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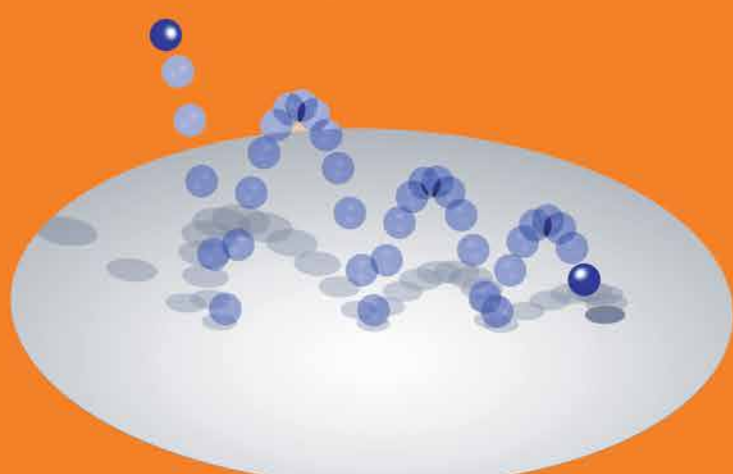
Student Textbook
Laboratory Notebook
Teacher's Manual
Lesson Plan
Study Notebook
Quizzes
Graphics Package

Focus On Middle School

Physics

3rd Edition

PREVIEW BOOKLET



Rebecca W. Keller, PhD

REAL SCIENCE 4 Kids

Introduction

Welcome to the ***Focus On Middle School Physics 3rd Edition Preview Booklet*** where you can take our one semester unit study program for a test run!

The materials sampled in this book are taken from a full semester course, with two chapters from each part of the curriculum:

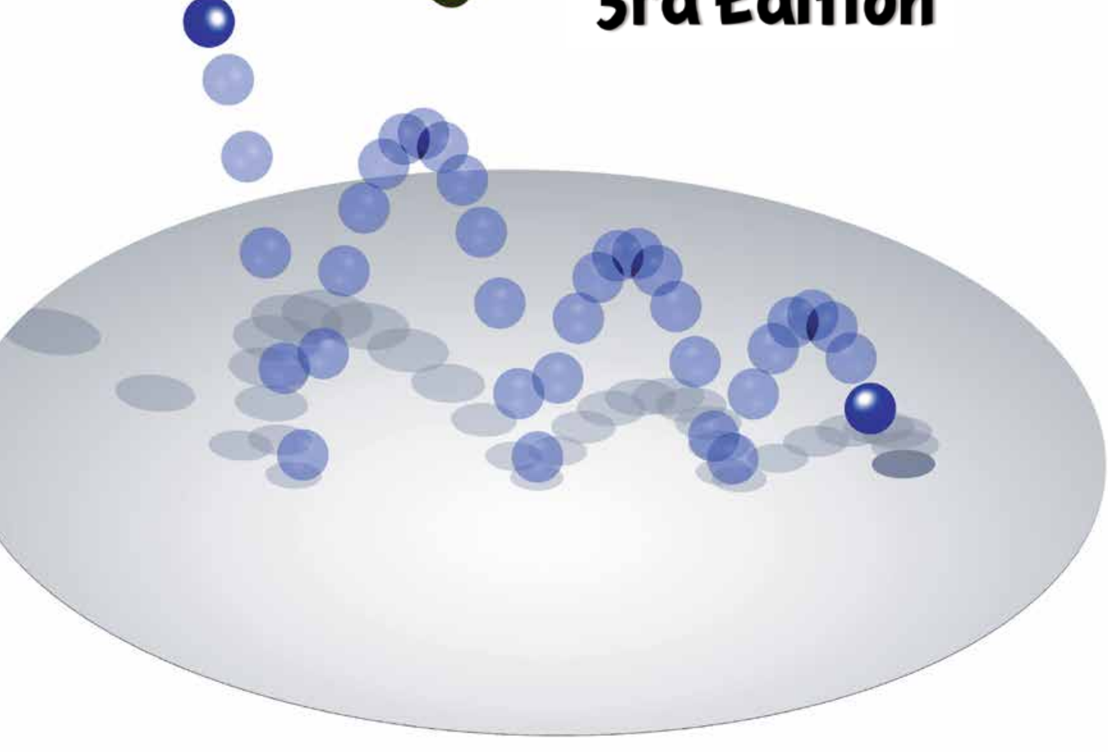
- The ***Focus On Middle School Physics Student Textbook–3rd Edition*** provides foundational science concepts presented in a way that makes it easy for students to read and understand. The many colorful illustrations make each chapter fun to look at and reinforce concepts presented.
- With two science experiments for each chapter, the ***Laboratory Notebook*** helps young students learn how to make good observations, an important part of doing science. Open-ended questions help students think about what they are learning, and information is provided to assist students with understanding what they observed while performing their experiments.
- The ***Teacher's Manual*** includes instructions for helping students conduct the experiments, as well as questions for guiding open inquiry. The commonly available, inexpensive materials used for all the experiments can be seen in the complete materials lists included in this booklet.
- Using the ***Lesson Plan*** makes it easy to keep track of daily teaching tasks. A page for each chapter in the ***Student Textbook*** has the objectives of the lesson and questions for further study that connect science with other areas of knowledge, such as history; philosophy; art, music, and math; technology; and language. Forms are included for students to use to do a review of material they've learned and to make up their own test for the chapter. Also included are icons that can be copied onto sticker sheets and used to help plan each day of the week.
- With the ***Study Notebook*** students learn to use critical and creative thinking while exploring their ideas about science. Thought questions are provided, and students are invited to take ownership of their learning by coming up with more questions and by doing research into their areas of interest.
- The one final and two midterm ***Quizzes*** are self-explanatory. For those who are not fans of quizzes, students can use the self-test at the end of the ***Lesson Plan*** instead.
- Another type of teaching aid is provided in the ***Graphics Package,*** which has two full-color images from each chapter of the ***Student Textbook.*** These graphics can be used to create additional teaching aids, such as flash cards, wall posters, PowerPoint lectures, or overhead projections.

Focus On

Grades 5-8

Middle School Physics

3rd Edition



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Real Science-4-Kids

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Chapter 1 What Is Physics?

1.1 Introduction

Have you ever wondered what makes a feather float but a boulder fall, or why a bird can fly but a whale can't fly? Have you ever noticed that when your mom quickly puts on the brakes, the car stops, but your ice cream ends up on the dashboard? Have you ever wondered why, when you slide your stocking feet on the carpet, you can "shock" your dad?

All of these observations, and others like them, begin the inquiry into the field of science called physics. The name physics comes from the Greek word *physika*, which means "physical or natural." Physics investigates the most basic laws that govern the physical or natural world.

