Playground Physics

by Dr. Mary Urquhart

Introduction

Playground Physics is designed as an introduction to some basic concepts in classical mechanics for upper elementary and middle school grades (4-7). The idea is to use the experience children have on the playground and relate that experience to basic physics concepts. For the younger children (grades 4 and 5) the experience is meant to be almost entirely conceptual, but for the older children, there should be a slightly more formal and mathematical approach. The unit is designed so that each of the 3 sections may be done independently on different days, or all in one special "physics in the park" day with a prior introduction and later follow-up. The sections are: **jungle-gym drop** to explore how gravity affects falling objects, **see-saw physics** to explore the concept of levers, and **swing-set physics** to explore the concept of pendulums. Slides can be used to study objects on inclined planes, and merry-go-rounds to explore concepts involved in circular motion (angular momentum, centripetal acceleration, centrifugal force, and instantaneous velocity). This unit is **not** intended as a replacement or alternative to the well established idea of taking physics classes to an amusement park. Rather, this unit is intended for a younger age group for whom the simple equipment of the playground is something with which they have everyday experience.

Time requirements:

The unit is intended to take minimal time. Each of the three sections can be done separately, perhaps one a week, or one a month. The introductions and follow-ups for each section need not be long or complicated depending on the needs and objectives of the teacher. If a single day approach for all 3 sections is used, I do recommend that teachers have students chose one concept or experiment to focus on for their evaluations.

No Physics Experience Required:

In the realization that many teachers at the elementary school level have little or no experience with physics, I have attempted to provide sufficient information to allow any teacher to be successful with this unit. For those with physics experience, please keep this in mind when you read the teacher guides. For those of you without physics experience, don't worry: this is an exercise for your students to explore physics concepts through experiment. If the teacher information I have provided is insufficient, a freshman physics text should provide you with all of the information you need. Or, feel free to email me with any questions you might have. I have several different sets of curriculum materials on the WWW, so please tell me to which program your question or comment refers.

Contents:

Introductory Materials:

Sections:

Assessment Aids:

The importance of fun:

My experience with college students in introductory astronomy labs and lectures is that most of the non-science majors tend to think of science and science experiments as a chore they are forced to participate in to complete degree requirements. One of my intentions in creating this project for children in grades 4-7 is to give them an introduction to physics that is fun and **not** a chore without sacrificing all of the instructional value (and hope that sense of fun remains with them in their future encounters with science). I would recommend to teachers who do one or all of the sections in this unit to attempt to preserve the fun when deciding the amount of work they will require from students to evaluate their performance.

The plan:

1. Introduce your students to the terms and basic concepts they will be exploring in the 3 sections. A general introduction is given in a document defining many of the terms and concepts found in the sections.
2. Each section also has a handout intended for the students that includes an explanation of the concepts they will explore in that section, along with a series of questions to be answered prior to the playground experiments. The teacher guides in each section provide guides to the experiments and suggestions for explaining concepts.

3. The students will decide upon their own hypotheses (alone, or in small groups) before they go to the playground. On the playground, with guidance from their teacher, they will work in small groups or as a class to test their hypotheses.
4. In mixed age groups, I would recommend that the younger children do their experiments independently from the older children. The experiments can then be geared toward the higher mathematical and conceptual ability of the older students, and still be understandable to the younger students. For example, the older students can be required to record all of their data, and write a short experiment report. The younger students should still take data (i.e. measurements of time, distance, mass, etc.) but may treat it less formally
5. Allow some time for independent experimentation.
6. Follow up with a discussion about their experience...what they learned, what they think would have done differently, etc. If the students work in small groups, perhaps each group could give an oral report on a specific experiment or concept.

Note: I have emphasized in every section's student handout that incorrect hypotheses are perfectly acceptable. The teacher should emphasis this as well!

Evaluations:

For younger students, I recommend each student write a short essay on "what I learned" in which they should discuss how well their own hypotheses held up against experimentation, what new things they learned from the experiments, and perhaps what other experiments they might like to do on their own. For the older students, they may also do more formal reports on one or more experiments.

