Archimedes on it.



Unit 3

Newton's Laws



NAME ______________________________ DATE __________________

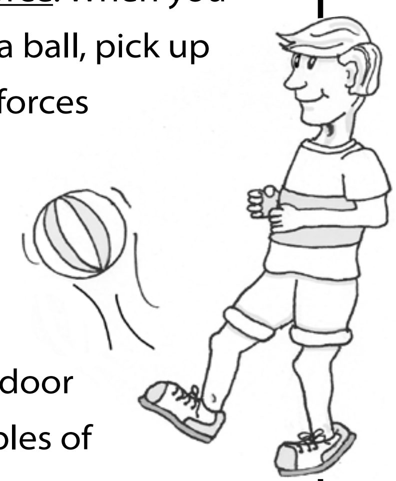
For my notebook

A Forceful Introduction

So far we've learned a lot about matter. We've seen that different types of matter have different characteristics. Some have a lot of mass in a small space, some have very little mass in a large space. Some bounce. Some are red. Some roll, and some don't. We had some fun learning that one needs to consider a number of characteristics of matter to figure out if an object will float.

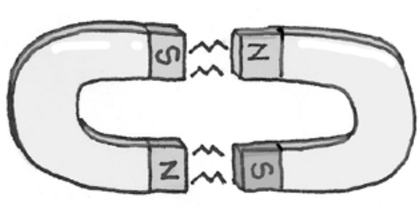
But floating a hunk of matter is only fun for so long. And just looking at a hunk of matter sitting still on a table isn't very interesting. It's when we start doing things to matter—pushing it, pulling it, dropping it, throwing it, crushing it, crashing one piece into another—that physics gets really exciting!

Scientists call any push or pull on a piece of matter a <u>force</u>. When you push a toy car, you're exerting a force on it. When you throw a ball, pick up a glass of water, pull open a door—all these are examples of forces applied to matter.



We can divide forces into two general categories. The first type of force is called a <u>contact force</u>. Any force that we apply to an object by touching the object is a contact force. So, pushing a car, picking up a glass of water, and opening a door all involve contact forces. Can you think of a few more examples of using a contact force?

The other type of force is called <u>action-at-a-distance force</u>. This is a big name for a simple idea. Any force that pushes or pulls on something without touching it is an action-at-a-distance force. Take a minute to think of what kinds of forces you know about that might be action-at-a-distance forces.



Did you think of any examples? Here are a couple you probably know a lot about already:

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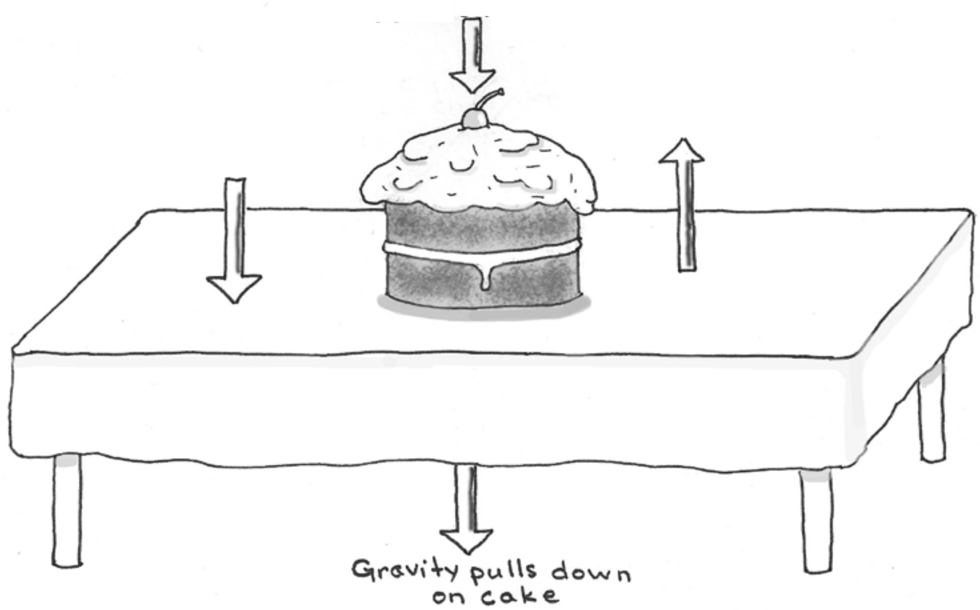
magnetism and gravity. If you've ever played with magnets, you know that they push and pull each other even when they aren't touching each other. Another action-at-a-distance force is gravity. Gravity is a force that pulls things toward the earth. Gravity doesn't need to reach out and touch an object to make it fall. It acts on matter from a distance.

When an object is at rest, when it's holding still, we say that all the forces acting on it are in equilibrium. That means that all the forces pushing on it and pulling on it balance out, and leave the object where it is. If you look around the room, you'll see a whole bunch of objects in a state of equilibrium—chairs, books, table, a cake, toys, the room itself. They're all just staying still, not appearing to do anything. It's really important to realize, though, that just because an object, like a cake on your table, is sitting still, there are still lots of forces acting on it. In fact, we're about to explore that idea a bit further in our next activity.

But first, see if you can identify four forces acting in equilibrium that keep the cake, pictured below, on the table. One of the forces, gravity, is the action-at-a-distance force, and it is labeled for you. The other three are contact forces; can you identify them?



Newton's Laws Lab #1: An Object in Equilibrium

Materials:

- Lab sheets, pencil
- Glass partly filled with water, placed on a table
- Drawing materials

Aloud: When most people look at a glass of water, they don't think much about it. Physicists, though, think it's pretty exciting. Really. Think about all the forces involved in keeping that cup of water on the table. For some reason, the glass doesn't fall through the table onto the floor. What's pushing up on the glass to keep it there? Why doesn't the glass float away? Why doesn't the water climb out of the glass and spill? There must be a number of forces acting on that glass of water to keep it in a state of equilibrium, at rest. In this activity, you're going to draw a picture of the glass of water and show all the forces you can think of that are keeping it in equilibrium. Use arrows to indicate in what direction the forces are acting. The first one is drawn in for you.

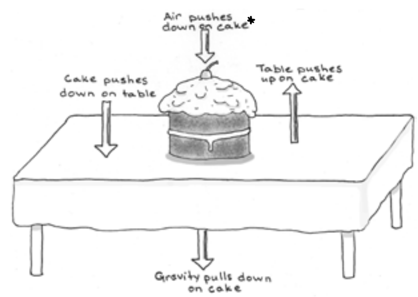
Procedure:

1. Observe the glass and draw arrows (and words) on the glass of water on the lab sheet showing the forces as described above.
2. Fill in the set diagram listing which forces are contact forces and which are action-at-a-distance forces.
3. Complete the final drawing showing what would happen to the glass of water if one force was removed.

Possible Answers:

For my notebook: Forces acting in equilibrium in cake picture:

* Note: Technically, air pressure is pushing on the cake and the table from all directions. Students shouldn't be expected to know much about the properties of air at this point. Air pressure and how it affects objects on Earth will be discussed in Unit 6.



Lab sheet:

Some of the forces to consider:

The pull of gravity on the water in the glass, the glass, the table, the floor (all action-at-distance forces)

Air pressure (from many directions) on the water and on the table (contact force)

The water pushing outward against the walls of the glass (contact force)

The glass pushing back on the water (contact force)

The table pushing upward on the glass (contact force)

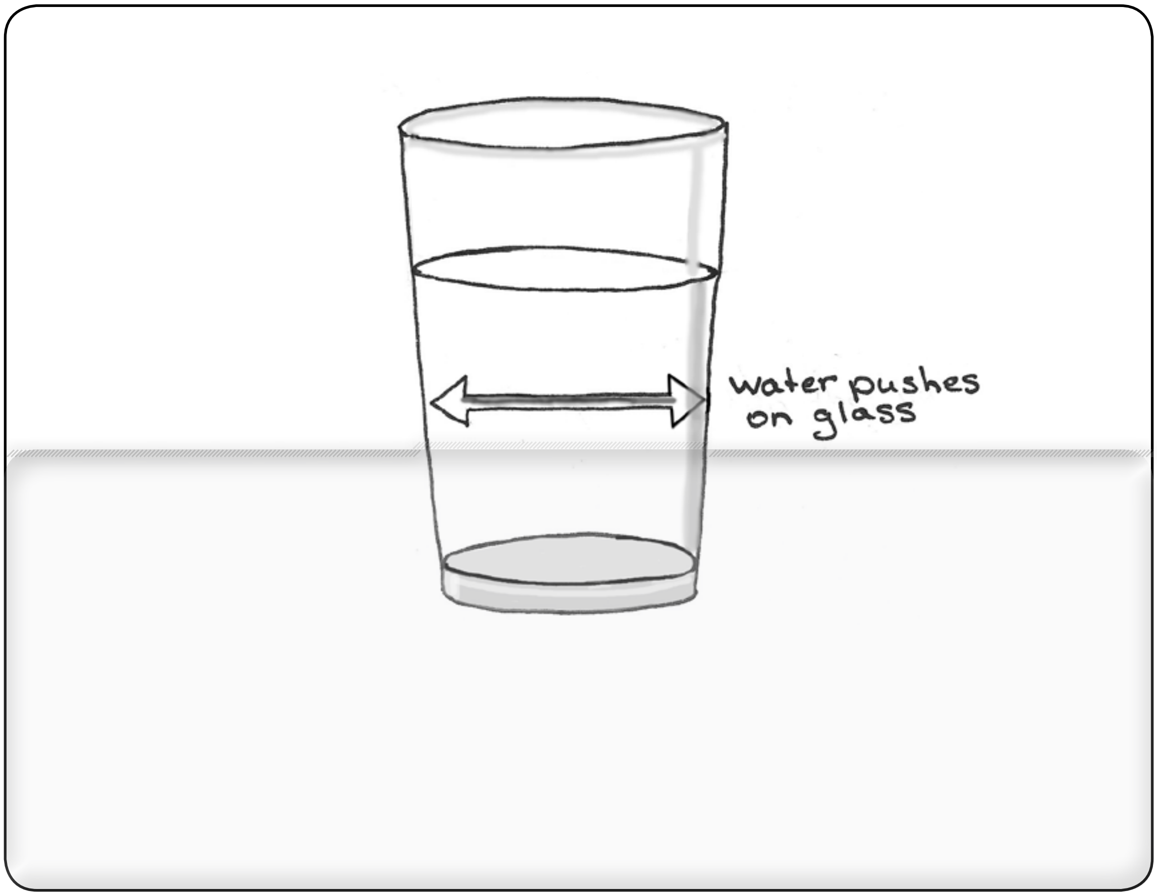
Note: Don't worry if not all the forces mentioned above are drawn in. The important thing is that students understand that lots of forces push and pull in different directions to keep an object in equilibrium.

Conclusion and Discussion:

1. Look around you. What other things are in equilibrium? Are there things you see that are not in equilibrium? Are there things you can think of that aren't in equilibrium? What "extra" force is being applied to them so that they move?
2. Think about yourself when you're sitting still. What forces are pushing and pulling on you?