1.2 The Basic Laws of Physics

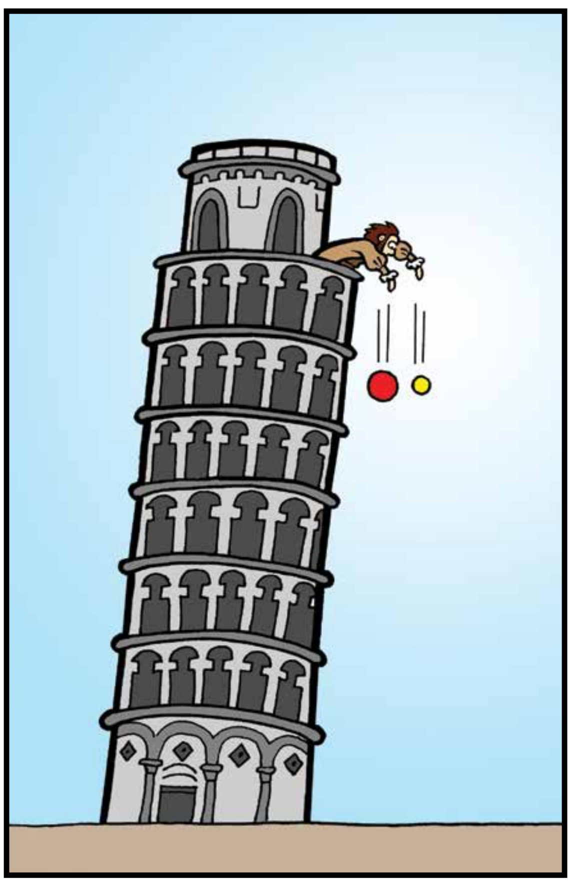
What is a basic law of physics? Are the laws of physics like the laws that tell us not to speed or not to steal? No. In fact, physical laws are statements that tell us about how the physical world works. Using these laws, we can understand why baseballs go up and then come down, why airplanes can fly, why rockets can land on the Moon, and why we see rainbows after it rains.

Physical laws are never broken, unlike laws that tell us not to speed or not to steal. For example, Newton's law of gravity tells us why we stay firmly on the surface of the Earth and do not sometimes just fly off. People have always known that the world behaves in regular and reliable ways. For example, people have observed for centuries that the Sun always rises and sets, that water always flows downhill, or that if it is cold enough, water will turn into ice. The laws of physics are statements about these regular and reliable observations.

We know that objects such as baseballs, airplanes, and people consistently obey the laws of physics and don't suddenly break one or two. It would be hard to play baseball if every once in a while the ball hit by the batter landed on the Moon!

1.3 How We Get Laws

How do we know what these laws are, and how did we discover them? Did the Earth come with a big instruction book that spelled out all of the laws? Not exactly. People had to figure them out on their own. Scientists use scientific investigation to discover how the world works.



One early scientist who used scientific investigation and helped develop the scientific method was Galileo Galilei. Galileo was an Italian astronomer born in Pisa, Italy in 1564. He showed how two lead balls fall at the same rate even if one is larger than the other. He performed a famous experiment where he is said to have dropped two cannon balls off the Leaning Tower of Pisa. He found that, even though the two cannon balls were different weights, they landed on the ground at exactly the same time!

People had trouble believing the results of Galileo's experiments, and it wasn't until Isaac Newton showed mathematically why this was true that it was finally accepted. Isaac Newton is considered to be one of the greatest scientists of all time. He is also considered to be the founder of physics as we know it today.

Sir Isaac Newton was born on January 4, 1643 in Woolsthorpe, Lincolnshire, England. When Newton was 18 years old, he went to the University of Cambridge to study mathematics, physics, and astronomy. By combining his interests in physics, mathematics, and astronomy, Newton was able to calculate how objects move and worked out a proof that showed the effect of gravity on the planets. Through his work, Newton determined the mathematical equations for the laws of motion.

One law that Newton discovered is called the law of universal gravitation. (We will discuss gravity later in this book.) Newton was able to confirm Galileo's experiments and showed mathematically why two falling objects will reach the ground at the same time even if one is heavier than the other.

One of the great discoveries of Newton's time is that mathematics can be used to describe events that happen in nature. For example, Newton was able to show that the force acting on an object is proportional to the mass of each object and inversely proportional to the square of the distance between them. The equation is:

$$F=G\frac{m_1 m_2}{r^2}$$

where F is *gravitational force,* G is the *gravitational constant*, m_1 is the *mass of object 1,* m_2 is the *mass of object 2,* and r is the *distance between them*. (F, m_1, m_2, and r are called variables because the amount they stand for can change, or vary. G is called a constant because its amount stays the same in different equations. Inversely proportional means that as one variable increases in value, another decreases.)

How can this equation be used to explain Galileo's experiment? If we fill in the values for each variable and use m_1 for the mass of Earth, we can see that because the mass of Earth (m_1) is huge and the mass of each ball (m_2) is very tiny in comparison, when the mass of Earth is multiplied by the mass of the ball, the value of F won't be affected by the mass of the ball. Therefore, the mass of each ball can be ignored because it doesn't make any difference to the answer to the equation. In other words, the equation shows that the gravitational force on any object is the same regardless of its mass as long as its mass is much smaller than the mass of Earth. This means that any two objects will fall at the same rate even if one object is heavier than the other. The equation that expresses this is:

$$F = Gm \text{ (m=mass of Earth) (for both balls)}$$

By using mathematics, Newton was able to prove Galileo's experiment.

1.4 Summary

- Physics is the study of how things move and behave in nature.
- The laws of physics are precise statements about how things behave.
- The laws of physics were determined using scientific investigation.
- Mathematics can be used to describe events that happen in nature.

1.5 Some Things to Think About

- What have you observed about objects that are or are not in motion?
- What do you think your life would be like if there were no physical laws?
- If you dropped a bowling ball and a golf ball off a high tower at exactly the same time, do you think they would hit the ground at the same time or different times? Why?

Chapter 7 Linear Motion

7.1 Introduction

How fast can you ride your bike? Can you race a car on your bike? Can you race a train? How fast does an airplane go? Does it go faster than a car? Does it go faster than a rocket? How can you measure how fast a bike, a car, or an airplane goes?

In the last chapter we looked at some general features of motion. We explored inertia and how an object will stay still or stay in motion because of inertia; how mass, momentum, and speed are related; and how friction will change or slow down the motion of an object. In this chapter we will take a closer look at a particular type of motion called linear motion.

Linear motion is, very simply, motion that occurs when any object travels in a straight line. In this chapter we will see that mathematics can be used to describe motion and that motion is defined by speed, acceleration, and velocity.

7.2 Speed

If you were to hop on your bike and cycle to the nearest grocery store for chocolate milk, how long would it take you? How long would it take to get to the same grocery store by car? Maybe you live in the remote wilderness and your only way to get to the store is by plane. How long would it take you to travel to the store by plane?

