Prerequisite Knowledge and Skills for *Thrill Ride* Events Based Science Unit

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Overview

This unit contains classroom activities for seven fundamental physics concepts that are prerequisite knowledge for the Events Based Science Module: *Thrill Ride*. *Thrill Ride* allows students to explore Newton's Laws and the Conservation of Energy. Before they can fully understand these concepts, they need to have mastered the concepts of distance, time, mass, speed, acceleration, force, and energy. Additionally they will benefit from being able to diagram forces and their interactions using vectors. For each concept or skill, this unit offers background material to summarize the content knowledge, tips for leading classroom discussion on that topic, practice problem solving exercises for students, in-class demonstrations and lab activities for students to do.

Rationale

Thrill Ride is an Events Based Science module used in the Pittsburgh Public Schools Seventh Grade Science curriculum. This module uses discovery based learning set in the context of the physics of amusement park rides to introduce students to Newton's Three Laws of Motion and the Law of Conservation of Energy.

The first part of the Events-Based Science Module is a "hook" that tries to capture student interest in amusement park physics by showing them news coverage of amusement park rides. Then the students discuss the rides they have seen in order to uncover their prior knowledge about force and motion. Next they are informed that at the end of the module they will have to design their own amusement park ride. They are then supposed to generate lists of what they want to learn in order to do so. Information gathering and formal instruction takes place during the remainder of the first part of the module. The materials included with *Thrill Ride* include five science activities (labs) which are supposed to answer many of the students information gathering needs. The first designs a ramp for a wheeled cart carrying a block. Students need to devise a design for the bottom of the ramp which will prevent the block from leaving the cart at the end of the ride. This activity covers the concepts of

Inertia (Newton's First Law), Force, Potential and Kinetic Energy, Energy Transformations, Friction and Weight. The second activity designs a ramp for a ball. Students need to devise a strategy to make the ball stop at a predetermined point. This activity covers the concepts of Velocity, Acceleration, Energy Transformations, Friction and Newton's Second Law. The third activity designs a device to spin a washer in a circle in a horizontal plane with differing amounts of force. Students alter the mass of the counter weight and the length of the swingarm as directed. Students must present their findings. This activity covers Centripetal Force, "G" force and Newton's first and second laws. The fourth activity designs a pendulum ride. The students must alter the given pendulum design to make the ride faster or longer in duration. This activity covers Simple Harmonic Motion, Potential and Kinetic energy, and Friction. The fifth activity designs a parachute drop. Students need to design a parachute to take as long a time as possible to fall 3 meters and still land in the designated landing zone. This activity covers Net Force, Newton's second Law and Free-fall.

The second half of the module is the "task". In *Thrill Ride*, the task is for the students, working in groups to design an amusement park ride. The students must create a working model of their ride and other materials to present their ideas. In the presentation of their design, students must label the ride to show where it demonstrates each of the three laws of motion: first the Law of inertia, second, the law of unbalanced forces, and third, the action-reaction pairs of forces. Additionally, they should be able to explain the energy transformations (potential-kinetic and mechanical-potential) that occur during the ride. They must also design a science experiment that riders can carry out during the ride. The design must be accompanied by a safety report which demonstrates that the ride does not subject riders to forces the human body cannot stand.

All of these activities assume a sophistication in hypothesis formulation, experimental design, data collection (including measurement and calculation), data analysis, data presentation, and interpretation of results that has not yet developed in middle school students. These skills need to be developed during the middle school years. A series of more teacher constructed activities for use before *Thrill Ride,* which ramp up all these components of the scientific method will enable our middle school students to be prepared to meet the science standards in this area by the end of the module.

Most of these activities also require students to be able to untangle the relationships between energy and motion that occur in the physical phenomenon demonstrated. For students' first exposure to these physical science concepts, they often find these demonstrations confusing instead of enlightening. Students are better able to use discovery learning if they are presented with a simpler one-concept demonstration first. The *Thrill Ride* module does not start with simple and fundamental concepts and build on them. It throws students into complicated situations which don't allow for building confidence. As with the scientific method skills, our students often need to have the motion and energy concepts start with the fundamentals and ramp up to the analysis of more complex phenomena. Students will benefit from doing activities relating to one simple concept at a time before starting *Thrill Ride*.

In my experience, many students entering seventh grade lack exposure or mastery of more elementary physics notions such as time, distance, speed, and acceleration. So I have found it necessary to first teach this material before doing the *Thrill Ride* module in order to give my students the implicit prerequisites it requires. In doing so, I also am able to give them the progressively more student directed practice which they need to develop their skills in the scientific method and practice in analyzing basic concepts of motion in observable phenomena. My students need these prior learning opportunities in order for them to benefit from the designated curriculum.

The *Thrill Ride* module teaches from the strategy that students will be able to see the physics in everyday life and in their own experiences. I try to carry this method into teaching what I have identified as prerequisite knowledge for this module. My students are usually unfamiliar with this way of using their own experiences to understand science, so I need to start with the very basics such as "how fast can you run?" and "how does that relate to the distance you traveled and the time it took?" From this first introspective (or, in some classes, experiential) learning, the students can build their knowledge and skills to the level needed to begin the *Thrill Ride* module.

The seven concepts I have identified that the students need to know before they start *Thrill Ride* are: distance, time, mass, speed, acceleration, force, and energy. Additionally they will benefit from being able to diagram forces and their interactions using vectors. Many students also need instruction in gathering, recording and reporting data; most need to learn to work with the notation of units and how they relate to measuring.