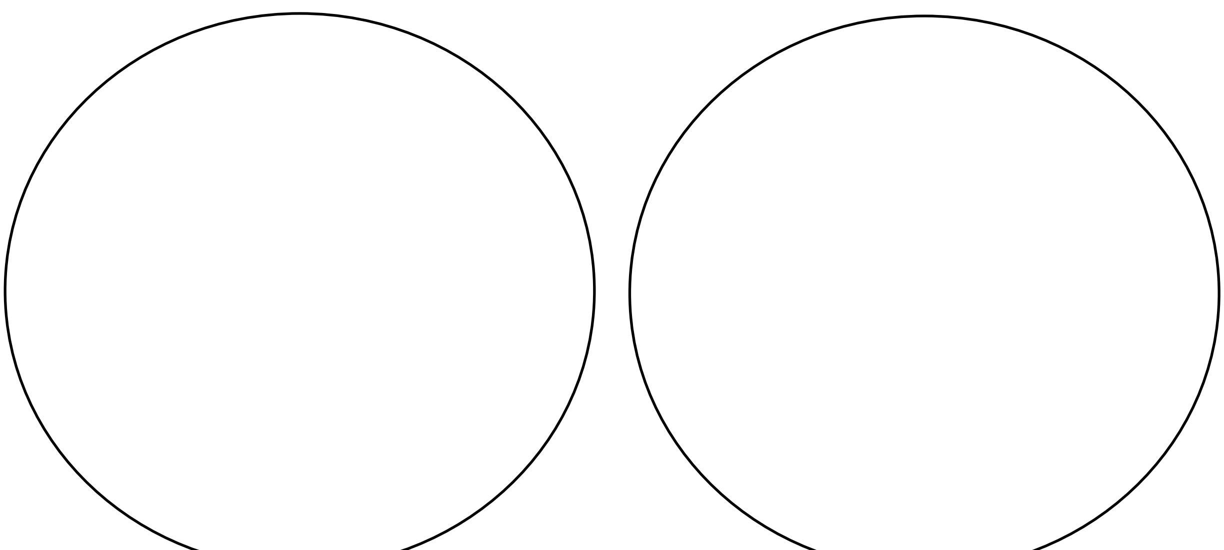
NAME ________________________________ DATE ___________________

An Object in Equilibrium



These are contact forces.

These are action-at-a-distance forces.



An Object in Equilibrium - page 2

Draw a picture, or describe in words, what would happen if you took away one of the forces acting on the glass of water. Here are a couple of my favorite examples to imagine: What would happen if gravity no longer pulled on the water in the glass? Or, what would happen if the table stopped pushing up against the glass?

What force did you decide to remove? ______________________________

What would happen if that force were removed?

Notice how removing just one force can take an object out of equilibrium and get things moving.

NAME ______________________________ DATE __________________

For my notebook

Moving with Newton

In 1643, **Isaac Newton** was born in England. He grew up, went to school, and then went to college in Cambridge, England. Just as he was finishing his studies at Cambridge University, which still exists today, all the schools in England were closed. The year was 1665, and a sickness called "the plague" was spreading throughout Europe. To prevent people from making each other sick, the government ordered that all big, public places where lots of people gather, be closed. So Newton left Cambridge and went to live in the country for a few years.

There's a famous story about Newton which may or may not be true. It is said that one day, while living in the country, Newton was out in an apple orchard when an apple fell on his head! Most of us would just say, "Ouch," eat the apple, and go on about our day. But, according to the story, Newton gave that apple a great deal of thought. He wondered what made it fall. What made it fall down instead of up or sideways? Why did other objects always fall toward the earth? Why didn't the moon fall to Earth like the apple?

In the two years Newton spent living in the country, he thought and thought about questions like these. During that time, Newton described what gravity is and how it works. He figured out why objects move the way they do. He also developed an entire area of mathematics called calculus, which is still used today.

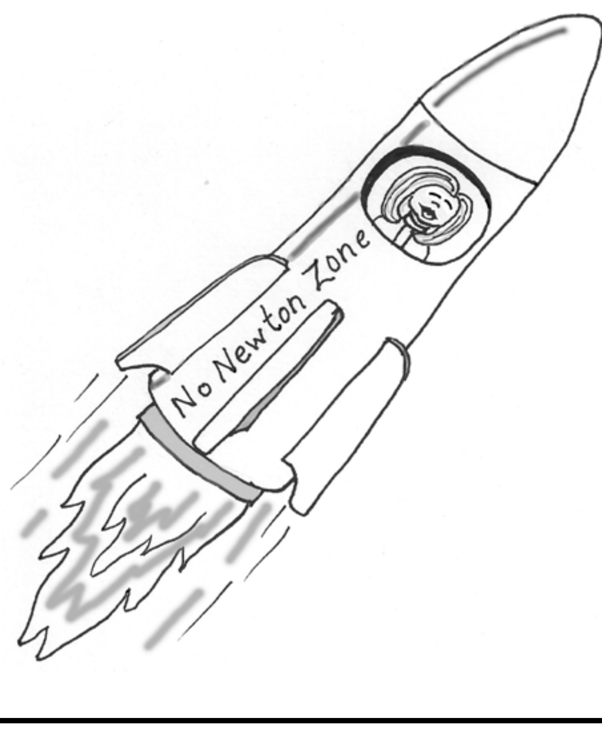
We're going to spend a lot of time learning about the answers that Newton figured out to his questions about how objects move. His answers are now called Newton's laws of motion. Newton's laws are very different from laws that make it a crime, say, to steal something. A scientific law describes what always happens given certain conditions. Every time you stand in front of your house and drop a stone with nothing in the way, it will

For my notebook - page 2

fall to the ground. This is something we know from the law of gravity, another scientific law attributed to Newton.

A scientific law also lets us predict what will happen. Using the laws of motion, I can predict that when I push a toy car across the floor, it will go for a certain distance and then stop. But in order to make this prediction, I need to know that certain conditions exist. I need to know that I'm pushing the car on Earth, where there's gravity. I need to know that I'm holding relatively still. As conditions change, the results that a scientific law predicts might change.

You should know that there are certain conditions under which even Newton's laws fail to predict what will happen. Newton's laws of motion are valid in almost every circumstance you or I will encounter in our lives. But, if we were to fly on a spaceship going almost as fast as the speed of light, which is much faster than any spaceship has ever gone, we would find that Newton's laws don't quite work. Or, if we were really, really tiny, smaller than even an atom, Newton's laws would also cease to predict what would happen. However, as none of us is currently traveling as fast as light or has shrunk to a subatomic size, we'll do just fine using Newton's laws to study forces and matter.



NAME ______________________________ DATE __________________

For my notebook

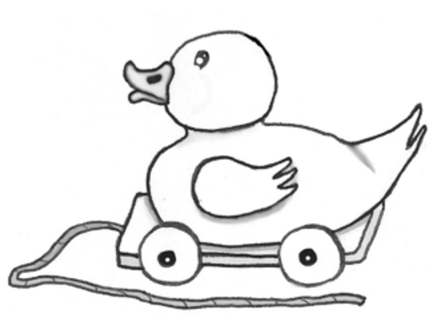
Newton's Laws: The First Law of Motion—Inertia

The first of Newton's laws is probably something you've understood all your life without really giving it much thought. Newton basically thought about what happens to objects when nothing happens to them! That is, he figured out what objects do when they're left alone. First, he broke this problem into two smaller problems:

(1) What happens to objects that are sitting still?

(2) What happens to objects that are moving at a constant (not slowing down or speeding up) speed?

Think about what happens to a book when you put it on the table. That doesn't take a lot of thought, does it? The book just lies there. And it remains there unless some outside force, some push or pull, occurs to move it. This is a demonstration of one part of Newton's <u>first law of motion</u>: **An object at rest tends to remain at rest unless an extra force is applied to it.** What does that mean? It means that if matter is holding still, it's going to keep holding still unless something pushes or pulls on it. The toy duck, below, will stay at rest unless a force is applied to it.



The next part of Newton's first law of motion is a bit trickier. What happens to an object that's moving if no other force acts on it? Think about throwing a ball. The ball is moving while it's in the air, and perhaps for a few seconds while it rolls on the ground. Does this mean that an object in motion tends to come to a rest? For centuries, people thought the answer was yes.

For my notebook - page 2

But Newton's answer was the correct, and very surprising answer: No! An object in motion does not tend to slow down and come to a rest! The second part of Newton's first law of motion states that: **An object in motion tends to remain in motion unless an extra force is applied to it.** The toy duck is rolling now, and it will continue to roll along unless an extra force is applied to stop it or slow it down.

So why when you throw a ball up into the air, does it land on the ground and just sit there? Shouldn't it continue to move? The main reason is that there is a force acting on it—gravity. Gravity pulls the ball to the ground whenever you throw it into the air. But what if there were no gravity? What if that ball were out in space, where there is no gravity to pull it and where there are no air molecules to push against it? Newton's law tells us that if the ball were moving in a gravity-free area of space without any air, it would keep on moving forever unless it encountered some force, like a planet's gravity, or another ball crashing into it. Basically, Newton's law states that an object tends to keep doing whatever it's doing unless something happens to change that. Newton called this tendency to stay at rest or in motion inertia, which is what our next experiment is going to explore.

Note to Parents and Teachers: You may have noticed the phrase "extra force" in this reading. An object at rest has many forces acting on it—as was discussed in a previous lesson. In physics, this is actually called a net force—meaning that the net force must change in order for an object at rest to move, or vice versa. The idea of an "extra" force that causes an object to change from rest to motion was used to help younger students understand the concepts.

Newton's Laws Lab #2: Inertia and You! - instructions

Materials:

- Lab sheets, pencil
- Drawing materials
- A toy vehicle with wheels and a relatively flat top, something a bit larger than a tiny matchbox car
- A small toy figure (a small plastic figure of a person or animal, 1-2 inches tall)
- Small rectangle of cardboard or card stock, about the size of the toy car
- Tape
- A flat, smooth surface like a wooden floor or tabletop.

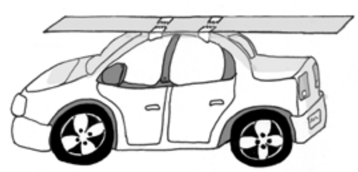
Aloud: It's probably no big surprise to you that objects that are staying still tend to stay still, and that objects that are moving keep moving unless something pulls or pushes them. Newton, however, wasn't satisfied to describe <u>inertia</u> in this general way. He asked himself several questions (scientists are ALWAYS asking questions): How much does an object tend to stay at rest or in motion? How hard is it to change an object from standing still to moving? Do some objects in some situations have more inertia than other objects? Does this make it more difficult to move them if they are at rest?

Think about these questions for a moment. If a brick and a block of foam are sitting on the table, which one is easier to push? Which of the two resists a change in its resting state more? What makes the brick different from the foam? Can you think of a rule that would help us to predict which objects have more inertia and which have less?