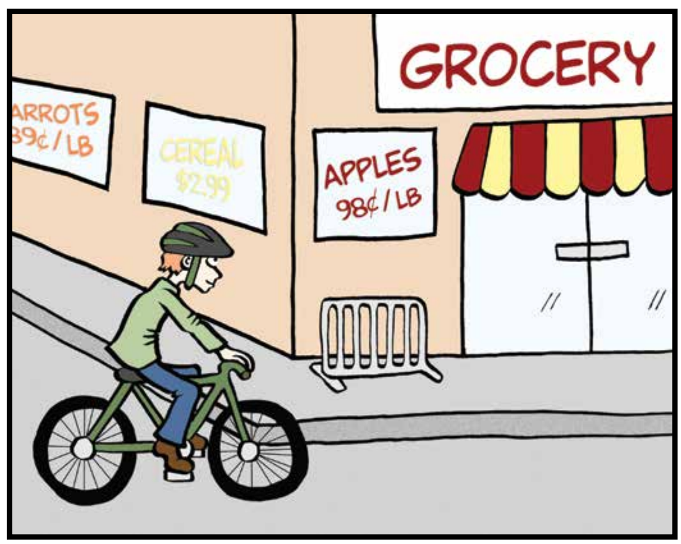
Whether you travel by bike, car, or plane, in each case you are going from one point to another. In other words, you are traveling a certain distance. If the distance is short enough, you could ride your bike. However, if the distance is far, you would probably want to take a car or even a plane.

The reason to choose a car or plane instead of a bike to travel a far distance is that a car or plane can go faster than a bike. In other words, a car or plane travels at a higher speed than a bike, and therefore a car or plane can travel a longer distance in less time than a bike.

Using mathematics we can calculate exactly how fast a car, plane, or bike can travel a certain distance. Speed is defined as the rate at which an object covers a given distance in a given amount of time. Recall that speed is defined mathematically by the following equation:

$$s = \frac{d}{t}$$

where “s” represents “speed,” “d” represents “distance,” and “t” represents “time.”



To see how this equation allows us to calculate speed, let’s imagine that you want to bicycle to the grocery store which is 16 km (10 miles) away. Because you’re in really good shape, it only takes you 30 minutes to get to the store to buy chocolate milk. How fast did you go?

If we plug in the value of 16 km (10 miles) for distance and 0.5 hours for 30 minutes we get:

$$s = \frac{\text{16 km (10 miles)}}{\text{0.5 hrs}} = \text{32 km per hour (20 miles per hour)}$$

Suppose you don’t know how long it might take you to ride your bike to the grocery store. But you do know how far it is to the store, and you know about how fast you can ride your bike. Can you figure out how long it will take? It’s easy! All you have to do is rearrange the equation and *solve for time*.

Some Basic Math Rules, Terms, & Symbols

These symbols all mean divide: —, /, ÷

These formulas all mean that speed equals distance divided by time:

$s = \frac{d}{t}$ $s = d/t$ $s = d \div t$

These symbols all mean multiply: x, *, ·

These formulas all mean that momentum equals mass times velocity:

$\mathbf{p} = m \times \mathbf{v}$, $\mathbf{p} = m * \mathbf{v}$, $\mathbf{p} = m \cdot \mathbf{v}$

v bold lower case "v" represents velocity
p bold lower case "**p**" represents momentum
Δ "delta" symbol—represents the difference between two quantities
| | "absolute value"—these upright lines mean that the result of a formula contained within them must be expressed as a positive number

variable - In an algebraic formula, a variable is a letter that represents a number that can change (vary).

1. In algebra when we perform the same operation to both sides of an equation, the two sides of the equation remain equal. We can add, subtract, multiply, or divide the same number (or variable) to both sides of the equation and the equation stays equal.

   For example, because $s = \frac{d}{t}$, then $s*2 = \frac{d}{t}*2$, or $s*x = \frac{d}{t}*x$, or $s*t = \frac{d}{t}*t$

2. In algebra if we multiply a variable by its inverse, we get 1.

   The inverse of a variable is its opposite, so the inverse of:

   $\frac{s}{1}$ is $\frac{1}{s}$ and $\frac{t}{1}$ is $\frac{1}{t}$ and $\frac{d}{1}$ is $\frac{1}{d}$

   If we multiply a variable by its inverse we get 1. For example:

   $\frac{s}{1} * \frac{1}{s} = \frac{s}{s} = 1$ $\frac{t}{1} * \frac{1}{t} = \frac{t}{t} = 1$ $\frac{d}{1} * \frac{1}{d} = \frac{d}{d} = 1$

   Any number divided by itself equals 1.

3. We can rearrange either side of an equation to help solve it. For example:

   $s*t = t*\frac{d}{t}$ can be rearranged to $s*t = \frac{t}{t}*d$

   Because... $\frac{t}{t} = 1$ we get... $s*t = 1*d$ so... $s*t = d$

Let's imagine that you want to go to the store in the next town because they have the most delicious chocolate milk. However, this store is 64 km (40 miles) away. If you can ride your bike at 32 km (20 miles) per hour, how long will it take to get to the store?

Here's how we can use some basic math (algebra) to *solve for time*. First we multiply both sides of the equation by "t" (time):

$$s = \frac{d}{t} \quad \text{(speed = distance divided by time)}$$

$$s * t = t * \frac{d}{t} \quad \text{(both sides multiplied by time)}$$

Because $t * \frac{1}{t} = 1$, the "t"s on the right hand side cancel each other out:

$$s * t = \cancel{t} * \frac{d}{\cancel{t}}$$

Results: $s * t = d$ (speed multiplied by time = distance)

Now, if we divide both sides by "s" (speed) we get:

$$\frac{s * t}{s} = \frac{d}{s}$$

Because $s * \frac{1}{s} = 1$, the "s"s on the left hand side cancel each other:

$$\frac{\cancel{s} * t}{\cancel{s}} = \frac{d}{s}$$

Results: $t = \frac{d}{s}$ (time = distance divided by speed)

Using this equation we can figure out how long it will take to go 64 km (40 mi.) at 32 km (20 mi.) per hour. Plugging in the values for "d" and "s" we get:

$$t = \frac{64\text{ km}}{32\text{ km per hour}} \quad \left(\text{or } t = \frac{40\text{ miles}}{20\text{ miles per hour}}\right)$$

Solution: $t = 2$ hours

Because the trip will take two hours, you might want to grab an extra chocolate milk for the ride home! Or, if you don't have four hours for a trip to the grocery store and back, you could go by car.

You Do it!

1. Your car will go 80 km per hour (50 miles per hour). How long will it take you to get to the grocery store and back if the store is 80 km (50 miles) away?

2. Which bicycle route will get you there faster?
   Route A: 30 km with an average speed of 15 km per hour,
   or
   Route B: 30 km with an average speed of 10 km per hour

See solution steps below.