Distance

Distance is a measurable quantity between points A and B. It measures change in location or the amount one-dimensional space between two objects or locations. Students are usually familiar with the concept of distance, although they may use the term "how far" instead of the more scientifically specific "distance." They usually need to practice measuring distances. Distance can be measured in many different units. The two most commonly used systems are the metric system (centimeters, meters, kilometers, etc) and the Standard system (inches, yards, feet, miles, etc.).

Distance is a basic measurement, which cannot be decomposed into smaller components. Distance is a scalar quantity; it has only magnitude, not direction. Displacement is a vector; it is distance with direction.

Time

Time is the basic measurement unit for duration: what the students usually express as "how long did it take?" or "how long did it last?" Time is measured by the same units in both metric and Standard systems (seconds, minutes, hours).

Speed

Speed is how fast an object moves. Speed is a composite measure: the distance traveled per unit of time. Speed (the scalar) with direction is velocity (the vector). Speed is always a positive quantity, but velocity may be positive (forwards) or negative (backwards). The units for speed are meters per second (m/sec), miles per hour (mph), etc.

Speed = change in Distance / change in Time

This equation can be manipulated to solve for any one of its arguments:

change in distance = speed x change in time

change in time = change in distance / speed

Acceleration

Acceleration describes how velocity changes with respect to time. The units for acceleration are expressed as distance traveled per $time^2$, such as m/sec^2, or $feet/sec^2$. Gravity is a special acceleration, usually denoted by g. Gravity accelerates objects toward the center of a mass. The acceleration due to gravity at sea level on our planet (earth) is always 9.8 m/sec^2 or 32 $feet/sec^2$.

acceleration = speed / time

speed = acceleration x time

time = speed / acceleration

Mass

Mass is the basic measure of how much matter is in a real object – an object that occupies space. Mass does not change when an object's location changes. The mass of the lunar landing module was the same on the earth and on the moon. Mass is measured in metric units (milligrams, grams, kilograms, etc.) and in Standard units (slugs – on earth, at sea level, a slug = 14.63 kg).

Force

Force is often described as a push or a pull. A more accurate definition is any action that changes the motion (or lack of motion) of an object, either its speed or direction. People on earth are constantly subject to forces. Force is a vector quantity, it has both magnitude and direction. Force is measured in Newtons, (kilograms x meters / sec^2) in the metric system and pounds (slugs x feet / sec^2) in the Standard system.

Force = mass x acceleration (This is Newton's Second Law of Motion)

Weight is an especially important force: it is the force due to gravity. So **weight = mass x acceleration due to gravity.** Students usually confuse mass with weight. Mass is independent of weight. The Lunar module's weight was less on the moon than on earth, but it's mass was the same.

The Thrill Ride Module utilizes Newton's Three Laws of Motion:

1. First Law The Law of Inertia: Objects at rest will stay at rest, objects in motion will stay in motion unless acted on by a force.

2. Second Law Force is proportional to the mass of an object and it's acceleration (F = m x a)

3. Third Law Every action has an equal and opposite reaction. This law describes what is happening between two objects, not what a force does to an object.

Vector Diagrams

Vector diagrams are useful to analyze the interaction of forces and objects. We can represent objects as a dot called a free body diagram. The forces are represented as arrows. The arrow's head shows the direction of the force and the length of the tail shows the magnitude.

In order to use vector diagrams to analyze forces, students must first master head-to-tail addition of vectors.

1. Step 1 Draw the first vector – be sure to copy its direction and length accurately.

2. Step 2 Draw the second vector attached to the first with the second vector's tail starting at the head of the first vector. Be sure to copy the direction and length of the second vector accurately.

3. Step 3 Draw the "resultant" vector (it helps to use a different color pen or pencil) which starts at the back end of the first vector's tail and ends at the head of the second vector.

Energy

Energy is the ability to do work. Work is the measure of the amount of force applied over a distance. The units for energy are Joules (newton x meters or kg x m^2 / sec^2). There are different types of energy: mechanical, heat, sound, light, electrical, work, kinetic, and potential. The most basic physical concepts that students perceive in their daily lives are energy and matter. Students often confuse work and force. Students often have a very intuitive concept of "work" as any effort they have to make (to carry a brick or lift a book over their heads).

Work = force x displacement

Potential energy describes stored energy. There are many types of potential energy, such as the energy stored in a battery or the gravitational potential energy in an object above the ground. The higher the object is above the ground, or the larger its mass, the more potential energy it has. **PE = m x g x height**

Kinetic energy is the energy associated with an object's motion. The larger the mass or the larger the velocity, the larger the object's kinetic energy.

KE = ½ m x v^2

Other skills

Measuring, Units – conversions, fractions (unit fractions), Abbreviations
The concepts in this unit require measurements. Most students are familiar with standard units (inches, pounds, etc.), but many need to develop their skills in manipulating these (such as converting inches to miles). They also need to become proficient with the metric system of measurements, and be conversant with converting from one measuring system to another. Many students will need help to learn how to manipulate the measurements of the compound attributes, such as force which is (mass x distance) / $time^2$. They often have trouble manipulating fractions, which are required for many calculations with forces and motion. Students need to develop accuracy in measurement of time, mass, and distance in order to carry out the activities of this unit and *Thrill Ride*.

Objectives

The students will have all the background knowledge and skills needed to successfully complete the *Thrill Ride* module.

Students will be able to compare and contrast vector and scalar attributes, such as distance vs. displacement.

Students will understand the difference between fundamental concepts and the building of more complex concepts.

Students will be able to utilize equations to model actions in the real world.