If you figured out that an object's mass is what determines its inertia, you came to the same conclusion as Isaac Newton. The heavier an object, the harder it is to change its state—to move the object if it's at rest, or to stop it if it's already moving. Because the brick has more mass than the foam, the brick is harder to push from a state of rest. This would be true even in space! Because of this, we say that the brick has more inertia than the foam block. Inertia isn't some distant characteristic of matter that only physicists think about. Inertia affects almost everything we do here on Earth. For example, inertia is very important to engineers and scientists who design cars. In this experiment, we're going to find out why the safety of passengers in moving vehicles depends so much on the effects of inertia.

Procedure:

1. Tape or attach a rectangle of cardboard onto the top of the toy car or truck. The idea is to make a platform that you can stand the other little toy on top of.
2. Place the car on a flat surface and stand the toy figure on the middle of the platform you made.



3. Fill in #1 on your lab sheet.
4. Watch carefully as you put your finger on the back of the car and give it a gentle push. Be careful to push only the car and not the toy on top of it. Watch what happens to the toy on top of the car.
5. Fill in #2-#4 on your lab sheet.
6. Fold the back of the cardboard platform up so that it makes a little seat-back for your toy figure.
7. Before you give the car a push, fill in #5 on your lab sheet.
8. Now, give the car a gentle push and observe what happens. Fill in #6-#8 on your lab sheet.

[continued]

Newton's Laws Lab #2: Inertia and You! - instructions page 2

Aloud: The first time you pushed the car, the toy figure's inertia caused it to be left behind—falling backward as the car moved forward. This was because it was trying to stay at rest and not move with the car. The second time you pushed the car, there was a seat-back behind the figure. Because the cardboard seat was attached to the car, when you pushed the car, you were also pushing the seat. And the force of the seat moving forward was strong enough to push the toy figure as well—overcoming its inertia.

When designing cars, safety engineers have to think about what will happen to the people in the cars as the cars move forward and backward. They also need to think about what will happen to the people in the car if the car is moving forward but comes to a sudden stop. We're going to model what happens by pushing our car with a seat and a toy figure into a wall. But before we do, use what you know about inertia to come up with a hypothesis of what you think will happen. Remember—the car, the seat, and the figure will all be in motion when they hit the wall.

9. Fill in #9 on your lab sheets.
10. Place the car on the ground a few feet from a wall. Place the figure on the seat, toward the rear of the car. Give the car a gentle push toward the wall and watch what happens to the figure when the car hits the wall.
11. Complete the remainder of the lab sheets.

Possible Answers:
#2: the figure should fall backward
#3a: at rest; #3b: at rest; #3c: stay at rest; #3d: started moving; #3e: stay still
#4: backward
#6: moved along with the car
#7a: at rest; #7b: was not attached; #7c: the back of the seat
#8: strong enough
#10: was thrown forward
#11: came to rest
#12: stay in motion / keep moving forward until it hit the wall

Conclusion and Discussion:
1. Using words like "force" and "inertia," talk about what happened to the toy figure when the car was pushed and when the car hit the wall.
2. You may not know this, but about 30 years ago, most of the seat belts in cars were "lap belts." They only went around a person's waist. When people were in a car crash, they would often injure their head. Can you figure out why, now that you understand inertia?
3. Once engineers developed shoulder seat belts, there were fewer head injuries. But other kinds of injuries were common, such as neck injuries and injuries to parts of a person's torso. Can you figure out what was happening? Do you know what we use now to solve this problem?

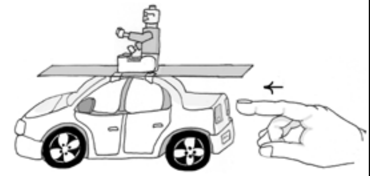
More Lab Fun:
1. The next time you go on a car ride, pay attention to how inertia works. When the car starts moving, can you feel your seat back push against your back? When the car comes to a stop, do you feel yourself pushed forward a bit? What do you think your body wants to do when the car goes around a curve? See if you can pay attention and find out.
2. Try running as fast as you can in a straight line. Is it hard to come to a sudden stop? Once again, inertia is propelling you forward when you're trying to stop. Cool!

Notebooking Ideas:
1. Use a definition page to define *inertia* and *equilibrium*.
2. Make a list of some of the things you do during the day to overcome inertia.

NAME ______________________________ DATE __________________

Inertia and You!

EXPERIMENTING WITH A FIGURE AT REST ON A MOVING PLATFORM:



1. **Hypothesis:** When I push the car, I think that the toy figure will **move along with the car** / **fall backward** / **fall forward**.

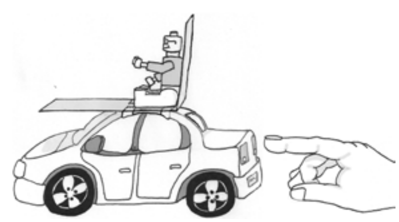
2. **Observation:** When I pushed the car, the toy figure **moved along with the car** / **fell backward** / **fell forward**.

3. **Data Analysis:**
   - A. Before I pushed the car, the car was **at rest** / **in motion**.
   - B. Before I pushed the car, the toy figure was **at rest** / **in motion**.
   - C. According to Newton's first law of motion, an object at rest will **tend to stay at rest** / **start moving until something pushes or pulls on it**.
   - D. I pushed on the car, so it **stayed still** / **started moving**.
   - E. I didn't push on the toy figure, so it tried to **stay still** / **move forward**.

4. **Conclusion:** Because of inertia, the toy figure fell **backward** / **forward** when the car was pushed.

EXPERIMENTING WITH A FIGURE AT REST ON A MOVING SEAT:

5. **Hypothesis:** When I push the car, I think that the toy figure will **move along with the car** / **fall backward** / **fall forward**.



6. **Observation:** When I pushed the car, the toy figure **moved along with the car** / **fell backward** / **fell forward**.

Inertia and You! - page 2

7. Analysis:

A. The car and the toy figure began **at rest** / **in motion**.

B. The seat I made out of cardboard was attached to the car. So when I pushed the car, I was also pushing the cardboard seat. But, the toy figure **was also attached** / **was not attached to the car**.

C. When I pushed the car with the seat, the toy figure moved along with the car because it was pushed by **gravity** / **the back of the seat**.

8. **Conclusion:** Although the toy figure started at rest and wanted to stay at rest, it started to move with the car and the seat. The force of the seat back pushing on the figure was **strong enough** / **too weak** to overcome the toy figure's inertia.

EXPERIMENTING WITH A FIGURE IN MOTION:

9. **Hypothesis:** When the car with the figure in the cardboard seat runs into the wall, I think the figure will **stop where the car stops** / **be thrown forward** / **be thrown backward**.

10. **Observation:** When I pushed the car into the wall, the toy figure **stopped where the car stopped** / **was thrown forward** / **was thrown backward**.

11. **Data Analysis:** When I pushed the car, the car, the seat, and the figure all moved from being at rest to being in motion. When the car hit the wall, aside from any bouncing, the car **came to rest** / **kept moving forward** / **made a huge hole in the wall**.

12. **Conclusion:** The figure in the seat wasn't attached to the car. Once it was in motion, Newton's first law says that it would tend to **stay in motion** / **come to rest**. Therefore, Newton's first law would predict that the figure would keep moving forward until it **hit the wall** / **stopped when the car stopped**. And that is what happened!

NAME ______________________________ DATE __________________

Physics in Action: Preventing Injuries in Car Accidents

Putting It All Together:

Now that you understand how inertia works, you know a lot about what engineers need to think about to prevent injuries during an automobile collision. Can you invent a new way to prevent injuries in head-on collisions if we didn't use seatbelts? What would it look like? What part, or parts, of the body would it protect? Draw a picture of your "inertia protection invention" below. Then turn over the page and describe your invention; explain how it protects against the effects of inertia.

Physics in Action: Preventing Injuries in Car Accidents - page 2

My Inertia Protection Invention

Newton's Laws Lab #3: Inertia Can Be Dizzying! - instructions

Materials:

- Lab sheets, pencil
- Paper cup (you need to write on it with marker or pen, so a plastic cup might not work)
- Permanent marker or pen

Aloud: Inertia affects not only the world around you, but also the world inside of you! You might not know this, but inertia plays a role in how your brain and body work together. Do you know why you get dizzy when you spin in circles? The answer might surprise you: It's because of how inertia affects some liquid inside your ear! There's an area inside your ear called, appropriately, your <u>inner ear</u>. Your inner ear is covered with a layer of tiny little hairs, called <u>cilia</u> (sil-ee-uh). This space is partially filled with liquid. As you move around, the liquid in your ear moves around. And as the liquid in your ear moves around, the tiny cilia swish around. Your brain detects this motion and uses it to keep track of where your head is, and whether it is moving, holding still, or tilting in some direction or another. Your brain uses this information to interpret what your other senses perceive, like what you see around you, and whether the world you see is moving, holding still, or tilting.

We're going to make a simple model of your inner ear to investigate what happens to the liquid when different forces are applied.

Procedure:

1. Get a paper cup. The paper cup is going to be your model of an inner ear.
2. Take your marker and make little lines or dots all over the inside of the cup. These little lines or dots represent the hairs (the cilia) in the inner ear. Make sure they are everywhere inside the cup—on the bottom of the cup and on all sides of the inside of the cup.
3. Fill the cup about one third of the way with water.
4. You've made a lovely model of an inner ear. Are you surprised that a model can be so simple? Sometimes, scientists use very simple models to focus closely on just one aspect of what they are studying. Draw a picture of your model in the space provided on the lab sheet.
5. Think about having something like the model inside your ear. What would happen to the liquid if you jumped up and down? Which of the "hairs" would sense liquid swishing past them? What if you tipped your head to the left? To the right? What if you spun around in circles? Imagine doing these things and fill in #1-#4 on your lab sheet. Don't forget about inertia when you fill in #4.
6. Pick up the cup and tilt it a little way to the left. Mark your observations on the lab sheet (#5). Notice how different "hairs" are touched by the water when the cup is tilted. Tilt your head a bit to the left and think about how the liquid in your inner ear behaves like the liquid in your model.
7. Repeat step 6, but tilt the model to the right. Fill in #6 on the lab sheet.
8. Pick up the cup and swish the water in circles. Stop, and immediately put the cup on the table. Observe the water. Record what happens (#7), paying attention to whether the water stops moving at the same instant you stop moving the cup. Think about what the hairs in the inner ear would be sensing if this were happening inside your ear.
9. Fill in #8-#11 on the lab sheet.

[continued]

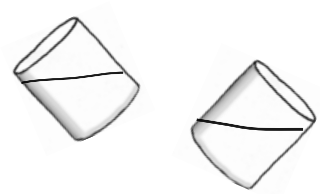
Newton's Laws Lab #3: Inertia Can Be Dizzying! - instructions page 2

Aloud: Now you can see how gravity and inertia interact with each other in your inner ear. The liquid in your inner ear stimulates different hairs depending on how you're holding your head—straight up, sideways, or tilted in one direction or another. When you move around, the liquid in your inner ear moves as well, just like the little figure we placed on the car shifted forward when the car moved in the previous experiment. Sometimes, because of inertia, the liquid in your inner ear needs some time to catch up with what your body is doing. For example, when you spin in circles, the liquid is pushed from a state of rest to a state of motion, swishing around inside your ear.