Solution Steps

1. **Calculate for time**

   80 km/h (50 mph) = speed = s
   80 km (50 miles) = distance = d
   We are looking for "time" = t

To solve:

$$\text{speed} = \frac{\text{distance}}{\text{time}} \qquad s = \frac{d}{t}$$

Multiply both sides of the equation by "t":

$$s*t = \frac{d*t}{t}$$

The "t"s cancel:

$$s*t = \frac{d*\cancel{t}}{\cancel{t}} \qquad s*t = d$$

Divide both sides by "s":

$$\frac{\cancel{s}*t}{\cancel{s}} = \frac{d}{s} \qquad t = \frac{d}{s}$$

The "s"s cancelled so this is my equation!

Plug in variables:

$$t = \frac{80\text{ km}}{80\text{ km/h}} = 1\text{ hour}$$

2. **Route A or B?** (See next page for solution steps.)

Solution Steps (continued)

2. **Route A or B?**

I'll use the equation for time.

To solve for Route A:

$d = 30\ km$

$s = 15\ km/h$

$t = \frac{d}{s} = \frac{30\ km}{15\ km/h} = 2\ hr$

Route A is faster!

To solve for Route B:

$d = 30\ km$

$s = 10\ km/h$

$t = \frac{d}{s} = \frac{30\ km}{10\ km/h} = 3\ hr$

In the previous example, we assumed a constant speed. In other words, we assumed that there are no stop signs or slow traffic or any other reasons to go faster or slower on our trip to the grocery store.

However, on most roadways there are stop signs and traffic congestion that will change the speed you are traveling. If you are riding a bicycle, there may be hills that cause you to go slower on the way up and faster on the way down.

When we use the total distance traveled divided by the total time it takes, we are actually calculating the average speed. The speed of the car or bicycle will change depending on whether or not there are other cars or bicycles on the road, turns to make, and traffic signs to obey. By using the total time and total distance, we don't see the changes in speed from one section of the trip to the next. However, if you have a speedometer, you can watch how fast or slow you go in certain sections of the trip and calculate how much time it would take you to travel only those sections. Knowing how long it might take to travel certain sections might change the route you take.

For example, suppose your house is in the middle of the block and in the middle of a steep hill. To get to the store you first have to get out of your neighborhood, and you can choose to either go to the north and up the hill or to the south and down the hill. Even if the distance is longer, you might decide to go south, riding a little farther but going downhill so you can ride faster. Your average speed would be different for each route because the speed you travel over a particular section would be different.

7.3 Velocity

In the last example we added "north" and "south" to our discussion of speed. North, south, east, and west are all directions. A direction describes where you are headed relative to your current position. If you say, "I am going north to the bowling alley," you are describing the direction of the bowling alley relative to your current position.

In physics, speed plus direction is called velocity. If you say you are going 25 km per hour, you are describing your speed. However, if you say you are going 25 km per hour to the north, you are describing velocity.

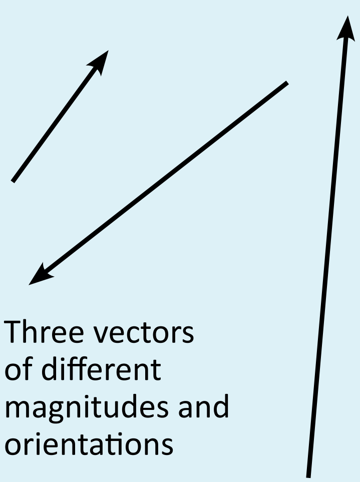
Although speed and velocity look similar, in physics they are actually quite different. Both speed and velocity have distinct but different mathematical meanings. Speed is a scalar quantity and velocity is a vector quantity. (See next page for definitions.)

Scalars and Vectors

Mathematically, speed is defined to be a scalar quantity. In math, the word scalar simply means an amount or magnitude. For example, if a car is traveling at 40 km per hour, this describes the *amount* of speed at which the car is traveling from one point to another. A scalar is simply a number that represents a value like speed, temperature, weight, or height. In an equation, a scalar is often written as a lower case letter. For example: s, d, t

Mathematically, velocity is defined to be a vector quantity. In math, a vector has both magnitude (amount) and direction (up, down, right, left, north, south, etc.). A vector is often written as a lower case letter in a **bold** font, such as "**v**" for velocity.

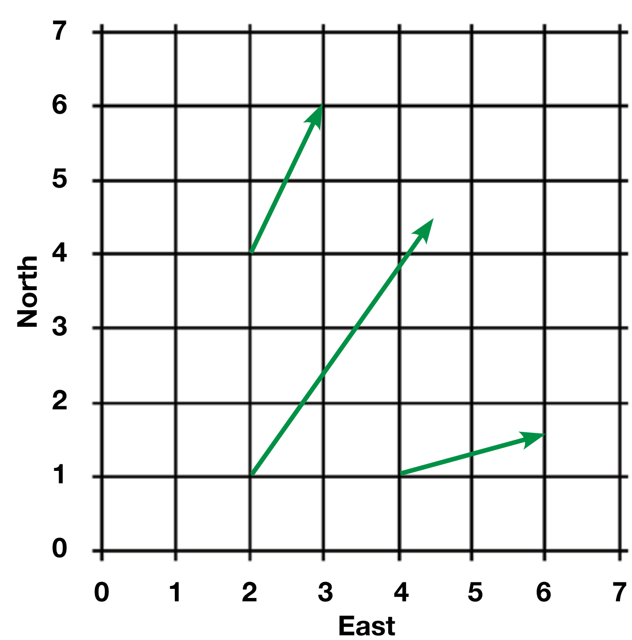
We can think of a vector as an arrow. The length of the arrow represents the magnitude, and the orientation of the arrow represents its direction.



Three vectors of different magnitudes and orientations

Speed (a scalar) is the magnitude (numerical value) for velocity (a vector). The length of the arrow represents the numerical value of the magnitude.

Three vectors on a graph.



The arrows are vectors. The arrow length is equal to the vector's magnitude, and the direction of the arrow shows the vector's orientation.

Technically speaking, speed is the rate at which an object moves, and velocity is the rate at which an object changes its position.

On a linear path the speed and velocity have the same magnitude (or amount). If a horse going north trots 13 km (8 miles) in one hour from point A to point B, the horse's speed is:

$$s = \frac{d}{t} = \frac{13\text{ km}}{1\text{ hr}} = 13\text{ km per hour}$$

And the velocity is:

$$\mathbf{v} = \frac{d}{t} = \frac{13\text{ km}}{1\text{ hr}} = 13\text{ km per hour north}$$

What happens if a horse is trotting on a circular path? Because velocity takes direction into account, speed and velocity are different.