Students will apply what is learned to real life examples.

Students will be able to design and carry out an experiment to test a hypothesis about forces or motion.

The objectives and content of this unit apply to Science Standards #1, 2, 4 and 6.

Strategies

I use a variety of methods to teach these concepts and skills. Most importantly, students need to use these concepts and skills to understand the physical world around them. By middle school, many students have begun to regard science as some mysterious pursuit, too difficult to understand, instead of as a way of understanding the world around them. The variety of activities they do in this unit extends from observing the motion of cars and the people in them as they walk home from school, to devising and carrying out experiments where they measure and compute forces. This range of activities is designed to help them make the connection between the theoretical concepts they learn in their textbooks and the world they observe in their everyday lives. Furthermore they should come to see how they can use science to solve real world problems.

Seeing motion and forces in their everyday experience - Introducing concepts

The first set of teaching strategies is designed to introduce the concepts and make students aware of them in their everyday life. It is important to understand that students have a vast amount of experience with forces and motion, but little practice in formally identifying or analyzing them. I usually start introducing the concepts with some type of discussion involving the whole class.

Open question with free association: This type of question is designed to elicit all that students know about a concept. "What causes an object to move? Give me some examples." This type of discussion often follows brainstorming formats - write down all ideas, but edit them for correctness (i.e. "What actually makes the car stop, the red light, the driver or the brakes?" – If you write down that the red light causes the car to stop, students will carry this misconception into their concept formation of forces and you may not be able to correct it later), then use the list to show how all of them are examples of forces.

Guided questions: This type of question follows the format of guided notes. Many students who will not answer open ended questions will respond to a "fill-in-the-blank" type of question. "A force will either push or ....an object."

"Anyone can answer it" questions: Another way to pull students into the discussion who usually don't participate is to ask them a question that relates to their lives to start the discussion. "Have you ever ridden in a car? What does it feel like when you go around a corner fast?"

Brainstorming: Once the students have learned the definition of the concept, brainstorm ideas about how to observe or investigate that concept. "On your walk home from school, what object do you expect to see with potential energy? With kinetic energy?"

Demonstrations: Demonstrations are good both to introduce concepts and to trigger thinking about how to apply those concepts to real world examples. Most forces and motion demonstrations can be done with easily obtained materials and household objects. (For example, you can recreate Galileo's leaning tower of Pisa demonstration with canned goods of equal volume, but different weights.)

It is important at the end of these discussions and demonstrations to standardize the definitions of the concepts and record them on a bulletin board, word wall, or in the students notes, or point them out in the textbook, if you are using one, so that the students make the connection between their experiences and the formal definitions that scientists use.

Seeing motion and forces in their everyday experience – Problem solving and analysis

After students have identified and defined the concepts, they need to start seeing them in the world around them. This is a good time to use group work, so that the students have a greater chance to participate actively in the higher level thinking processes. Either in the directions for the group discussion, or in the scoring rubric for presentations (written or oral) the teacher should emphasize the utilization of the science concepts.

Group discussion, analysis, critique, or presentations: Students should consider questions which reinforce and apply the concepts, such as "Why doesn't a bowling ball move when you yell at it, but it does move when you push it?" Or you can give the groups a list of verbs to classify as force and not force (such as push, hit, look at). Most students need a well defined form of the result or answer they are supposed to achieve in group work.

Demonstrations are also a good stimulus for the analysis or problem solving strategies. You can present a demonstration of a motion situation and then have the students explain what happened and why. If the acceleration due to gravity is constant, why do bowling balls fall faster than feathers?

Journals: If the students keep science journals, this is a good time to assign specific observational tasks. "Find three examples of potential energy in your house. Draw or describe them."

Using the scientific method and theoretical problem solving

Students will need to learn to apply the concepts also in hypothetical situations. The traditional scientific pedagogy includes problem sets and tests which feature hypothetical situations. Students need to become as proficient at these types of problem solving as they are in solving word problems in math class. Worksheets and group problem solving are very effective at the middle school level for mastering these types of problems. The teacher should emphasize the connection between the hypothetical word problem and real world examples. This is a good place to review the use of models in science and to emphasize that motion and forces can be modeled with mathematical equations.

Labs: As the students become more proficient at seeing and analyzing forces and motion in the world around them, they are ready to start using experiments to explain some of those situations. Depending on your students' level of proficiency with experimental procedures and reporting, you may want to review the scientific method, design of experiments, data recording and the format of lab reports. The first labs should be done with teacher designed objectives and procedures, but before they begin *Thrill Ride*, the students need to be able to design their own experiments to test theories that they generate.

Classroom Activities

The classroom activities are divided into three sections:
Motion: Distance, Time, Speed, Acceleration
Force: Mass, Vector Diagrams
Energy

Motion: Distance, Time, Speed, Acceleration

Motion - Discussion Questions

What is motion?
How do you know I moved?

What did I cover? (Distance)
How much did I move? How do you measure how far I moved?
What is the difference between measuring that distance in feet and in inches? in meters and in centimeters?
What is a unit of measurement?
Can everything be measured in meters?
What else can I measure besides distance?
What is the difference between the first way I moved (slowly) and the second (fast)?
Can the measurement of distance or time be broken down into more basic units?
Can the measurement of speed be broken down into more basic units?
What are the two parts of speed?
What units are used to measure the speed of a car?
Where else do you see examples of distance and time as measurements of speed?
Have you ever seen the white lines across the street or highway?
If speed is the change of distance with respect to time, how do you get to that speed?
What do you call the gas pedal in a car?
What happens to the car's speed when you push the accelerator?
What happens to the speed when you "go faster"?
Do cars only get faster?
So what does acceleration describe?
So what are the two parts of acceleration?
So what units can we use to measure acceleration?
Do you see why there is a "squared" term in the unit distance/time^2 ?
Given meters, seconds, meters/second, and meters/second^2, which units measure distance, time, speed, and acceleration?
How can we represent slowing down?