When you stop spinning, the liquid in your ear takes a few seconds to stop spinning around because an object (liquid) in motion tends to stay in motion unless another force (like gravity) acts on it. So, when you stop spinning, the liquid in your ear keeps spinning for a few seconds. You may be holding perfectly still, but your brain receives the message that your head is moving in circles! Let's find out what your brain makes of this situation.

10. Find an open, safe space. Spin around in circles a few times, until you get just a bit dizzy. Open your eyes and look at the room. What do you see? Are you actually moving? Is the room actually moving? When you feel steady again, fill in #12 and #13 on the lab sheet.

Possible Answers:



#7. keeps moving for a moment
#8. starts moving
#9. inertia, gravity
#10. keeps swishing around before coming to a stop
#11. still turning in circles
#12. the room still turning in circles
#13. the liquid in my inner ear is still spinning even though I have stopped, because of inertia

Conclusion / Discussion:
1. Liquids, like all matter, obey Newton's laws of motion. Talk about why this results in confusion when you spin around.
2. We learned how observing the world closely is an important part of science. But as we just saw, sometimes even our eyes can fool us. This is why scientists use not only all of their senses but also measuring devices to make their observations. Can you think of some examples of scientific measuring devices?
3. Can you think of other times when inertia "fools" your brain?

More Lab Fun:
1. Watch a video of a skater or dancer spinning in circles. How do such performers spin so quickly without getting dizzy? The answer involves what they do with their head and eyes while spinning. Watch closely to see if you can figure it out.
2. If you're interested in how our brains and eyes work together to interpret our world, you might want to get a book from the library about optical illusions. Try to find a book that explains why our brains misinterpret the illusions.

NAME ______________________________ **DATE** __________________

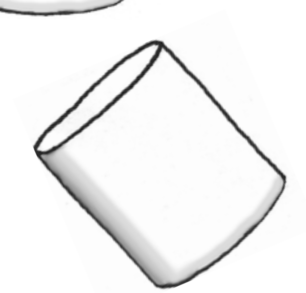
Inertia Can Be Dizzying!

Draw your model of the inner ear here. Be sure to show how high the water reaches.

Hypotheses:

1. When the model of the inner ear is still and sitting on a flat surface like a table, the waterline looks like this:

2. I think that if I were to tip the model to the left, the waterline would look like this:



3. I think that if I were to tip the model to the right, the waterline would look like this:

4. If I were to spin the model in circles and then stop spinning it, I think the water would (describe what you think would happen):

____

____

____

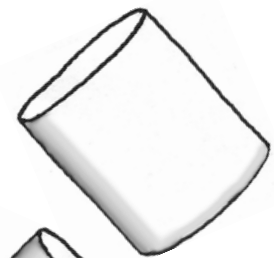
____

____

Inertia Can Be Dizzying! - page 2

Observations:

5. When I tip the model to the left, the waterline looks like this:



6. When I tip the model to the right, the waterline looks like this:

7. When I swish the water around in circles and then stop, the water

____.

Data Analysis and Conclusions:

8. Newton's first law says that an object in motion tends to stay in motion. When I swish the water in the cup, the water **starts moving** / **holds still**.

9. When I stop swishing the water, the water's **inertia** / **gravity** keeps it moving in circles until the **inertia** / **gravity** of Earth causes it to settle back down.

10. The inner ear sends messages to my brain based on what the little hairs inside my inner ear sense. If I were to turn around in circles and then stop, the liquid in my inner ear would **stop immediately** / **keep swishing around before coming to a stop**.

11. So even if I were standing still, my brain would be getting messages that I was **running forward** / **still turning in circles** / **floating away**.

So What?

12. When I spin in circles and then stop and look around, I see: ____________________

____.

13. This happens because ____

____.

NAME ______________________________ DATE ___________________

For my notebook

Newton's Second Law—From Aristotle to Newton

When people talk about how fast an object, like a car, can move, they usually talk in terms of how far it can go in a certain amount of time. For instance, you've probably seen road signs indicating that the speed limit for cars is 55 MPH, or 55 miles per hour. That means that if a car were traveling at that speed, it would travel 55 miles in one hour. Physicists call the speed of an object in a particular direction its <u>velocity</u>.

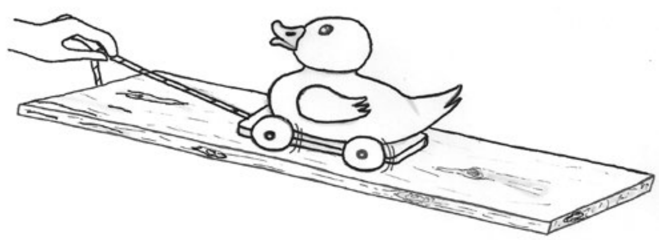
We can rephrase Newton's first law of motion using the idea of velocity: An object's velocity remains the same unless some net force acts on it. This is just the same as saying that an object that is holding still (with a velocity of zero) will continue to hold still until something pulls or pushes it in a particular direction. It is also the same as saying that an object that is moving will continue to move until something pulls or pushes it in a particular direction. Newton's first law has to do with how objects behave when they're left alone.

Newton's <u>second law of motion</u> describes what happens when objects are pulled or pushed by a force. **The second law talks about how a force can change the speed and direction of an object**. <u>Acceleration</u> is the word that physicists use to describe a change in speed or velocity. Any time something speeds up or slows down, it is experiencing acceleration. Some people say that slowing down is called deceleration, but we'll just call any change in velocity, acceleration. You may have heard people talk about a fast car that "goes from zero to sixty miles per hour in 10 seconds." What this is describing is how quickly the car accelerates, how quickly it changes its velocity from zero (holding still) to 60 MPH (going pretty fast).

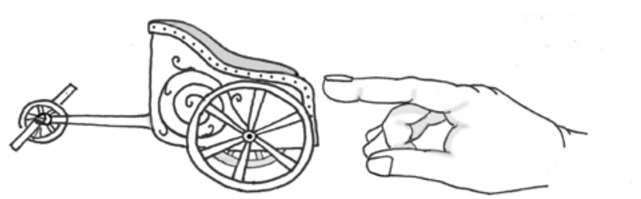
This all might seem pretty straightforward, but the difference between velocity and acceleration confused the brightest minds for hundreds of years. Think about this statement for a moment: In order to keep an object moving at the same speed, a force needs to be applied to it continuously. For

For my notebook - page 2

example, to keep a toy duck moving at the same speed, you need to keep pushing or pulling it. Do you think that statement describes how objects behave?



The famous Greek philosopher and scientist **Aristotle** thought that was an accurate statement (though he probably thought about toy chariots instead of ducks). And as far as observations of objects on Earth go, just about everyone thought that Aristotle was correct: If you push a toy duck (or a toy chariot), it will slow down and then stop. To keep it moving, it seems that you must keep pushing or pulling on it.



But there was a big piece of the picture that Aristotle was missing. He never thought about what happens to objects in an area with no outside forces—no gravity or air molecules pulling or pushing against objects. As you know, if you give a car a push out in space, it will keep going at the same speed forever unless it runs into something like a planet with gravity. Even for objects on Earth, Aristotle wasn't precisely correct, as we'll discover in our next experiment.

Newton's Laws Lab #4- You've Got to Keep It Moving - instructions

Materials:
- Lab sheets, pencil
- A toy with wheels. The toy should have a place you can tie or tape a string to pull it along behind you.
- A piece of string about 5 feet long
- A large flat area

Aloud: According to Aristotle, if I keep pulling on an object with the same amount of force, I'll keep that object moving at a steady speed. He would say that the velocity would remain constant and there would be no acceleration. Newton disagreed. According to Newton, an object in motion tends to stay in motion—without needing some force to keep pulling or pushing it. Newton would say that if I were to keep pulling on an object with the same amount of force, its velocity would change. In scientific terms, Newton would say that the object would accelerate and start to move more quickly if I continued to apply a force to it.

Let's find out whether Aristotle or Newton is correct.

Procedure:
1. Tie the string around the toy (or tape it to the toy) so that you can pull it along and the wheels can still turn freely. Usually tying the string to the front of the toy toward the center works best.
2. Fill in #1, #2, and #3 on your lab sheet.
3. Go to one side of a large flat area. Walk in as straight a line as you can at a steady pace and pull the car behind you. Observe what happens: Does the toy keep going at the same speed (leaving the string straight), or does it start going a bit faster, so that the string becomes slack and is no longer pulling on it?
4. Fill in #4 and #5 on your lab sheet.
5. Complete #6 and #7 on the lab sheet.

Possible Answers:

#1: Aristotle believed that the object would keep moving at a constant speed.
#2: Newton believed that the object would accelerate, its velocity would change.
#4: The string should be drawn taut.
#5: The string should be drawn loose (and the toy is moving faster, so it is closer to the child)
#6: The toy accelerated. As I walked, the string became less taut and the toy started to catch up to me.
#7: Newton was correct.

Conclusion/Discussion:
1. Imagine that you are planning the first spaceflight to the moon. What difference would it make in your plans if you believed Aristotle was correct rather than Newton? How would this change your spaceship design? [Hint: If you are having trouble figuring this out, think about it this way: Once your spaceship is in space and traveling at a constant velocity, what would Aristotle have said about whether you need fuel or engines to keep it going? What would Newton have said?]

[continued]

Newton's Laws Lab #4- You've Got to Keep It Moving - instructions page 2

2. Make sure that you understand that objects on Earth slow down because there are extra forces acting on them—forces like gravity and friction. Can you think of circumstances in which it would appear that Aristotle's ideas are correct? (Hint: other forces, like gravity and friction, would have to cancel out exactly a constant force on an object.)

Notebooking Ideas:
1. Use a definition page to define *velocity* and *acceleration*.
2. Draw a picture or write a story about what would happen if physicists had believed in Aristotle's idea of motion as described in #1 of the lab sheet.

NAME ______________________________ DATE __________________

You've Got to Keep It Moving!

1. What did Aristotle believe would happen if a person kept pushing on an object with the same amount of force?

____
____
____

2. What did Newton believe would happen in the same circumstances?

____
____
____

3. **Hypothesis:** Who do you think is correct, Aristotle or Newton? Can you explain why you think this person is correct?