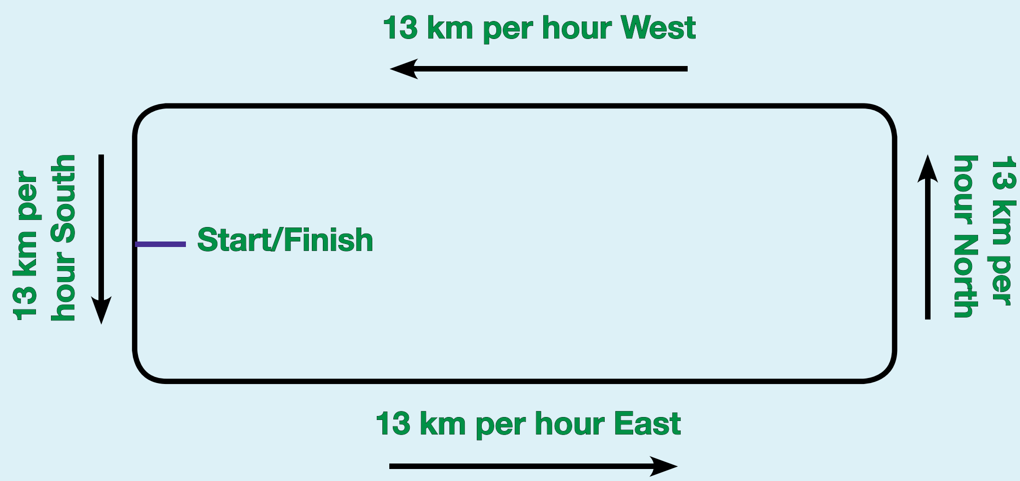
Imagine the horse is on a 1 km (.6 mile) track and trots around the track 13 times, traveling 13 km in one hour and returning to the starting line. The speed, or rate, at which the horse trotted is:

$$s = \frac{d}{t} = \frac{13\text{ km}}{1\text{ hr}} = 13\text{ km per hour}$$

However, since the horse stopped and started at the same place, there was no change in its position and the velocity would be zero! (See the math on the next page.)

Strange but True Velocity Math!

In the example of the horse trotting around the track, we can use an illustration to see how the velocity is equal to zero. If we divide the track up into different sections and add the velocities of each section, it looks like this:



The total velocity of the horse is:

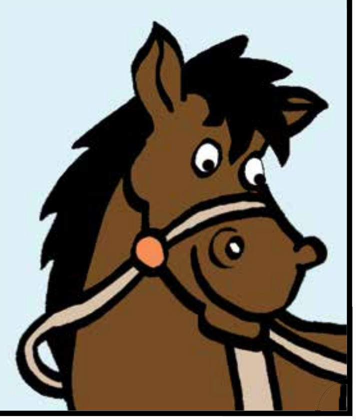
Total $\mathbf{v}_T$ = 13 km/h north - 13 km/h south + 13 km/h east - 13 km/h west

$$\mathbf{v}_T = \mathbf{v}_n - \mathbf{v}_s + \mathbf{v}_e - \mathbf{v}_w$$

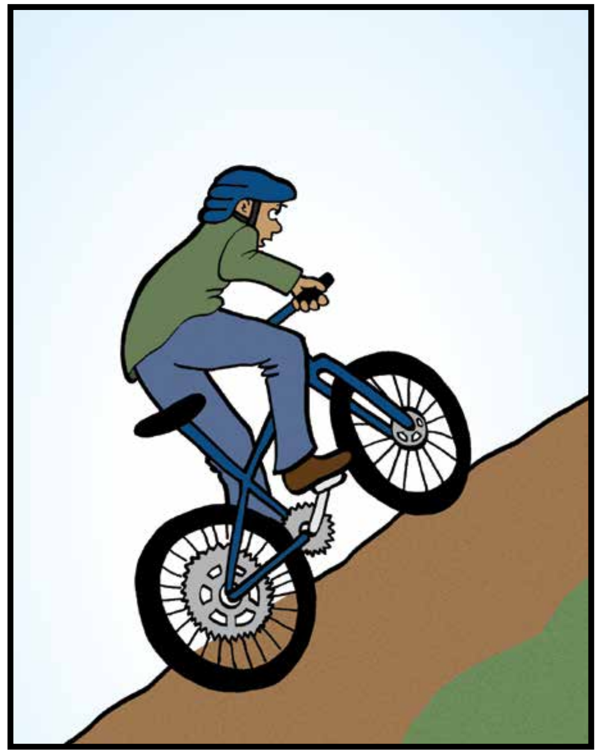
Because velocity is a vector, the directions cancel each other and we see that:

$$\mathbf{v} = 0$$

In this example the velocity of the horse is zero even though it maintained a constant speed of 13 km per hour. When the horse returned to its starting position, there was no change in its position from when it began trotting, so the total velocity is zero.



7.4 Acceleration



Sometimes velocity changes. If you are riding your bike and come to a big hill, you might slow down as you climb up. When you go over the top and then have a long descent, you will most likely go faster. In both cases your velocity will change because both your direction and speed change as you slow down or speed up and go up or down the hill.

You have probably felt the effects of going faster or slowing down on a bike, in a car, or in a plane. If you are racing to the finish line on your bike, you might spin your legs faster to win! When you spin faster, you can feel your body jerk a little as you suddenly speed up. If you are in a car and the light turns yellow, you might press on the brake to slow down to a full stop. As you quickly push on the brake, you can feel your body move forward. In both cases you can feel the moment when you suddenly change velocity.

We change the velocity of something by changing its speed, its direction, or both its speed and direction. When velocity changes over a given time it is called acceleration. Acceleration can be represented by the equation:

$$\mathbf{a} = \frac{\Delta \mathbf{v}}{\Delta t}$$

where "**a**" represents acceleration, "Δ (delta) **v**" represents the change in velocity and "Δ (delta) t" represents the change in time. Acceleration equals the change in velocity divided by the change in time.

The small delta symbol (Δ) is a mathematical symbol that represents the difference between two quantities. In this equation "Δ**v**" stands for the difference between the final velocity and the initial velocity, and "Δt" stands for the difference between the final time and the initial time. When we expand the equation by plugging in the variables for the initial and final velocities and times, we get:

$$\mathbf{a} = \frac{\mathbf{v}_f - \mathbf{v}_i}{|t_f - t_i|}$$

Where "$\mathbf{v}_f$" is the final velocity, "$\mathbf{v}_i$" is the initial velocity, "t_f" is the final time, and "t_i" is the initial time. Also, for acceleration, time is always a positive number. "Δt" represents the "change in time." When the result of a calculation must be a positive number, or absolute value, the calculation is placed between two upright lines. In the acceleration formula, the change in time is written as $|t_f - t_i|$ to show that the result is expressed as a positive number.

Acceleration MATH!

Example 1:

Calculate the acceleration of a bowling ball going from zero to 2 meters per second in 2 seconds.

$$\mathbf{a} = \frac{\mathbf{v}_f - \mathbf{v}_i}{|t_f - t_i|} = \frac{2\text{ m/sec.} - 0\text{ m/sec.}}{|2\text{ sec.} - 0\text{ sec.}|} = \frac{2\text{ m/sec.}}{2\text{ sec.}} = 1\text{ m/second}^2$$

Example 2:

Calculate the acceleration of a projectile slowing down from 50 meters per second to 10 meters per second in 10 seconds.

$$\mathbf{a} = \frac{\mathbf{v}_f - \mathbf{v}_i}{|t_f - t_i|} = \frac{10\text{ m/sec.} - 50\text{ m/sec.}}{|10\text{ sec.} - 0\text{ sec.}|} = \frac{-40\text{ m/sec.}}{10\text{ sec.}} = -4\text{ m/second}^2$$

You Do the Acceleration MATH!