Motion – Demonstrations

Motion – teacher moves from one location to another in the classroom. Or move an object from one location to another.
Speed / Time – teacher moves from one location to another in the classroom first slowly, then quickly.
Acceleration – teacher accelerates and decelerates.

Motion - Practice Problem Solving (Group Work)

Develop a list of metric vs. standard units for different measurable characteristics.

Motion - Practice Problem Solving (Worksheets)

Unit Conversion Worksheet I – Appendix B1

Unit Conversion Worksheet II – Appendix B2
Unit Conversion Worksheet III – Appendix B3

Unit Conversion Worksheet IV – Appendix B4

Speed worksheet I – Appendix B5

Speed worksheet II – Appendix B6
Speed worksheet III – Appendix B7
Acceleration Worksheet I – Appendix B8
Acceleration Worksheet II – Appendix B9

Motion - In class activities and Labs

Measuring activity: Use a meter stick to measure objects in the classroom. Report back to class. Good to reinforce the metric system.
Speed Lab – Appendix C1

Force, Mass and Vectors

Force - Discussion Questions

What is a force?
What makes a force big?
What is the difference between a large person bumping into you and a small person bumping into you?
What is the difference between a large person bumping into you and a small person bumping into you when you are in outer space?
What is mass?
Is mass determined by gravity?
Is there less of you on the moon?
How much do weigh in outer space? On the moon?

Do you disappear in outer space?
How is mass measured? (in metric units? in standard units?)
Will an object with more mass have more or less force?
Does it hurt more to walk into a wall or to run into a wall? Does it matter how much mass you have?
Is it the running or the stopping that hurts? What physical attribute of my body changes when I hit the wall?
How would scientists define force?
Do forces have direction?
Do forces have magnitude?
How can we draw a force?
Are forces a vector or a scalar quantity?
What is weight?
Why does weight change on the moon, but mass doesn't?
Does gravity have mass?
Does gravity have acceleration?
What happens to the speed of objects as they drop for longer time periods?
If you jump from 10 cm vs. 2 meters, which landing will have more force?
Is the mass the same for both jumps?
Is the landing speed the same for both jumps?
What do you know about Isaac Newton?
Would it have hurt more if it had been a taller tree or a bigger apple?
Why doesn't the bowling ball move when I yell at it?
What happens to the bodies of the passengers when the car they are riding in stops suddenly?
How can both the car and the passengers be following Newton's First Law of Motion?
What is the relationship between mass and acceleration which determines a force?
What is an "equal and opposite reaction"?
Why aren't you sitting on the ground? Isn't gravity acting on you now?
When you are sitting, if gravity is pulling you down, what force is the equal and opposite reaction? Can you draw a vector diagram of your situation?

Force – Demonstrations

Contrast the teacher bumping into a student with a small student bumping into a student.
Contrast the teacher bumping into a student while walking and while running.
Teacher runs into wall. Teacher walks into wall. Students estimate amount of pain.
Lean against the wall. Sitting on a chair.

Two people sit in rolling chairs on a smooth floor and push against each other.

Force - Practice Problem Solving (Group Work)

Perform the following activities, find the forces in each activity: running, stand up, turn, pick up an object, two people lean into each other, etc.
Choose: do you want to drop a book onto your head from 1 cm or from 1 meter? Which will hurt more? Why?
Weigh yourselves, convert to mass in kilograms.
Find the equal and opposite forces in the following situations: a tire on a car moving on the road, a tire spinning on ice. A foot walks on pavement. Two hockey players collide.

Force - Practice Problem Solving (Worksheets)

Vector worksheet I – Appendix B10
Vector worksheet II – Appendix B11
Force worksheet I – Appendix B12
Force worksheet II – Appendix B13

Force - In class activities and Labs

Force Lab – Appendix C2

Energy

Energy - Discussion Questions

What is energy?
Why do you need energy?
What do you mean by work?
Are work and force the same? Why?
If you hold an object steady off the ground, it isn't moving, are you doing work?
Complete the analogy: Effort is to Force as Work is to Energy.....

Energy – Demonstrations

Have student hold a chair off the ground. Then carry the chair around the room. (Effort, Work)
Tie a bowling ball in a bag on the end of a rope, suspend from the ceiling and do pendulum tricks: start at your nose, release, let swing back – DON'T MOVE. Helpful to demonstrate against a wall marked with a grid to measure height. This demonstration also works with objects of lesser mass, but it's not as dramatic.

Energy - Practice Problem Solving (Group Work)

List as many types of energy as you can.
For each of the following objects or activities, identify the energy and classify it as potential or kinetic: a bowling ball held steady at 1 meter above the ground, a book on a shelf, a book on the ground, a person running, a ball rolling, a ball going through a basketball hoop. A pendulum swinging, a pendulum held at a 45 degree angle to vertical, a pendulum at the bottom of its swing

Energy - Practice Problem Solving (Worksheets)

Work worksheet – Appendix B14
Potential/Kinetic Energy Worksheet I – Appendix B15
Potential/Kinetic Energy Worksheet II – Appendix B16

Energy - In class activities and Labs

Start the *Thrill Ride* Module.