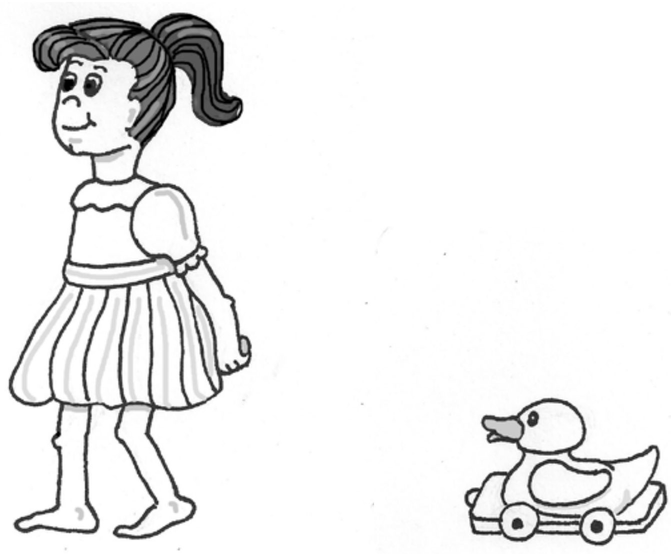
____
____
____
____

Observations:

4. Draw what the string looked like just as you started pulling the toy.

You've Got to Keep It Moving! - page 2

5. Draw what the string looked like at the end of pulling it.



6. Describe what you observed. How did the toy and the string behave when you pulled at a constant speed?

____

____

____

____

____

7. **Conclusion:** Who turned out to be correct, Aristotle or Newton?

____

____

NAME ______________________________ DATE __________________

For my notebook

Newton's Second Law: Momentous Momentum

Newton's first law is all about what objects will do if no new force disturbs them. If an object is at rest and no new force is applied to it, it will hold still. If an object is moving and no new force is applied to it, it will keep moving. But what happens when we don't leave objects alone? Newton's answers to this question make up his second of law of motion. I think these answers will seem pretty obvious to you.

First, **an object will move in the direction it's pushed**. Push a basketball away from you and it rolls away from you. It doesn't roll toward you, off to the left or right, or jump up into the sky. So the change in the basketball's direction depends on the direction of the force you applied to it.

Second, **the harder you push an object, the faster it will accelerate**. If you push the basketball harder, it will move more quickly than if you push it gently. In more scientific terms, the basketball's acceleration depends on the amount of force you use to push it.

Third, **the more mass an object has, the harder it is to push**. If a giant beach ball were rolling toward you, you could easily push it off in another direction. But what would happen if a giant ball of concrete the same size as the beach ball were rolling toward you? It might be traveling at the same velocity, but it will take a lot more force to push it out of the way because the concrete ball has a lot more mass than the giant beach ball.

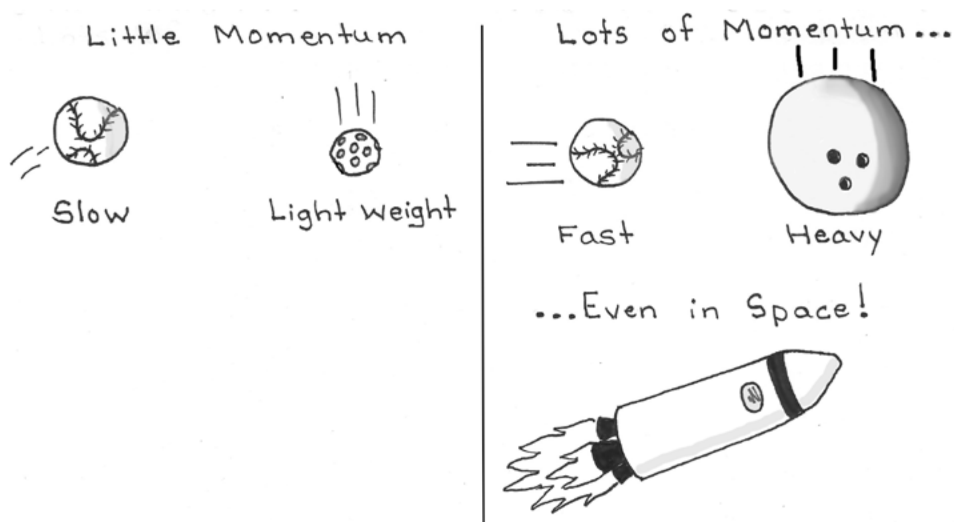
Now you know what Newton's second law of motion tells us, and you're probably thinking, well that's obvious! You could say all of this is very obvious. Why did it take someone like Isaac Newton to discover something like "an object will

For my notebook - page 2

move in the direction it is pushed" and "heavy things are harder to push than light things"? The answer is that Newton didn't really "discover" these laws. What he did was to find a mathematical way to describe and measure how an object behaves when a force is applied. He called the tendency of an object to keep moving in whatever direction it is moving <u>momentum</u>. The more momentum an object has, the harder it is to change its velocity or direction.

If you look closely at the three parts of Newton's second law of motion, you can probably figure out how to tell if an object has a lot of momentum or a little momentum. How much momentum an object has depends on two things—how fast it's moving and how much mass it has. An object that's moving quickly, even if it doesn't have a lot of mass, will have a lot of momentum. A fast baseball is much more difficult to stop than a baseball that was tossed gently into the air. And objects with a lot of mass have more momentum than objects with less mass. That's why the rolling ball of concrete is more difficult to push out of the way than the rolling beach ball, even if the rolling ball of concrete is moving slowly toward you.

The effects of momentum exist even in a zero-gravity environment like space. Rocket ships may weigh nothing because without gravity, there is no weight. But a fast-moving spacecraft will have a lot of mass and a lot of velocity. That means it will have a lot of momentum, so it will take a great deal of force to change speed or direction, even in space.



Newton's Laws Lab #5- Giving the Gift of Momentum - instructions

Materials:
- Lab sheets, Do Your Own Experiment sheet (located in the Appendix), pencil
- Several marbles—at least three of the same size, and at least two of different sizes
- Cardboard roll from paper towel or wrapping paper—you'll need to cut this, so not a really thick cardboard roll
- Pen or marker
- Basketball
- Tennis ball
- Flat surface
- Tape
- An open space to bounce a basketball (such as a driveway) with nothing breakable too close by. This part of the experiment is best done outside, because the height reached is often higher than a ceiling.

Aloud: So far most of what we've learned about Newton's second law of motion and momentum has probably seemed pretty obvious to you. But there's another aspect of momentum that I find truly amazing: momentum can be transferred from one object to another. Have you ever played with the balls on a pool table or crashed one marble into another marble? When a moving ball hits a ball that's holding still, the moving ball tries to transfer its momentum to the ball that was holding still. If the balls are exactly the same size and shape and mass, the moving ball will stop, having transferred its momentum to the other ball. The ball that was at rest now has the momentum and starts rolling.

This makes sense if you remember that momentum depends on two things: mass and velocity. If a moving object crashes into an object that is holding still, the moving object transfers all the momentum it can to the object at rest. We can observe how much of the momentum is transferred by watching how the velocity of the two objects changes. If the two objects are about the same mass, then the moving object will transfer pretty much all of its momentum in the form of velocity—it will stop moving and the object it hits will start moving.

Really amazing things start to happen when objects of different mass and velocity try to transfer momentum to each other. Let's see what those amazing things are.

Procedure:

<u>Preparation (can be done ahead of time)</u>

1. Cut the cardboard roll down the middle lengthwise so that you have two "canals" in which you can roll marbles.
2. Place the two halves end to end and tape together. Try your best not to have a bump in the middle that will interfere with marbles rolling. You're trying to make a longer track in which to roll marbles. Place the assembly on a flat surface.
3. Make a mark about an inch or two in from one end of your marble run. This is the starting mark. On the same half of the marble run, make another mark at the middle of that cardboard tube-half.

<u>Marbles of Equal Mass</u>

4. Get two marbles of the same size. Place one marble at the "starting mark" you made at one end of the marble run. Give it a medium-strength push with your finger. Try to push it straight along the marble run. Record your results (#1).
5. Using the same marble and another of the same size, place one at the starting line and one on the other mark you made in the middle of the tube half. Fill in #2 and #3 before you do anything else.

[continued]

Newton's Laws Lab #5- Giving the Gift of Momentum - instructions page 2

6. Give the marble at the starting line a medium-strength push with your finger. Try to make it as close to the same kind of push you did in step 4. Watch what happens. Try this a few times to see if you always get the same results. Sometimes, you might not push the marble exactly in a straight line, so your results might change. Figure out what usually happens. Record your observations (#4 and #5).
7. Play around with how hard you push the marble. If you push it harder, does the marble that began at rest move faster? What if you give the marble a very gentle push? Fill in #6.

Aloud: If everything in this experiment were perfect, the marble you pushed would stop exactly on the spot that the other marble sat. With practice, you can probably make this happen. But lots of factors can interfere with this experiment. Your cardboard tubes might not be perfectly smooth or level. Your push might not have been perfectly straight. The marbles might not have exactly the same mass. Most of the time, you should see the marble you push stop or roll a little ways after colliding with the marble that began at rest. This is because it will have transferred its momentum—mass x velocity—to the marble that started at rest. Because both of the marbles have about the same mass, most of this transfer takes the form of velocity—sending the second marble rolling--just about as fast and as far as the first marble would have, had there not been something in its way.

8. Fill in your analysis and conclusions (#7 & #8).

More Marble Experiments

9. Now that you understand how to set up a momentum experiment, you're going to set up a few of your own. There are some "Do Your Own Experiment" sheets included with the notebooking pages. You should design an experiment to test further what happens with marbles and momentum. You can use one experiment sheet to do the following: hit a smaller marble with a larger marble, place two marbles of the same size touching each other, and then roll a third marble into them, and one collision you design yourself. Fill in the "Do Your Own Experiment" sheet and write down your results. Pay attention to how far and how fast the different marbles roll.

Momentum Is So Cool

Aloud: You now have a pretty good sense of how the transfer of momentum works with marbles. Did you figure out that when a larger marble crashes into a smaller marble, two things happen? First, the larger marble doesn't stop—it keeps rolling, just more slowly. Second, the smaller marble not only starts to roll, but it actually ends up rolling more quickly than the larger marble does! If you didn't notice this, try it again and watch carefully.

Another thing you might have noticed is what happens when two marbles at rest are touching each other and a third marble crashes into them. In an instant, all the momentum from the moving marble is transferred to the marble in the middle. In that same instant, the momentum in the marble in the middle is transferred to the last marble, which rolls off down the marble run.

What do you think would happen if one of the marbles were not just a little more massive, but a whole lot larger than the marble it crashed into? We're going to find out by using a basketball and a tennis ball.

10. Go outside onto a surface on which you can bounce a basketball. Hold the basketball straight out in front of you and let it drop. Watch what happens. Try to remember about how high the basketball comes up the first time it bounces.
11. Repeat step 12 with the tennis ball. Don't throw it down on the ground. Let it drop.

[continued]

Newton's Laws Lab #5- Giving the Gift of Momentum - instructions page 3

12. Fill in #9 and #10.
13. Take a moment and think about this experiment: You're going to place the tennis ball on top of the basketball and let them drop. The basketball will hit the ground and bounce up. What will happen to the tennis ball? Write down your hypothesis in #11.
14. Try the experiment. Hold the basketball in front of you with one hand. Balance the tennis ball on top of it with the other hand. Let go of both balls at the same time. What happens? Were you surprised? Fill in #12 and #13.

Possible Answers:

#1: Will depend on what happens, but you should push hard enough to get the marble to travel all the way along the marble run.

#4 & #5: The marble that is pushed should either stop at the point of collision or travel a little bit farther. The marble that started at rest should start rolling and travel about as far as the marble that was simply rolled, with no other marble in the way, travelled. If you're having trouble, try pushing a little more gently or with a little more force.