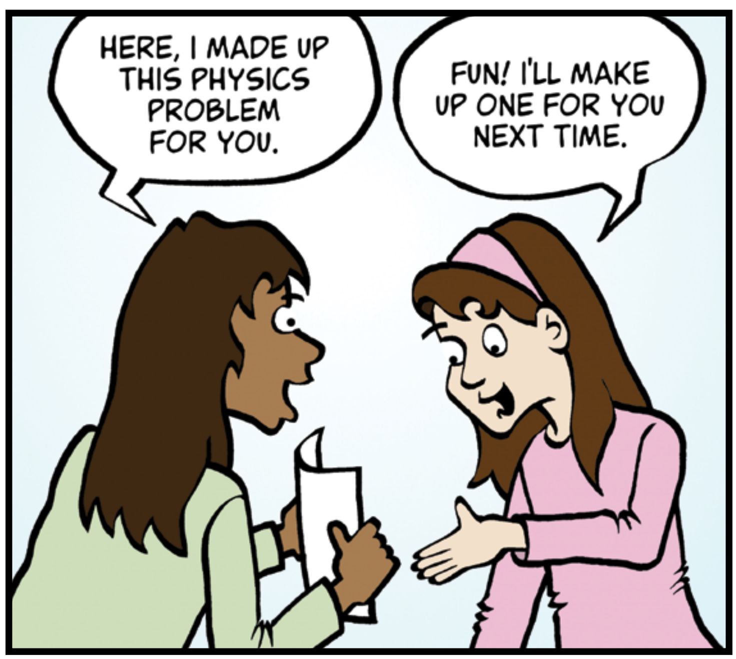
Physics Math Problem 1

1. Calculate acceleration where $\mathbf{v}_f$ =10 m/sec., $\mathbf{v}_i$ = 25 m/sec., t_f = 5 seconds, t_i = 0
2. Calculate acceleration where $\mathbf{v}_f$ = 40 m/sec., $\mathbf{v}_i$ = 10 m/sec., t_f =10 seconds, t_i = 0

(See end of chapter for solution.)

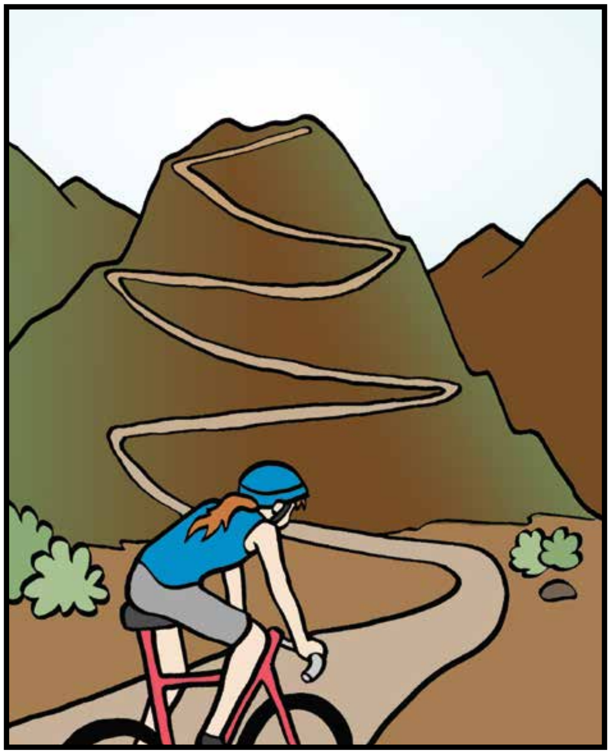
7.5 A Note About Math

You can see in this chapter that you can describe linear motion exactly with mathematics. Learning mathematical terms like scalar and vector, symbols like delta, and algebra rules can make linear motion both clearer and more complicated, depending on how much math you understand.



As we discussed in the last chapter, mathematics is an essential tool for physics. Because physical actions like linear motion can be described exactly using math, scientists have been able to launch rockets into space, put people on the Moon, and explore the possibility of traveling to other worlds.

The best way to learn the math is to practice. By understanding and solving the problems in this book and making up your own problems over and over again, you can master physics and math!



More Math!

Physics Math Problem 2

Imagine you are riding your bike in the Tour de France and you come to the famous mountain, the Col du Galibier. It is full of hairpin turns and steep inclines as the road winds up to Plan Lachet.

When you start up the mountain, you are going strong, but near the top you start to fade. You slow down from 20 km/h to 6 km/h in 6 minutes. What is your velocity (acceleration)?

(See end of chapter for solution.)

7.6 Summary

- Linear motion is the motion of an object in a straight line.
- Linear motion is described by three quantities — speed, velocity (speed + direction), and acceleration.
- Speed is defined by the distance traveled divided by time: s = d÷t
- Velocity is defined by the distance traveled in a particular direction divided by time: $\mathbf{v} = d \div t$
- Acceleration is defined by the change in speed (or velocity) divided by the change in time: $\mathbf{a} = \frac{\Delta \mathbf{v}}{\Delta t}$
- Mathematics is an essential tool for doing physics.

7.7 Some Things to Think About

- What are some examples of linear motion?
- List some experiments or projects a scientist might be working on that would require the calculation of speed.
- Do you think calculating speed could be important to athletes? Why or why not?
- In your own words, define velocity and speed.
- How would you describe acceleration?
- Make up your own physics math problems and share them with a friend.

Appendix: Math Solutions

Physics Math Problem 1 Ch. 7

1. $$\frac{10 \text{ m/sec.} - 25 \text{ m/sec.}}{|5 \text{ seconds} - 0 \text{ seconds}|} = \frac{-15 \text{ m/sec.}}{5 \text{ seconds}} = -3 \text{ m/second}^2$$

2. $$\frac{40 \text{ m/sec.} - 10 \text{ m/sec.}}{|10 \text{ seconds} - 0 \text{ seconds}|} = \frac{30 \text{ m/sec.}}{10 \text{ seconds}} = 3 \text{ m/second}^2$$

Physics Math Problem 2 Ch. 7

$\mathbf{v}_i$ = 20 km per hour

$\mathbf{v}_f$ = 6 km per hour

$\mathbf{t}_i$ = 0

$\mathbf{t}_f$ = 0.10 hour (6 minutes)

What is the acceleration?

$$\mathbf{a} = \frac{\mathbf{v}_f - \mathbf{v}_i}{|t_f - t_i|} = \frac{6 \text{ km/hr} - 20 \text{ km/hr}}{|0.10 \text{ hr} - 0 \text{ hr.}|} = \frac{-14 \text{ km/hr}}{0.10 \text{ hr}} = -140 \text{ km/hr}^2$$