Annotated Bibliography / Resources

Websites

Roller Coaster Physics Book by Tony Wayne
http://141.104.22.210/Anthology/Pav/Science/Physics/book/home.html

Amazing book, available as PDF files and web pages. Includes instructions and diagrams for demonstrations, directions for in-class labs, at-home labs and labs to be done on an amusement park field trip.

Very detailed and accurate information on the simple physics and mechanics of roller coasters. Makes connections between the psychological and physiological sensations roller coaster riders experience and the physics of the ride. (i.e. why does it feel like the bottom dropped out of your stomach or why are you dizzy?)

Excellent resource for teachers and gifted or very interested students.

Home Page of Events-Based Science developers
http://www.mcps.k12.md.us/departments/eventscience/

You can order modules or activity materials kits and find information on training workshops on the EBS homepage.

Each EBS module has a separate page. There is not much helpful supplementary material on the Thrill Ride! page. It includes one correction, one teaching hint from other users and a few links to roller coaster web sites. The Thrill ride resource list (http://www.mcps.k12.md.us/departments/eventscience/pdf/ThrillRideResources.PDF) includes a materials list for each activity.

Annenberg CPB Project Amusement Park Physics
http://www.learner.org/exhibits/parkphysics/

A very good source. Start here for amusement ride physics. Covers 5 types of rides: roller coasters, carousel, bumper cars, free fall and pendulum. Excellent explanations of the physics in each ride. A very readable website for students. Good glossary. The explanations of Newton's laws are under "Bumper Cars".

The K-8 Aeronautics Textbook On-Line,
http://wings.avkids.com/Curriculums/Forces_Motion/index.html

K8AIT is a Cooperative Agreement between NASA's Learning Technologies Project and Cislunar Aerospace, Inc. The section on Forces and Motions has dozens of short hands-on activities and labs. My favorite is the seatbelt model using a ramp, a toy car, a clay snowman, and a pencil (crash barrier). When you select an activity from the index, be sure to look at both the "Summary" page and the "How To" page.

The Physics Classsroom, by Tom Henderson, Glenbrook South High School, Illinois
http://www.glenbrook.k12.il.us/gbssci/phys/Class/BBoard.html

High School Physics Tutorials and other class materials. Good review for teachers on Newton's Laws.

How Stuff Works: roller coasters
http://www.howstuffworks.com/roller-coaster.htm

Fairly easy explanations of the physics of roller coasters. Especially good on applying the concepts of kinetic and potential energy and on relating the physics to the effects the body feels.

Playground Physics, by Mary Urquart
http://lyra.colorado.edu/sbo/mary/play/

Complete lesson plans for a unit on acceleration, force, gravity, mass, momentum, using playground equipment – swings, slides, monkey bars. Designed for grades 4-7.

Eastern Illinois University Physics 1350 class page.
http://oldsci.eiu.edu/physics/DDavis/1350/05Laws/ToC.html

Good explanations and examples – review for teachers who took a physics course in high school or college.

The Effects of New Technology on Roller Coaster Thrills, Safety and Economics, by Jessica Kruidhof and Selene Kucera
http://www.me.utexas.edu/~uer/roller/index.html

The latest mechanical engineering for roller coasters and a good analysis of the tradeoffs between safety and thrills. Suitable for teachers and serious students. A nice way to give students a taste of the real level of design and analysis involved in creating roller coasters.

The Roller Coaster Data Base
http://www.rcdb.com/

Data on over 1000 roller coasters includes height, speed, length, duration, largest drop, location, date built, and a picture of each coaster. Could be useful for students to figure out height and speed relationships.

Appendices

A. Content Standards

B. Worksheets

B1 Unit Conversion Worksheet I

B2 Unit Conversion Worksheet II
B3 Unit Conversion Worksheet III

B4 Unit Conversion Worksheet IV

B5 Speed worksheet I

B6 Speed worksheet II
B7 Speed worksheet III
B8 Acceleration Worksheet I
B9 Acceleration Worksheet II
B10 Vector worksheet I
B11 Vector worksheet II
B12 Force worksheet I
B13 Force worksheet II
B14 Work worksheet
B15 Potential/Kinetic Energy Worksheet I
B16 Potential/Kinetic Energy Worksheet II

C. Labs

C1 Speed Lab
C2 Force Lab

Appendix A: Content Standards for the Pittsburgh Public Schools, Science and Technology

1. All students ex plain how scientific principles of chemical, physical and biological phenomena have developed and relate them to real world situations.

2. All students demonstrate knowledge of basic concepts and principles of physicacl, chemical, biological and earth sciences.

3. All students use and master materials, tools and processes of major technologies which are applied in economic and civic life.

4. All students explain the relationships among science, technology and society.

5. All students construct and evaluate scientific and technological systems using models to explain or predict results.

6. All students develop and apply skills of observation, data collection, analysis, pattern recognition, prediction and scientific reasoning in designing and conducting experiments and solving technological problems.

7. All students evaluate advantages, disadvantages, and ethical implications associated with the impact of science and technology on current and future life.