#6: faster, faster

#7: momentum

#8: about the same, velocity

#12: The tennis ball should shoot off toward the sky, much higher than you'd anticipate.

#13: inertia, a lot, velocity

Conclusion/ Discussion:

1. Momentum depends on two characteristics—mass and velocity. Talk about how momentum changes from an object with a tiny mass to an object with a very large mass. How does this affect how we try to change those objects' movements? You could compare how we handle ping-pong balls to how we handle bowling balls.
2. Talk about how velocity affects momentum. Would you be able to catch a speeding baseball with your bare hand? Why or why not? What if it were a gently tossed baseball?
3. Remember that momentum can be transferred from one object to another. Talk about how this happens in the experiments you just performed. Do you think the energy and speed of the tennis ball in the tennis ball experiment could be used, say, to launch a rocket? Why or why not?

More Lab Fun:

1. Ideas for momentum experiments are endless. Experiment with lining up five marbles and roll two marbles toward them. What do you think will happen? What does happen? Why? If you find this fun, you might invest in a Newton's Cradle. This is the device that Isaac Newton used to experiment with momentum. It has swinging balls instead of marbles and offers a fabulous demonstration of the transfer of momentum.
2. Build a giant marble run using cardboard tubes, rolled-up paper, whatever you can find. Use what you know about physics to get it to work. Can you make a marble run that rings a bell at the end? That knocks over a paper cup? Give it a try!

[continued]

Newton's Laws Lab #5- Giving the Gift of Momentum - instructions page 4

Notebooking Ideas:

1. Use a definition page to define *momentum* and *transfer of momentum.*
2. Add momentum = mass x velocity (momentum = m x v) to an equation notebooking page.
3. Write story about what it would be like to be an ant on top of the tennis ball during the tennis ball/basketball experiment. This is not as silly as it seems. Physicists imagine this kind of thing all the time to understand how things look from the "frame of reference" or perspective of a particular object.

NAME ______________________________ DATE _______________

Giving the Gift of Momentum

MARBLES OF THE SAME SIZE AND MASS

Control:

1. When I push the marble along the marble run with nothing in the way, the marble **holds still** / **travels part way down the marble run** / **travels all the way down the marble run**.

Hypotheses:

2. When I push the marble at one end into the other marble, I think that the marble I pushed will **travel just as far and as fast as it did without a marble in the way** / **stop** / **travel a little less and a little more slowly than it did without a marble in the way**.
3. I think that the marble that was sitting still will **travel to the end of the marble run** / **stay still** / **travel part way down the marble run and stop**.

Observations:

4. When I pushed the marble at one end into the other marble, the marble I pushed **travelled just as far and fast as it did without a marble in the way** / **stopped** / **travelled a little less and a little more slowly than it did without a marble in the way**.
5. The marble that started out sitting still **travelled to the end of the marble run** / **stayed still** / **travelled part way down the marble run and stopped**.
6. The harder I push the marble, the **faster** / **slower** it goes. If I push the marble faster, the marble that gets hit travels **faster** / **slower**.

Data Analysis and Conclusions:

7. Without a marble in the way, the marble I pushed would have kept going toward the end of the marble run. Because there was a marble in the way, the marble I pushed transferred its **gravity** / **momentum** / **inertia** to the marble that started at rest.
8. The marbles have **about the same** / **very different** masses. Momentum depends on mass and velocity. Because the mass stayed the same, I saw a change in the **mass** / **velocity** of both marbles after they collided.

Giving the Gift of Momentum - page 2

MOMENTUM IS SO COOL…. A BASKETBALL AND A TENNIS BALL

9. When I drop the basketball, it bounces up to about my _______________. (knee, waist, neck—fill in whatever body part applies)

10. When I drop the tennis ball, it bounces up to my ____________________.

11. **Hypothesis:** When I drop the basketball with the tennis ball on top of it, I think the tennis ball will ____ ____.

12. **Results:** When I dropped the basketball with the tennis ball on top of it, this is what happened: ____ ____.

13. **Conclusion:** When a large object collides with a smaller object, it transfers **momentum** / **inertia** / **gravity** to the smaller object. Here, the basketball has a lot more mass than the tennis ball. When they collide, the basketball is moving upward after bouncing and the tennis ball is traveling downward from being dropped. They collide with a whole lot of velocity, so that the momentum involved is **a lot** / **not very much at all**. Because there's so little mass in the tennis ball compared to the mass in the basketball, the momentum transfer takes the form of an increase in the **velocity** / **mass** of the tennis ball.

NAME ______________________________ DATE __________________

For my notebook

Newton's Third Law: Lift-Off!

Newton's <u>third law of motion</u> is the easiest to state, but probably the toughest to understand. Here's what it says: **Every action has an opposite, but equal, reaction**. Let's look at this one a little bit at a time.

Imagine that you are hopping up off the ground. To keep things simple, we'll look at the interaction between two objects—your shoe and the ground. In this example, what does <u>action</u> mean? It means a force applied by one object to another object. When you jump, your shoe pushes down against the ground. That pushing force is an action.

So, what is a <u>reaction</u>? You probably know that in everyday language, "reaction" means that one thing happens in response to another thing. When your hand touches something that's too hot, you react by pulling your hand away. When you are happy, you react by smiling. When the dinner gets burned, you react by ordering pizza.

In Newton's third law of motion, reaction means that another force is applied in response to an initial force. Newton's third law describes what happens when two objects act on each other. When your shoe pushes down on the ground, the ground pushes back on your shoe. If it didn't push back, your shoe would go straight through the ground!

Newton's third law tells us that every action has an <u>equal and opposite reaction</u>. So, when you hop, the ground pushes back on your shoe with exactly the same amount of force as your shoe uses when it pushes down on the ground. That is why the reaction is called equal. And the ground pushes back on your foot in exactly the opposite direction as your shoe pushes on the ground. That is why the reaction is called opposite.

For my notebook - page 2

We can show these actions and reactions using a picture. The arrows in the picture represent forces—pushes or pulls. You might notice that the two arrows are the same size. This shows that they are equal forces. And you probably noticed that the arrows are pointing in opposite directions. This shows that the two forces are opposite.

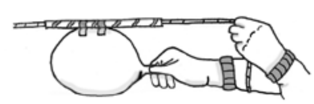
Physicists use arrows like these all the time to illustrate forces and their directions. The technical name for such arrows is vectors. There's a lot of advanced mathematics involved in using vectors, but for our purposes, it's enough to understand that the arrows show in which direction the force is acting and that the length of the arrow shows how big the force is. In the next experiment, you're going to use vectors to show some of the forces involved in propelling rocket ships.

Newton's Laws Lab #6- Rocket Science - instructions

Materials:
- Lab sheets (pp. 103-108: Rocket Science and Newton's Brain Teasers), pencil
- String, try to get 20-30 feet
- A few straws
- Several (6+) balloons of various shapes and sizes (some round balloons and some of the longer ones)
- Ruler or tape measure
- Strong tape
- Marker
- Clothespin (optional)

Aloud: One of the ways in which scientists use Newton's third law of motion is in propelling rocket ships. Inside the rocket ship's propulsion chamber, fuels are mixed and heated in order to produce lots and lots of gases—that's the smoke you see when a rocket blasts off. All of these gases are pretty much squirted out the bottom of the rocket at a very high speed. As you know, for every action (gases rushing out of the rocket) there is an opposite, but equal, reaction. So, the rocket is propelled upward by those gases shooting downward. Let's see if we can use these ideas to make our own little rocket ship.

Procedure:
1. Put the string through the straw. Tie the string to doorknobs, chairs, whatever you can find to make it taut and straight. If you have several people, you can take turns holding the string. For this experiment, try to get the string fairly level, so that it is parallel to the ground and not slanted up or down.
2. Use a marker to mark a "starting line" on the string. This starting line should be about 18 inches from one end of the string.
3. List the balloons you've gathered up on the first three columns on the chart on your lab sheet. You'll want to focus on their shapes and sizes. You're going to send these balloons racing along the string. What characteristic of the balloons do you think will affect which one goes the farthest? Which balloon do you think will go the farthest? Write down your HYPOTHESES (#1).
4. Now blow up one of the balloons, but don't tie off the end. While holding the end shut (a clothespin can help with this), tape the straw to the balloon as illustrated.
5. Line up the front of the straw with the starting line. Let go of the balloon and let the air out. Watch the little rocket go!



6. Measure how far the rocket went by measuring from your starting line to the point that the front of the straw reached on the string. Record your measurement on the last column of the chart. Complete the lab sheet.

Possible Answers:

5: To answer this question, children should understand that they could test two balloons of the same size and shape but of different colors.

Conclusion / Discussion:
1. Why does the balloon travel along the string when it is released? Talk about this in everyday language (the air pushes it) and in terms of Newton's third law—using words like action, equal, opposite, and reaction.
2. Does the fact that a reaction has to be "equal" help you to understand why some balloons travel farther?
3. Do you think this method would work in space? Why or why not? You'll be finding out the answer soon.

[continued]

Newton's Laws Lab #6- Rocket Science - instructions page 2

More Lab Fun:

1. Why do you think we used the string for this experiment? What happens if you release the balloon and it's not forced to travel along the string? Try it.
2. Can you figure out a way to get the balloon to travel straight up? Write down your design in your notebook and give it a try.

NEWTON'S BRAIN TEASERS (pp. 107-108): First, allow students to think through the brain teasers themselves using what they have learned about Newton's laws. Then read the following:

1. Jumping. **Aloud: You might remember from Newton's second law that more massive objects take more force to move than less massive objects. When you push your left hand against your right hand, the right hand pushes back with approximately equal force. Your left hand isn't significantly stronger or more massive than your right hand, so the two forces hold each other in equilibrium and your hands don't really move. On the other hand, Earth's mass is about 6,000,000,000,000,000, 000,000,000 (six septillion) kilograms. Your mass is probably around 30 to 40 kilograms. That's a HUGE difference in masses. When you push against Earth, you don't push with nearly enough force to cause a noticeable acceleration of Earth. But when Earth pushes back with the exact same force, it's enough to move your relatively little bit of mass up into the air a little ways. In fact, you do cause Earth to accelerate, but because of the huge difference in masses, the acceleration is so teeny-tiny, it pretty much can't be detected. Next time you jump, think about the fact that even a kid like you can move the whole planet, just a teeny-tiny bit.**

2. Rocket Ships. **Aloud: Here's a very interesting bit of history for you. More than 200 years after Newton described the laws of motion, people were still struggling to understand them. In the 1920s, a rocket scientist named Robert Goddard thought about Newton's third law when he was trying to figure out how people could travel to the moon. He realized that when the rocket pushes gas out of its engines, the rocket's acceleration is NOT caused by the air pushing against the ground. There are two objects interacting—gas and the rocket. The rocket pushes the gas out in one direction, and the gas itself pushes the rocket in the opposite direction. Robert Goddard realized that this meant that a rocket could propel itself through a vacuum without a problem. Even though this is a clear and easy example of Newton's third law, people made fun of Robert Goddard for his idea. But he was absolutely correct, and today NASA's Goddard Space Flight Center is named after him.**

3. Flies in a jar. **Aloud: Many people will answer that the jar weighs less when the flies are in the air than when they're all sitting on the bottom of the jar. But we know that the mass of the jar and the mass of the flies stay the same, right? Whether the flies are on the bottom of the jar or flying around, we haven't added or taken away any of the matter in the jar. The weight of the jar should stay the same.**

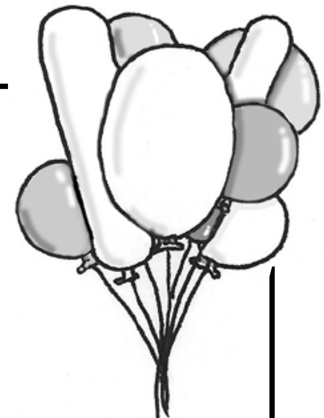
   Why do many people think that the jar will weigh less when the flies are in the air? Probably because they think that the weight of the flies—the force of gravity pulling the flies down—is no longer pushing on the bottom of the jar. But this isn't entirely true.