Focus On

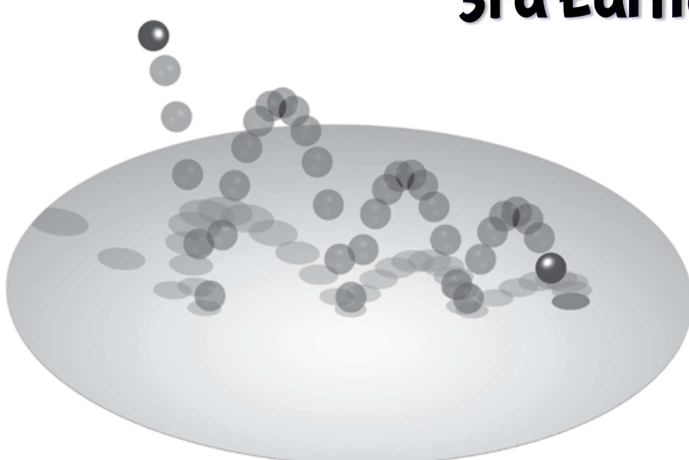
Grades 5–8

MIDDLE SCHOOL

PHYSICS

Laboratory Notebook

3rd Edition



Rebecca W. Keller, PhD

REAL SCIENCE 4 Kids

Real Science-4-Kids

Illustrations: Janet Moneymake

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Keeping a Laboratory Notebook

A laboratory notebook is essential for the experimental scientist. In this type of notebook, the results of all your experiments are kept together along with comments and any additional information that is gathered. For this curriculum, you should use this book as your laboratory notebook and record your experimental observations and conclusions directly on its pages, just as a real scientist would.

The experimental section for each chapter is pre-written. The exact format of a notebook may vary among scientists, but all experiments written in a laboratory notebook have certain essential parts. For each experiment, a descriptive but short *Title* is written at the top of the page along with the *Date* the experiment is performed. Below the title, an *Objective* and a *Hypothesis* are written. The objective is a short statement that tells something about why you are doing the experiment, and the hypothesis is the predicted outcome. Next, a *Materials List* is written. The materials needed for the experiment should be gathered before the experiment is started.

Following the *Materials List* is the *Experiment*. The sequence of steps and all the details for performing the experiment are written beforehand. Any changes made during the experiment should be written down. Include all information that might be of some importance. For example, if you are to measure 237 ml (1 cup) of water for an experiment, but you actually measured 296 ml (1 1/4 cup), this should be recorded. It is hard sometimes to predict the way in which even small variations in an experiment will affect the outcome, and it is easier to track a problem if all of the information is recorded.

The next section is the *Results* section. Here you will record your experimental observations. It is extremely important that you be honest about what is observed. For example, if the experimental instructions say that a solution will turn yellow, but your solution turned blue, you must record blue. You may have done the experiment incorrectly, or you might have discovered a new and interesting result, but either way, it is very important that your observations be honestly recorded.

Finally, the *Conclusions* should be written. Here you will explain what the observations may mean. You should try to write only valid conclusions. It is important to learn to think about what the data actually show and also what cannot be concluded from the experiment.

Contents

Experiment 1

It's the Law!

Introduction

Use the scientific method to determine Newton's First Law of Motion!

I. Think About It

❶ When you drive a car, can you choose to follow the speed limit? Why or why not?

❷ Do you think laws like following the speed limit can be broken? Why or why not?

❸ When you throw a ball up, does it always come down? Why or why not?

❹ Do you think a ball will behave in the same way at the top of a mountain as it does at the bottom? Why or why not?

❺ Do you think a ball will behave in the same way on Earth and on the Moon? Why or why not?

❻ Are there physical laws that can be broken? Why or why not?

II. Experiment 1: It's the Law!

Date ___________

Objective In this experiment we will use the scientific method to determine Newton's First Law of Motion.

Hypothesis ____

____

____

Materials

tennis ball
yarn or string (3 meters [10 ft])
paperclip
marble
bouncing ball (1 or more)

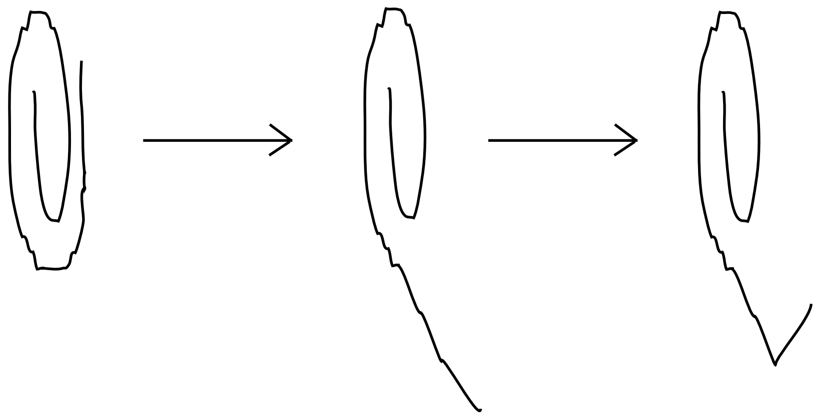
EXPERIMENT

Part I

❶ Take the tennis ball outside and throw it as far as you can. Observe how the ball travels through the air. In the space below, sketch the path the ball traveled.

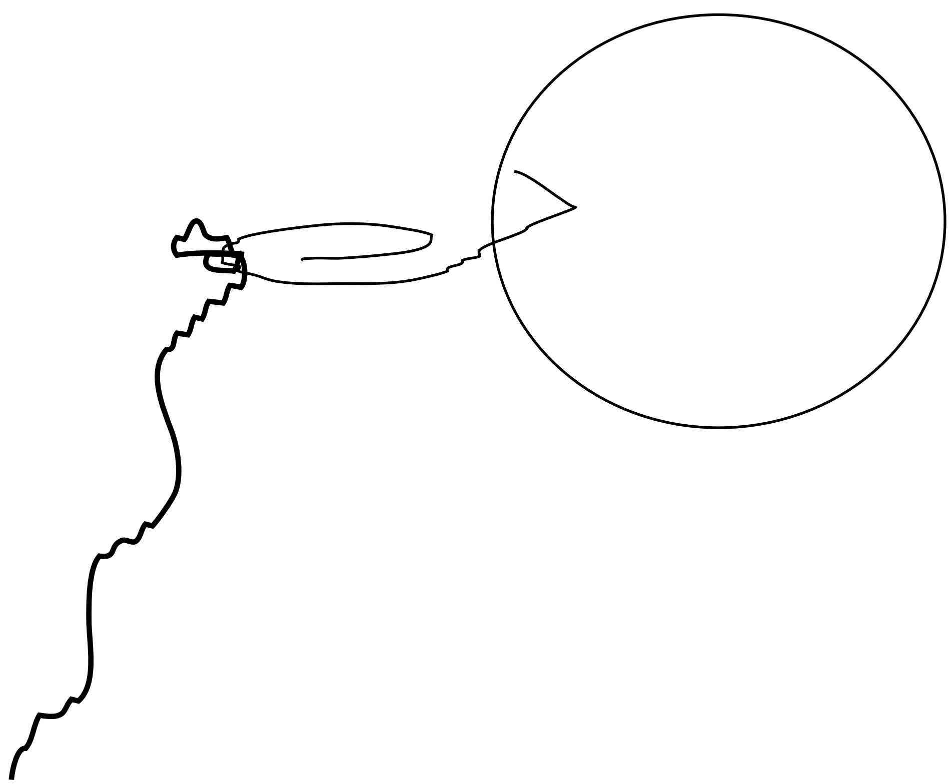
❷ Take the piece of string or yarn and attach it to the tennis ball as follows:

① Open the paperclip up on one side and make a hook on the end as shown below:



② Insert the hook on the end of the paperclip into the tennis ball by gently pushing and twisting.