Appendix B1: Unit Conversion Worksheet I

Develop the two conversion factors for the following relationship:

1. $1 = 4 quarters
2. 10 pennies = 1 dime
3. 1 year = 365 days
4. 1 hour = 60 minutes
5. 1 hour = 3600 seconds
6. 1 minute = 60 seconds
7. 3 feet = 1 yard
8. 1 foot = 12 inches
9. 1 yard = 36 inches
10. 1 meter = 100 centimeters
11. 1 centimeter = 10 millimeters
12. 1 kilogram = 2.2 pounds

Appendix B2: Unit Conversion Worksheet II

Convert the following problems:

1. $2.50 = ? quarters
2. 36 quarters = $?
3. 10 inches = ? centimeters
4. 50.8 centimeters = ? inches
5. 4 meters = ? centimeters
6. 456 centimeters =? meters
7. 5 minutes =? seconds
8. 2 hours =? minutes
9. 3 hours=? seconds
10. 180 seconds=? minutes
11. 4 yards=? feet
12. 18 feet=? yards
13. 5 kilograms=? pounds
14. 44 pounds=? kilograms
15. 5 dimes=? pennies
16. 2 yards=? inches
17. 120 millimeters=? centimeters
18. 3 years=? days (assume there is no leap year in this problem)

Appendix B3: Unit Conversion Worksheet III

1. $7 = ? quarters
2. 16 quarters = $?
3. 5 inches = ? centimeters
4. 25.4 centimeters = ? inches
5. 8 meters = ? centimeters
6. 500 centimeters =? meters
7. 4 minutes =? seconds
8. 4 hours =? minutes
9. 6 hours=? seconds
10. 240 seconds=? minutes
11. 6 yards=? feet
12. 36 feet=? yards
13. 10 kilograms=? pounds
14. 88 pounds=? kilograms

15. 7 dimes=? pennies
16. 4 yards=? inches
17. 200 millimeters=? centimeters
18. 5 years=? days (assume there is no leap year in this problem)

Appendix B4: Unit Conversion Worksheet IV

For the following problems, use the correct conversion factor to change the units and answers.

1 m=1000 mm   1 m=100 cm   1 m=10 dm   1 dm=10 cm   1 dm=100 mm
1 cm=10 mm   1 km=1000 m

1. 5m = ______________dm
2. 5m = _______________cm
3. 5m = _______________mm
4. 7.5m = ______________dm
5. 7.5m = ______________cm
6. 7.5m = ______________mm
7. 3dm = _______________cm
8. 3dm = _______________mm
9. 4.6dm = ______________cm
10. 4.6dm = ______________mm
11. 6cm = _______________mm
12. 23cm = ________________mm
13. 7.9cm = _______________mm
14. 3000m = ________________km
15. 4200m = ________________km
16. 100mm = _______________cm
17. 100mm = _______________ dm
18. 100mm = ________________m
19. 520mm = ________________cm
20. 520mm = ________________dm
21. 70cm = ________________dm
22. 70 cm = ________________m
23. 125cm = ________________dm
24. 125cm = ________________m
25. 10dm = _______________m

26. 15dm = _______________m
27. 8.7dm = _______________m
28. 1000m = ______________km
29. 2300m =_______________km

Appendix B5: Speed worksheet I

Either define the term or use one of the following formulas to solve the problem:

speed = distance / time distance = speed x time time = distance / speed

1. Define scalar quantity.
2. Define vector quantity.
3. What is a measurement, and what are the two parts?
4. A boat travels 120 miles in 4 hours. What is its speed?
5. A train travels 400 miles in 8 hours. What is its speed?
6. After 3 hours, a car has traveled 63 miles. What is its speed?
7. A person ran 100 meters in 10 seconds. What is his/her speed?
8. A snail travels 32 feet in 8 minutes. What is its speed?
9. A cat walks 16 meters in 4 seconds. What is its speed?
10. How far does a car go in 4 hours, traveling at 45 miles per hour?
11. How far does a plane travel, going 1000 kilometers per hour after 2.5 hours?
12. How far does a ball roll after 8 seconds, traveling at 12 meters per second?
13. How long does it take a car to go 105 miles traveling at 35 miles per hour?
14. How long does it take a person to travel 5280 feet, if they are running at 20 feet per second?
15. How long does it take a bike rider, traveling at 22 miles per hour to go 88 miles?

Appendix B6: Speed worksheet II

For the following problems, use the speed formula to solve the problem:

speed = distance / time (s = d/t)

1. A car travels 350 km in 7 hours. What is its speed?
2. A train covers 1000 miles in 20 hours. What is its speed?
3. A plane flies 2400 miles in 6 hours. What is its speed?
4. A horse runs 800 m in 8 s. What is its speed?

5. A sprinter runs 100 m in 10 s. What is her speed?
6. A ball rolls 20 feet in 5 s. What is its speed?
7. A truck travels 360 miles in 6 hours. What is its speed?
8. A biker moves 1 mile in 10 minutes. What is his speed?
9. A motorcycle travels 140 miles in 1 hour. What is its speed?
10. A snail travels 27 inches in 9 minutes. What is its speed?
11. A rocket travels 3000 km in 3 minutes. What is its speed?

Appendix B7: Speed worksheet III

Use one of the following formulas to solve the problem:

speed = distance / time distance = speed x time time = distance / speed

1. A car travels 70 miles in two hours. What is its speed?
2. A plane travels 2400 km in 4 hours. What is its speed?
3. A caterpillar travels 12 inches in 12 minutes. What is its speed?
4. How fast is a bike going if it travels 5 km in 1 hour?
5. A motorcycle takes 2 hours to go 80 miles. How fast is it going?
6. A ball rolls 4 meters in 2 seconds. What is its speed?
7. A car travels at 40 miles per hour for 5 hours. How far does it go?
8. How far does a student go in 2 hours, walking at 4 km per hour?
9. A plane travels at 1000 km per hour. How far does it go in 10 hours?
10. How far does a bird, flying at 20 km per hour, go in 3 hours?
11. How long will it take a car, traveling at 100 km per hour, to travel 100 km?
12. How long will it take a train to travel 140 miles, if it travels at 70 miles per hour?
13. A car is traveling at 20 miles per hour. How long will it take it to go 100 miles?
14. What is the speed of a boat that travels 250 km in 5 hours?