Playground Physics, like all of my materials, was produced as part of my voluntary public outreach, and is distributed only on the World Wide Web. I have no way of determining how many people are using my materials or how they work in classrooms beyond my local field test, unless I receive an email from the users. If you intend to use these materials in part or in whole (or have a comment on what you see), I would appreciate hearing from you!

Education Objectives for Playground Physics

Matched with National Science Education Standards

- To introduce students to physics and physics terminology in a fun environment.
- To aid students to develop abilities necessary to do scientific inquiry and understandings about scientific inquiry. Including making hypotheses, planning experiments, taking data, and re-examining hypotheses with the willingness to discard hypotheses not supported by the data rather than disgarding the data. **Matches NSES Content Standard A.**
- To give students the opportunity to make scientific investigations of an environment with which they are already familiar. To help students develop good habits in recording experimental data (such as including units with all measurements).
- To aid students in their understanding of the properties of objects and materials position and motion of objects. Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured using tools, such as rulers, balances, and thermometers. The position and motion of objects can be changed by pushing or pulling, and the size of the change is related to the strength of the push of pull. **Matches NSES Content Standard B for grade 4.**
- To aid students in the development of their understanding of motion and forces. **Matches the second portion of NSES Content Standard B for grades 5-8**.
- To give students an opportunity to relate mathematics to scientific inquiry.

These activities fulfill the following for Science:

Standard 1: Students understand the processes of scientific investigation and design, conduct, communicate about, and evaluate such investigations.

In grades K-4, what students know and are able to do include:

- asking questions and stating predictions (hypotheses) that can be addressed through scientific investigation;
- selecting and using simple devices to gather data related to an investigation (for example, length, volume, and mass measuring

instruments, thermometers, watches, magnifiers, microscopes, calculators, and computers);

- using data based on observations to construct a reasonable explanation;
- and communicating about investigations and explanations.

As students in **grades 5-8** extend their knowledge, what they know and are able to do includes

- identifying and evaluating alternative explanations and procedures;
- using examples to demonstrate that scientific ideas are used to explain previous observations and to predict future events (for example, plate tectonics and future earthquake activity);
- asking questions and stating hypotheses that lead to different types of scientific investigations (for example, experimentation, collecting specimens, constructing models, researching scientific literature);
- creating a written plan for an investigation;
- using appropriate tools, technologies, and measurement units to gather and organize data;
- interpreting and evaluating data in order to formulate conclusions;
- communicating results of their investigations in appropriate ways (for example, written reports, graphic displays, oral presentations);
- using metric units in measuring, calculating, and reporting results;
- explaining that scientific investigations sometimes result in unexpected findings that lead to new questions and more investigations;
- and giving examples of how collaboration can be useful in solving scientific problems and sharing findings.

Standard 2: Physical Science: Students know and understand common properties, forms, and changes in matter and energy.

In Grade 4

- examining, describing, classifying, and comparing tangible objects in terms of common physical properties (for example, state of matter, size, shape, texture, flexibility, color);

- measuring common physical properties of objects (for example, length, mass, volume, temperature);
- and recognizing that energy (for example, light, heat, motion, sound, mechanical) can affect common objects and is involved in common events;
- comparing quantities associated with energy movement and change by constructing simple diagrams or charts (for example, graph of launch distances, chart of melting time).
- predicting what changes and what remains unchanged when matter experiences an external influence (for example, a push or pull, addition or removal of heat, division of clay into pieces, melting an ice cube, changing a ball of clay to a flattened shape).

In Grades 5-8

- measuring quantities associated with energy forms (for example, temperature, mass, speed, distance, electrical charge, current, voltage);
- and describing qualitative and quantitative relationships, using data and observations and graphs, associated with energy transfer or energy transformation (for example, speed of object vs. height of ramp; length of string vs. pitch of sound; electric current vs. volume of gas produced in electrolysis, with length of time kept constant).
- identifying and classifying factors causing change within a system (for example, force, light, heat);
- identifying and predicting what will change and what will remain unchanged when matter experiences an external force or energy change (for example, boiling a liquid; comparing the force, distance, and work involved in simple machines);

describing, measuring (for example, time, distance, mass, force) and calculating quantities that characterize moving objects and their interactions within a system (for example, force, velocity, acceleration, potential energy, kinetic energy).