   Something is keeping those flies flying around and not on the ground—the flapping of their wings. Every time they flap their wings, the wings push down on air. And, as we've learned from Newton's third law, the air pushes right back, keeping the flies aloft. Meanwhile, an air current has been created that pushes against the bottom of the jar with about the same force as gravity on the fly. So, the weight of the jar stays pretty much the same, whether all the flies are on the bottom or all the flies are in the air.

Note to Parents and Teachers: Have some aluminum foil handy for the first reading in Unit 4.

NAME ______________________________ DATE __________________

Rocket Science



1. **Hypotheses:** I think the balloon that is ____________________ -colored, ______________________ -shaped, and __________________ -sized will travel the farthest. I think the **size** / **shape** / **color** of the balloon will affect how far the balloon travels (you may choose more than one characteristic). I think the **size** / **shape** / **color** of the balloon will NOT affect how far the balloon travels.

Observations:

Balloon Color	Balloon Shape	Balloon Size	Distance Traveled

2. What were the characteristics of the balloon which traveled the farthest distance? ____
____
____

3. What were the characteristics of the balloon which traveled the least distance? ____
____
____

4. Why do you think some balloons traveled farther than others? __________
____
____

Rocket Science - page 2

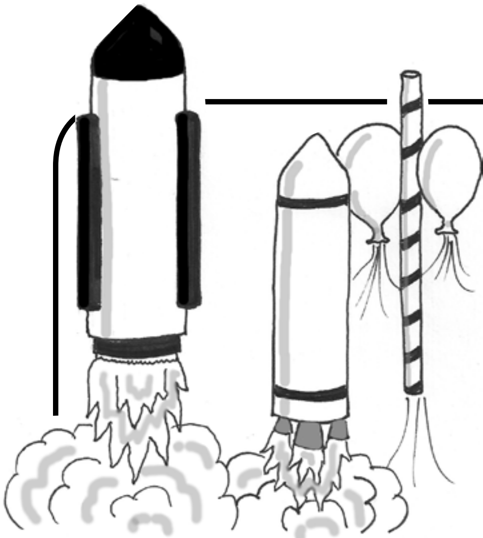
5. How might you find out if the color of a balloon makes a difference in how far it travels? ____
____
____

Draw a picture illustrating how your experiment was set up. Show the balloon, the string, and the straw. Use vectors to illustrate in what directions the forces on your balloon were applied. Don't worry about the size of the vectors for now.

Explain how this experiment illustrates Newton's third law of motion—that every action has an opposite, but equal, reaction.

____
____
____
____

Rocket Science - page 3



Here's a challenge for you:

Can you design a rocket that will travel farther than any of the ones on your chart? Maybe you could use two balloons? If so, what combination do you think will work best? Can you use the information you gathered earlier about the balloons to come up with some ideas?

Here's a sketch of what I tried:

Rocket Science - page 4

Here's a description of what happened. Try to describe not only how far your invention traveled but why you think it traveled farther or less far than the balloons in the first part of the experiment.

NAME ______________________________ DATE ___________________

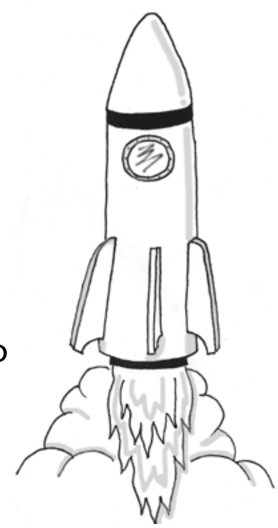
For my notebook

Newton's Brain Teasers

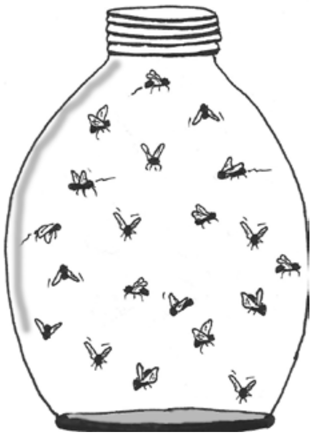
Newton's third law of motion is one of my favorite parts of physics. Why? I think it's because this law, more than almost any other, can make a person think really hard about how the world around us works. In fact, there's a whole series of puzzling questions that physics students have tried to figure out almost since Newton came up with his laws. So, get ready to think!

1. **Jumping**: Try pushing your hands against each other with about equal force. They don't move, right? But we've learned that when we jump into the air, our feet push down on the ground and the ground pushes up on our feet with equal force. Why is this different than when our hands push on each other? Why do we actually move upward when we jump? And, if we move up into the air a few inches, why doesn't Earth move downward a few inches?

2. **Rocket Ships**: We've learned that rocket ships are propelled upward by forcing gases at a high velocity out of their engines. A lot of people think that the gases push off of the ground (or off the air in the atmosphere) to keep the rocket moving. If this were true, rockets could not move around in the vacuum of space using their engines. What do you think? Can rockets move around in space by propelling gas out of one end? If so, why?



For my notebook - page 2



3. **Flies in a jar**: Imagine you could put 20 houseflies into a jar. Then, you put the jar into the refrigerator for a bit, to put the flies to sleep. With all the little critters asleep on the bottom of the jar, you weigh the jar on an extremely accurate scale. Then you wait for a while, until all the flies wake up and start buzzing around in the jar. You manage to find a time when they are all flying in the air in the jar and weigh the jar again. Does the jar weigh more than, less than, or the same as the jar did when all the flies were lying on the bottom? How come?

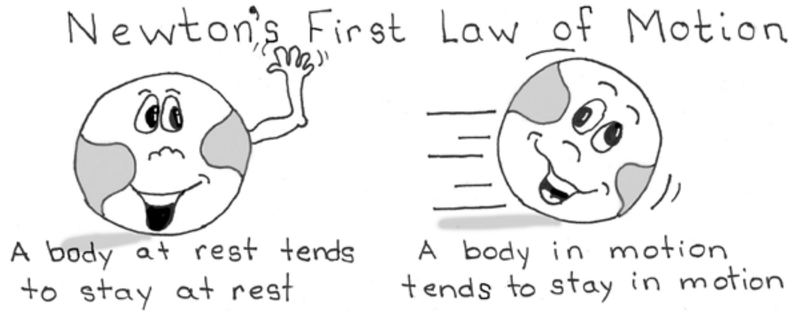
I hope you had some fun with these brain ticklers. The world around you is full of puzzlers like these. All you need to do is to look around and think about the forces at work on the objects you see. What happens when the car you're in comes to a sudden stop? What happens when you jump up in an elevator? What forces are at work when you pull on a wagon or ride a bike? Think about these or other questions, and write about your thoughts in your science notebook.

Newton's laws tell us so much about the world that it's really important to understand and remember them. The next page summarizes Newton's laws for you so you can have them all in one place in your science notebook. If you do copy work, you might want to copy these rules yourself. Try illustrating each law with a picture of an example.

NAME ______________________________ DATE __________________

For my notebook

Newton's Laws of Motion: A Summary

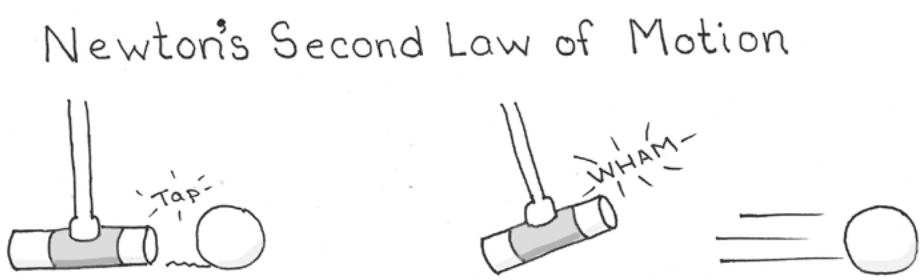


Scientific statement: An object at rest tends to stay at rest. An object in motion tends to stay in motion.

In everyday language: If something is sitting still, it will keep sitting still until something changes. If something is moving, it will keep moving, until something changes.

Also known as: Inertia

Examples: A cake sitting on a table stays there until you move it. A spacecraft will travel at the same speed through a gravity-free vacuum forever unless it runs into some force like the gravity from a planet. The liquid in your inner ear keeps spinning for a moment even when you've stopped spinning.



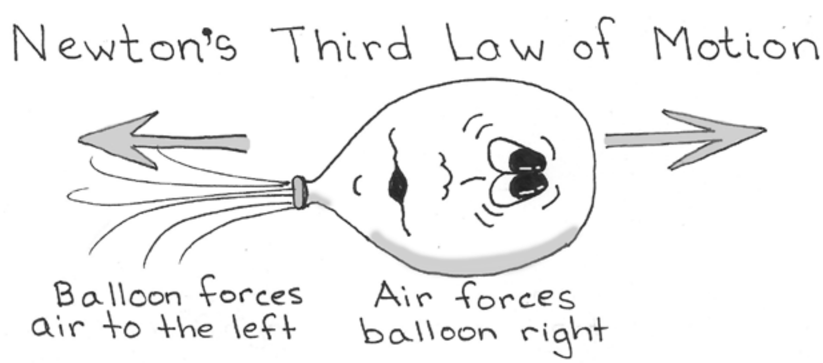
Scientific statement: The acceleration of an object is in relation to the force acting on the object and moves the same direction as the force.

In everyday language: 1) The more massive an object is, the harder it is to move. 2) Objects move in the same direction as you push (or pull) them. 3) The harder you push (or pull) an object, the more it speeds up.

For my notebook - page 2

Also known as: Momentum

Examples: A brick is harder to push than a beach ball. If you kick a ball forward, it goes forward, not left or right or backward. The harder you push (kick) on a ball, the faster it goes.



Scientific statement: Every action has an opposite, but equal, reaction.

In everyday language: When one object pushes on another, the second object pushes back in the opposite direction and with just as much force as the first.