Appendix B8: Acceleration Worksheet I

Use the following formulas to solve the problems below: a = s/t, s = a x t, t = s/a.

1. What is the acceleration of a bike that goes 15 km/hr from a rest, after 0.1 hours?
2. A car going 25 m/s accelerates to 75m/s in 10 seconds. What is its acceleration?
3. A bus traveling at 30 km/hr stops after 0.05 hours. What is its acceleration?
4. A plane is traveling at 450 m/s from rest, after 30 seconds. What is its acceleration?

5. A sprinter goes 10 m/s after starting from a rest, in 10 seconds. What is his acceleration?
6. A car stops from 40 km/hr after 0.02 hours. What is its acceleration?
7. A bird flying at 5 m/s is chased by a hawk and accelerates to 15 m/s in 3 seconds. What is its acceleration? (And does the bird escape?)
8. A car is racing towards a yellow light at 100 m/s, when it turns red. The car slams on its brakes and stops in 4 seconds. What is its acceleration?
9. A ball is rolling at 11 m/s with friction working on it. It stops after 8 seconds. What is its acceleration?
10. A sitting dog sees a cat and races towards it. When the dog reaches 28 m/s it catches the cat. It took the dog 4 seconds to catch the cat. What is its acceleration?

Appendix B9: Acceleration Worksheet II

Use the following formulas to solve the problems below: a = s/t, s = a x t, t = s/a.

1. What is the acceleration of a speed boat that starts at rest, and after 10s is going 150m/s?
2. What is the acceleration of a car that is going 10m/s at 20s, then speeds up to 40m/s, with time=35s?
3. How fast will a car be going after 8s, when it accelerates at $20m/s^2$?
4. How fast will plane be going after accelerating at $110m/s^2$ for 30s?
5. How fast will a runner be going after accelerating at $3m/s^2$ for 5s?
6. How long will it take a car to reach 30m/s accelerating $5m/s^2$?
7. How long will it take a bird to reach 8m/s accelerating $2m/s^2$?
8. How long will it take a bike to reach 12m/s accelerating $3m/s^2$?

Appendix B10: Vector worksheet I

Head-to-tail addition is how we add forces together to find the overall effect. You start the end of the second arrow's tail on the head of the first arrow, and draw the second arrow, being sure to draw it in the correct direction. Then draw the overall arrow from where the first arrow started to where the second arrow ended. This arrow shows the resultant force, or overall motion.

Draw the vector addition problem. Show the resultant vector and give its value.

1. 7N ? + 3N ?
2. 5N ? + 4N ?
3. 8N ? + 3N ?
4. 2N ? + 4N ?
5. 3N ? + 4N ?

6. 5N ? + 6N ?
7. 8N ? + 3N ?
8. 2N ? + 2N ?
9. 10N ? + 2N ?
10. 4N ? + 4N ?

Appendix B11: Vector worksheet II

Head-to-tail addition is how we add forces together to find the overall effect. You start the end of the second arrow's tail on the head of the first arrow, and draw the second arrow, being sure to draw it in the correct direction. Then draw the overall arrow from where the first arrow started to where the second arrow ended. This arrow shows the resultant force, or overall motion.

Draw the vector addition problem. Show the resultant vector and give its value.

1. 10N ? + 3N ?
2. 5N ? + 3N ?
3. 4N ? + 5N ?
4. 6N ? + 3N ?
5. 5N ? + 2N ?
6. 5N ? + 2N ?
7. 2N ? + 2N ?
8. 1N ? + 1N ?
9. 8N ? + 4N ?
10. 3N ? + 4N ?
11. 11N ? + 6N ?
12. 6N ? + 6N ?
13. 3N ? + 3N ?
14. 10N ? + 5N ?
15. 3N ? + 4N ?

Appendix B12: Force worksheet I

Remember that forces can be drawn with arrows, and the length of the tail indicates how big the force is. Forces can also be drawn as arrows with the number of Newtons (N) to indicate how big it is. Head-to-tail addition is how we add forces together to find the overall effect. You start the end of the second arrow's tail on the head of the first arrow, and draw the second arrow, being sure to draw it in the correct direction. Then draw the overall arrow from where the first arrow started to where the second arrow ended. This arrow shows the resultant force, or overall motion.

Draw the vector addition problem. Show the resultant vector and give its value.

1. A person walking with a force of 10 N is pushed from behind with a force of 5N.
2. A car traveling forward with a force of 7N is hit from behind with a force of 3N.
3. A ball moving forward with a force of 8N is hit from behind with a force of 4N.
4. A bumper car moving East with a force of 4N is hit with a force of 3N by another bumper car moving East.
5. A bumper car moving East with a force of 8N is hit with a force of 3N by another bumper car moving West.
6. A train traveling forward with a force of 10N is hit head on with a force of 5N.
7. A train traveling forward with a force of 7N is hit head on with a force of 7N.
8. A bumper car moving East with a force of 6N is hit with a force of 3N by another bumper car moving North.
9. A bumper car moving East with a force of 8N is hit with a force of 2N by another bumper car moving South.
10. A car traveling forward with a force of 6N is hit from behind with a force of 6N.

Appendix B13: Force worksheet II

For the following problems, use the formula Force = mass x acceleration to solve the question.