Playground Physics

Physics Terms

Key Words:

acceleration

force

gravity

mass

momentum

weight

Mass:

The mass of an object is the measure of how much substance is in that object. Every physical object has mass: you do, the Earth does, and the Sun does. Your mass is the same no matter where you are or what you are doing. To lose mass you have to get rid of some of the stuff you are made of. To gain mass you have to add to the stuff your body is made of.

Mass is often measured in pounds or kilograms. One kilogram of mass is the same as a little over 2 pounds (2.2 pounds per kilogram) of mass.

Acceleration:

Acceleration is a change in speed or direction of motion. To understand acceleration, imagine that you going to give a first grader a ride in their red wagon. You decide to give the kid a ride on a long block. You start off **very** slow, moving one step a second. You steadily go faster so that when you pass the first light post your speed is 2 steps a second. Because your speed has been steadily increasing you have experienced constant acceleration. That means how fast your speed changes have stayed the same even as your speed increased.

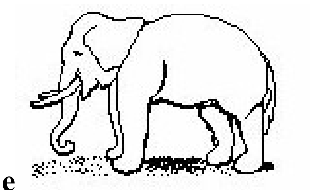
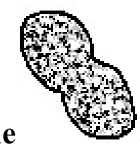
After a while you decide you don't want to go any faster, so you stop accelerating, and your speed stays the same. When you reach the end of the block your speed stays the same as you turn the corner **BUT** you accelerate again because you are changing directions. The first grader you are pulling feels the acceleration, and has to hold tightly on to the sides of the wagon to keep from falling out.

If you decide to slow down, you would also be accelerating, but most people call it deceleration to distinguish between speeding up and slowing down.

Gravity:

All mass pulls on all other masses with gravity. Gravity is **VERY** weak though. In fact, gravity is so weak that it take a **HUGE** amount of mass for its effects to be noticeable. You have mass, and therefore, you pull other masses toward you with your gravity. It doesn't matter how far away something is, your gravity is still pulling on it. The pull of your gravity on an object does get weaker the farther away from you another object is. It doesn't matter, though. You have so little mass that the pull of your gravity is very weak and won't be noticed by any person or object no matter how close you are. It takes the mass of something as big as a moon to be noticeable at all. The Earth has a lot of mass, and you definitely feel its gravity. You have very little mass, so the Earth isn't affected by your gravity even though you are standing on it. The Moon, which has **MUCH** more mass than you doesn't have much of a pull on the Earth compared to the pull the Earth has on the Moon.

Example:

The  **and the** 

In one kilogram of peanuts (in the shell) there are about 370 individual peanuts. A single adult elephant can have a mass of about 1000 kilograms. That means that it would take about 370,000 peanuts to equal the mass of one elephant. So the mass of a single peanut is **MUCH** less than the mass of an elephant. If you wanted to gather enough elephants so that their combined mass equaled the mass of the Earth, you would need about 6,000,000,000,000,000,000,000 elephants! So the mass of a single elephant is **MUCH MUCH** less than the mass of the Earth, and the pull of gravity from one elephant (or even all living elephants grouped together) is too tiny to feel.

Force:

In order to make an object accelerate, a force has to act on it. The amount of force it takes to move an object is defined as the mass of the object times the acceleration of that object. Suppose you have two carts, an empty cart and a cart full of bricks. You push both push carts (apply a force) with the same effort (the same force). The empty cart will speed up and move faster than the cart full of bricks. Once an object is moving, it takes another force (like friction) to stop it (decelerate it). Otherwise, it will keep moving at a constant speed. So, a force is necessary to make things speed up or slow down, but not to stay moving with a constant speed. Friction happens whenever one object rubs against another (roads, sidewalks, and even air counts). That means that things you see everyday **do** slow down and don't move at a constant speed if no other force is applied. Either of the carts will slow down (and eventually stop) if you don't keep pushing it because of friction with the ground.