Also known as: Conservation of Momentum*

Examples: A rocket ship blasting off, you standing on the ground without falling through, jumping off the ground, flies in a jar.

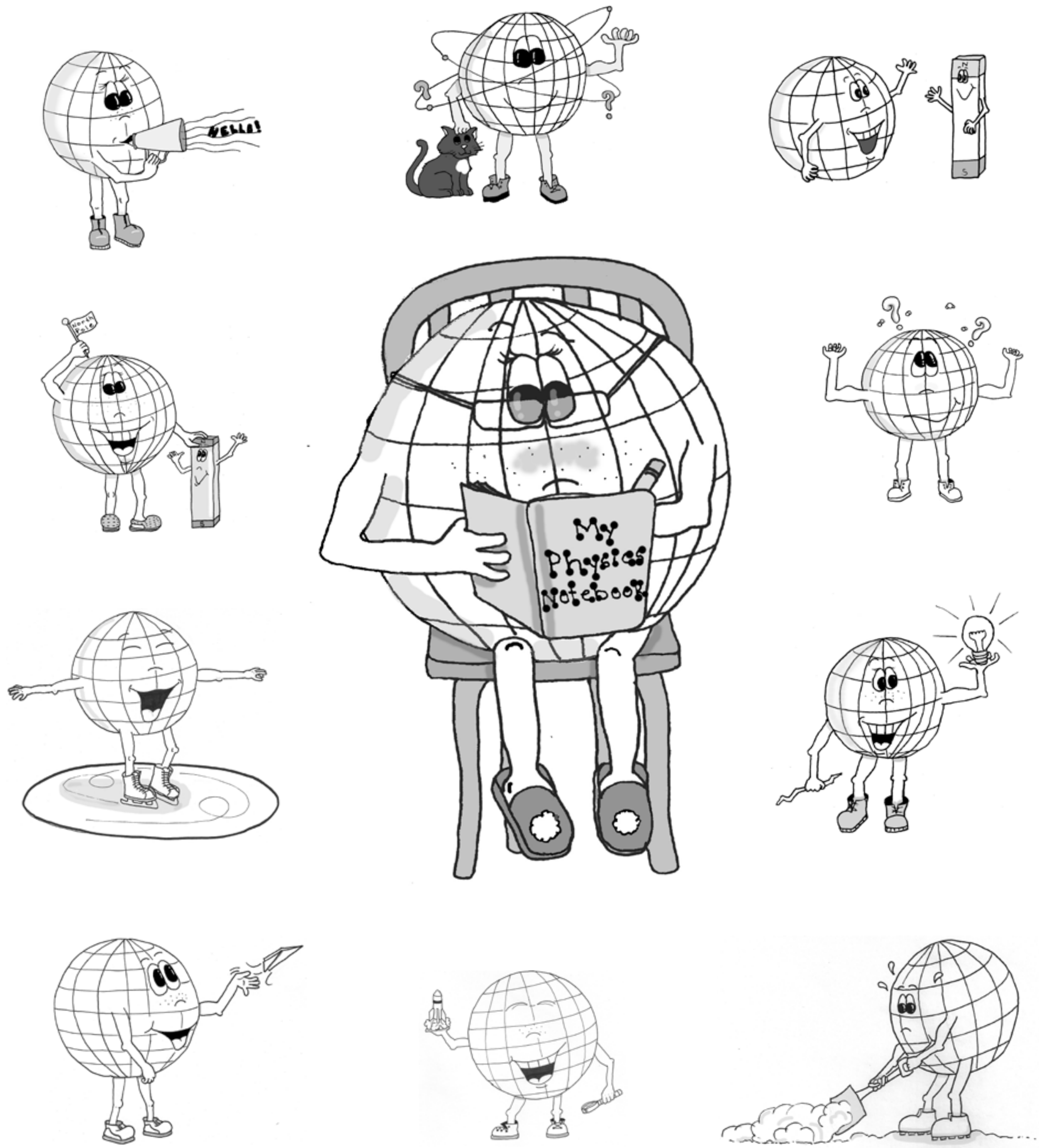
*This complicated name is because momentum in a system, like a rocket blasting off, is "conserved" in the following way: When momentum is given to the gases expelled from the rocket, equal and opposite momentum is given to the rocket to propel it forward. This way, no momentum is added to or subtracted from the "system" of the rocket and the gases being expelled. Therefore, physicists say that momentum has been "conserved."

Notebooking Pages

Cover sheet for your Physics Notebook - Cut, color, and glue to construction paper

Physics Notebook

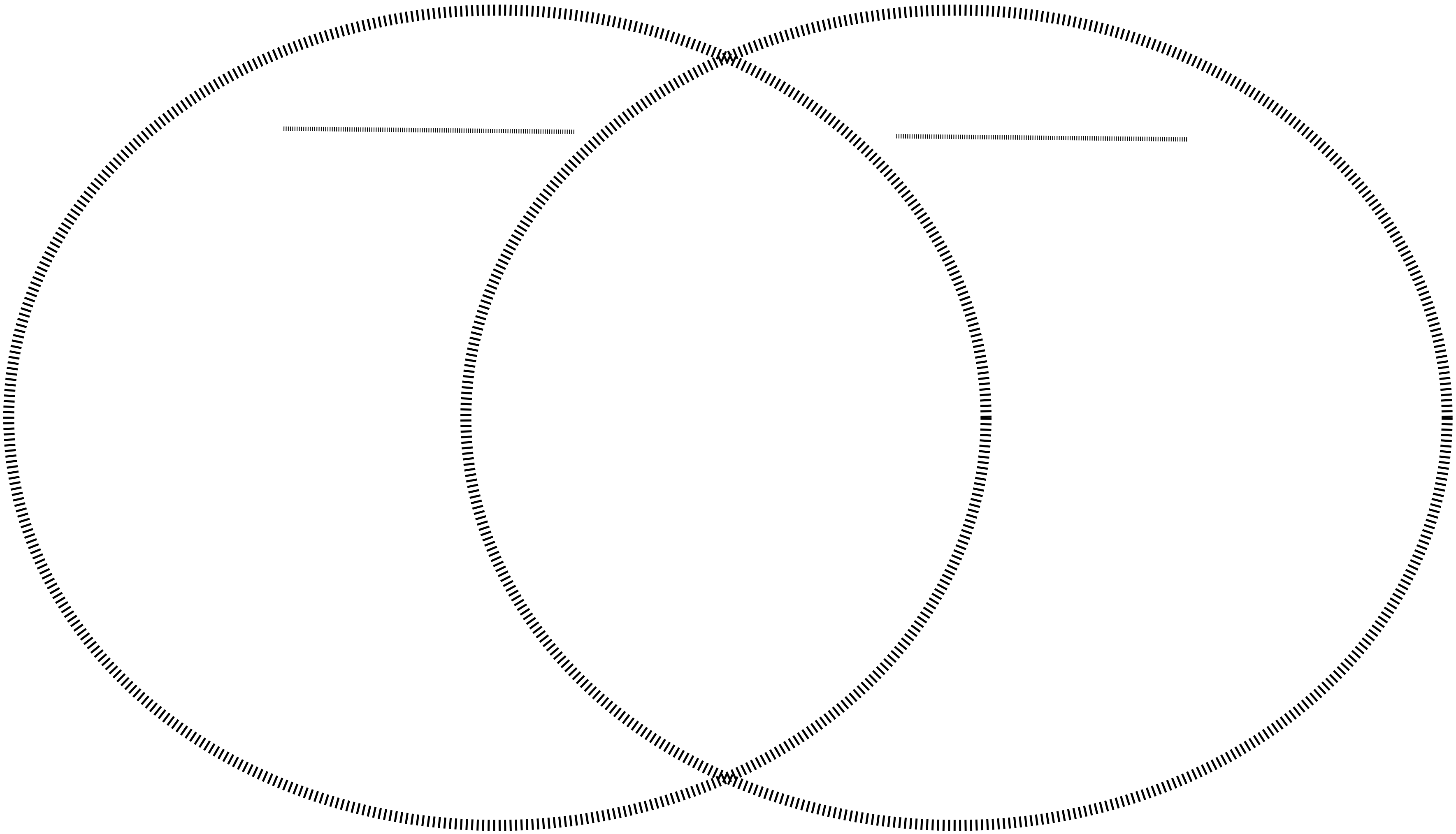
by ______________________________



NAME ______________________ **DATE** ____________

Notebooking - Venn Diagram

This Venn Diagram is about ____ .



NAME ______________________________ DATE ________________

Notebooking - Definitions

Important definitions I learned while studying ____________________ .

Word:

Definition: ______________________________

Word:

Definition: ______________________________

Word:

Definition: ______________________________

Word:

Definition: ______________________________

Notebooking - Definitions

Important definitions I learned while studying ________________________ .

Word:	Definition: ________________________

Word:	Definition: ________________________

Word:	Definition: ________________________

Word:	Definition: ________________________

NAME ______________________________ DATE ________________

Notebooking - Do Your Own Experiment!

Experiment Title: ____

(Title should explain what the experiment is about, like "Momentum & Marble Collisions.")

Materials I will need:

____

____

____

The question I'm trying to answer with this experiment is:
(Make sure you include what scientific idea you are exploring—for example, momentum.)

____

____

____

My Hypothesis—What I think will happen and why I think that is:

____

____

____

Here is what I am going to do: (draw a picture, describe it in words, or both)

Notebooking - Do Your Own Experiment! - page 2

☐ I have reviewed what I'm going to do with an adult and the adult said it is okay.

Observations: When I did the experiment, this is what happened:

Analysis and Conclusions: What I learned from doing this experiment: (You might include: (1) whether your hypothesis was correct; (2) why you think what occurred happened; (3) what scientific idea the results show; (4) what you think could have interfered with your results; (5) what further experiments you might do to explore these ideas more.)

NAME ______________________________ **DATE** ________________

Notebooking - Equations

An Equation about ____

____

The equation:

The letters in the equation stand for:

Describe what this equation tells us about physics in your own words:

____

____

____

____

____

____

Other notes about this equation:

____

____

____

____

____

NAME ______________________________ **DATE** ________________

Notebooking - Equations

An Equation about ____

____

The equation:

The letters in the equation stand for:

Describe what this equation tells us about physics in your own words:

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Other notes about this equation:

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NAME ______________________________ **DATE** _________________

My Lab Report for ____

Statement of the Problem: (What question are you trying to answer with this lab?)

Hypothesis: (In a complete sentence, write a possible solution to the problem. Given what you know before you conduct the experiment, what do you predict the result will be?)

Materials: (A list of all the materials used in the lab.)

Procedure: (A step-by-step list. You may include sketches of the lab setup and steps. Continue on the next page and attach extra sheets if necessary.)

Observations and Data: (Describe what happened without judgement. Include any calculations, observations, sketches, graphs, and charts. Attach separate sheets if necessary.)

Conclusion: (Describe the result—the answer to the problem question. Did the result match your hypothesis? Explain why it did or did not. Discuss any errors and problems with the lab.)

Thank you for previewing RSO Physics (level one). We hope you are enjoying the course so far!

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