1. An object with a mass of 1500kg is accelerating at $10m/s^2$. What is the force acting on the object?
2. A ball with a mass of 2kg is caught. It decelerated at $15m/s^2$. What is the force acting on the object?
3. A backpack has a mass of 7kg, and is being accelerated downward at $10m/s^2$. What is the force acting on the object?
4. What force is needed to stop a car, mass = 2000kg, traveling at 27m/s, in 1s?
5. What is the force needed to accelerate a 50kg person at $12m/s^2$?
6. The acceleration due to gravity is $10m/s^2$. What is the force acting on your body?
7. A tennis ball, m = 0.06kg, is falling (acceleration due to gravity = $10m/s^2$). What is the force acting on the object?
8. You are in a car traveling at 27m/s and you crash into a wall, coming to a stop in 0.01sec. What is the force acting on you? (remember, your mass = your weight divided by 2.2)
9. How much force is needed to lift a 40kg box. You must overcome the acceleration due to gravity?

10. A mass of 8kg, starts at rest, and is going 15m/s after 3s. What is the force acting on the object? (acceleration = change in speed/change in time)
11. A 100kg person is floating in water. The water must exert how much force upwards?

Appendix B14: Work worksheet

For the following problems, use the formula: work = force x distance (W = f x d)

1. A person carries a box with a force (weight) of 400N over a distance of 20m. How much work is done?
2. Two people carry a table with a weight of 1000N for 3m. How much work is done?
3. A person applies a force of 45N to push a tray 4m across the floor. How much work is done?
4. A person holds a weight of 250N completely still. How much work is done?
5. A ball rolls with a force of 100N across the floor for 10m. How much work is done?
6. Three students help push a truck weighing 5000N down to a gas station 300m away. How much work is done in total? How much work does each student do if they each put in an equal amount of effort?
7. A fire extinguisher with a mass of 10kg is moved 4m. How much work is done?

Appendix B15: Potential/Kinetic Energy Worksheet I

Use the correct formula to solve the following problems: K.E. = $0.5\ mv^2$ P.E. = mgh

1. A car, with a mass of 1000kg, is moving at 0 m/s. What is its kinetic energy?
2. A car, with a mass of 1000kg, is moving at 5 m/s. What is its kinetic energy?
3. A person, with a mass of 50kg is running at 5 m/s. What is its kinetic energy?
4. A basketball, with a mass of 2 kg, is moving at 8m/s. What is its kinetic energy?
5. A bird, with a mass of 1.5 kg, is moving at 12 m/s. What is its kinetic energy?
6. What is the potential energy of a bucket of water, mass = 10kg, that is 5m above the ground? (Remember, gravity is 10 m/s^2.)
7. If the bucket in #6 is raised to 10m, what would be its new potential energy?

Appendix B16: Potential/Kinetic Energy Worksheet II

Read each of the questions below and determine which formula to use. Remember, the formula will tell you what pieces of information you need. Use your notes!!

$KE = 0.5 mv^2$ $PE = mgh$ $(g = 10 m/s^2)$

Total Energy = KE + PE

1. A 2 kg object is hoisted 10m above the ground. What is its potential energy?
2. A 2.5 kg object is sitting on a shelf, 2m above the ground. What is its potential energy?
3. A box has a mass of 15 kg and is 7m off the ground. What is its potential energy? Will it hurt if it hits you?
4. A student with a mass of 50 kg stands on a 5m diving board. What is her potential energy?
5. A ball with 1 kg mass is thrown 8m into the air. At the top of its flight, what is its potential energy?
6. A car with a mass of 1500 kg is traveling at 27 m/s (60 mph). What is its kinetic energy?
7. A train with a mass of 150,000 kg is traveling at 13 m/s. What is its kinetic energy?
8. A student with a mass of 50 kg is running at 3 m/s. What is his kinetic energy?
9. A bird with mass 1 kg is flying at 20 m/s. What is its kinetic energy?
10. A tennis ball with mass 0.06 kg is served at 54 m/s. What is its kinetic energy?

Appendix C1: Speed Lab

Purpose: Determine speed of people
Practice gathering data.
Practice reporting results.

Materials: Meter stick
Stop watch
Masking Tape

Procedure: Measure out 5 meters on the floor or ground
Place tape marks at 1 meter increments
Select a timekeeper, a starter, a recorder, and at least four motion subjects
Each subject uses a different form of motion (running, hopping, etc.)
Record the time it takes each subject to travel the 5 meter distance and the form of motion he/she used
Calculate the speed of each subject

Results/Data: Create a table which shows the person's name, form of motion, distance, time, speed

Conclusion: Answer the following questions:
1. Using the fastest speed, how long would it take to travel 100 meters?
2. Using the fastest speed, how far would the person go in 20 seconds?

Appendix C2: Force Lab

Purpose: Determine amount of force applied by different actions and objects.

Practice gathering data and reporting results.

Materials: Newton spring scale
Objects of various mass

Procedure: Part A: Force due to gravity: Place each object (one at a time) on the scale and record the force.
Part B: Human Force: Hold the spring scale horizontally. Gently pull on the spring scale, hold it at 1 Newton, 5 Newtons, 10 Newtons for 2 minutes each.
Record your subjective impressions of the task.

Results/Data: Part A: Create a table which shows the objects, their forces, calculate their masses (given g ˜ $10 m/sec^2$).

Conclusion: Part A: How does the mass of an object affect the force due to gravity that it exerts?
Part B: Which amount of force required more effort?