Weight:

Weight is a force. The pull of gravity on an object or a person is acceleration. Your weight is your mass times the pull of the Earth's gravity on you (the acceleration due to gravity). Weight and mass are often confused with one another. A scale measures weight, but the number the scale gives you usually already has been divided by 9.8 meters per second squared, or 32 feet per second squared (the acceleration due to gravity). The special metric unit for weight is a Newton (or N for short). A weight of 9.8 N is the same as a mass of 1 kg multiplied by the gravitational acceleration of the Earth.

In the American system of units, weight and mass are especially confusing. Technically, the unit of mass in the American system is the slug, and the unit of force (weight) is the pound. However, almost no one uses the term slug, and conversions are frequently made directly between kilograms, which is a unit of mass, and pounds. In this case, pound refers to pound-mass rather than pound-force. If you buy a pound (lb) or roughly half of a kilogram (kg) of bananas at the store, you can say the bananas weigh 1 lb or a bit less than half a kg, and everyone will know what you mean. But you know now that the bananas really have a mass, not a weight, of 1 lb (or 0.45 kg). The confusion between pounds of force and pounds meaning mass is one of many reasons why the metric system is preferred by scientists over the American system of units. After all, weight and mass are complicated enough without using units of the same name to mean both!

Momentum:

The momentum of an object is defined as the mass of an object times the speed an object is moving. The force acting on an object may be constant, but since the object is accelerating the speed of the object is constantly increasing. Since the speed of an object is increasing, so is the momentum of the object. A fast moving low mass object can have the same momentum as a slow moving high mass object.

Playground Physics

Units, Units, Units

Key Words:

centi

conversion factor

gram

kilo

meter

metric system

milli

second

Why are units important?

Measurements without units are numbers without much meaning. If you asked someone how far away the nearest playground was and they said "10" you would be confused. "Ten what?" you would probably ask. "Ten feet? Ten blocks? Ten miles?" Without units the number "10" is worthless to you. You won't know if the playground is next door where you can walk to it, or across town. Whenever you take a measurement make sure you write down the unit, too!

Metric System vs. American System Units:

Most of you are already familiar with the two major systems of units we use in the United States: The **American system** of units (sometimes called the English system of units) has the fundamental units for length and mass of the foot and the pound. These units are not easily related to other American system units. To convert one foot into the yard, the mile, or the inch you have to memorize many different **conversion factors.** A **conversion factor** is the number you multiply or divides one unit by to convert to another unit.

Example: The distance between your school and Andy's house is 1760 ft. How many miles do you have to walk to get from school to Andy's house?

The conversion factor from feet to miles is 5280 ft/mile. To get how many miles:

1760 ft / 5280 ft/mile = 1/3 mile

So, Andy's house is 1/3 mile from school.

In the **metric system** all units are related to each other by factors of 10, so it is very easy to divide and multiply units in the metric system. Also, you don't have to memorize many different conversion factors. The basic units in the metric system are the **meter (m)**, the **gram (g),** and the **second (s).** Prefixes are added to metric units to show how many powers of 10 each unit represents compared to the basic units. Some common prefixes are:

Prefix	Abbreviation	Value
milli	m	1/1000th or 0.001
centi	c	1/100th or 0.01
kilo	k	1000

A centimeter is therefore 1/100th of a meter and is abbreviated as cm. So to convert from 80 cm to meters, you just divide by 100 and get 0.8 m. Metric units are the units most commonly used in physics. For ***Playground Physics*** you too will use metric units.

American units of length and mass are more familiar than metric units for most people in the United States. Metric units can be related to American units the same way feet can be related to a mile.

1 meter = 39.4 inches = 3.28 ft = 1.09 yds

1 kg = 2.2 pounds = 35.2 ounces

If you don't know how long a meter really is, converting the meter to a unit you are more familiar with might help.

Example: A flag pole is 3.50 meters tall. How many feet tall is it?

The conversion factor from meters to feet is 1 m = 3.28 ft. To get feet when you have meters multiply the number of meters you have by 3.28 ft/m:

3.50m x 3.28 ft/m= 11.48 ft

So, the flag pole is 11.48 ft tall.

Don't forget to **ALWAYS** write down the unit you are using with the number you measure or calculate. The unit is as important as the number itself.