③ Tie the string securely to the end of the paperclip.



❸ Holding onto one end of the string, again throw the ball into the air as far as you can. Note how the ball travels, and in the space below, record what you see. Do this several times.

Part II

❶ Take a marble and find a straight, clear path on a smooth area of the floor or outdoors. Roll the marble and record how it travels. Note where and how it stops or changes direction. Do this several times and record your observations in the next box.

❷ Repeat Step ❶ using a rough surface on which to roll the marble.

III. Conclusions

Based on your observations, what conclusions can you draw from the results of this experiment?

IV. Why?

Physical laws are not laws we make up ourselves. The physical world is ordered, reliable, and consistent. This orderliness means there are underlying physical laws, or general principles, that we can discover to better understand the world. Physical laws are regularities that scientists have discovered in the way things behave. Physical laws are described by mathematics. Because the universe is ordered, mathematics can be used to precisely describe the laws that govern it.

In this experiment you discovered Newton's First Law of Motion by observing the movements of a tennis ball and a marble. Newton's First Law of Motion can be stated as: *A body will remain at rest or in motion until it is acted on by an outside force.*

By attaching one end of a long string to a tennis ball, you were able to observe a difference in how the ball traveled once it was thrown. The string changed the path the tennis ball followed. When the ball was thrown, it began traveling in an arc, but when the string reached its full length, the ball abruptly stopped and fell to the ground. The path the ball followed only changed when the string acted on it.

In a similar way, when the marble was rolled on a smooth surface, it traveled in a mostly straight line. When the marble was rolled on a rough surface, the irregularities of the surface changed the path traveled by the marble. If you roll a marble on a smooth surface and the marble runs into an obstacle such as small building block, you will observe the marble traveling straight until it contacts the obstacle. The obstacle provides the outside force to act on the marble and change the path it's following. The marble's trajectory, or path, is not changed unless it is contacted by something — like a rough surface or a building block.

V. Just For Fun

Play with a rubber bouncing ball. Bounce it softly. How high does it go? Bounce it hard. How high does it go this time?

How many times can you get it to bounce if you drop it softly? How many times can you get it to bounce if you drop it hard?

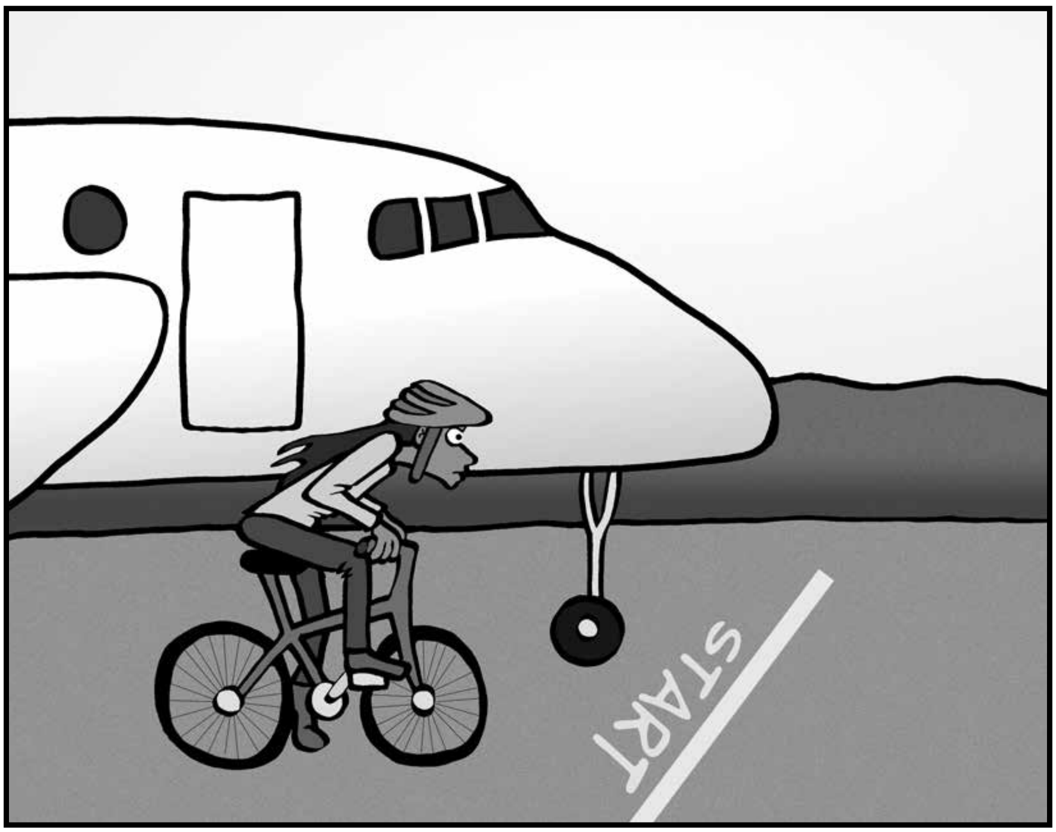
What happens if you bounce it using the same amount of force but vary the height from which you drop it?

If you have a bouncing ball of a different size, repeat the experiment and observe any differences.

Record your observations.

Experiment 7

Accelerate to Win!



Introduction

How can knowing about velocity and acceleration help you win a race?

I. Think About It

❶ How do you think long distance runners win a race?

❷ What do you think happens on the last lap of the Indy 500?

❸ If you were riding in a horse race, what do you think you might do to win?

❹ What do you think you would do if you were neck-and-neck with your best friend in a running race?

❺ How do you think you could win a bike race with friends?

❻ How do you think you might train for winning a foot race? What do you think you would need to know?

II. Experiment 7: Accelerate to Win!

Date ___________

Objective ____

____

Hypothesis ____

____

____

Materials

stopwatch
compass
an open space large enough to run (park, schoolyard, playground, backyard, etc.)
5 markers of your choice to mark distances
a group of friends

EXPERIMENT

Imagine that you are training for the final race of an Olympic running race and you are determined to win. You have to go the full distance without stopping before the end and you need to go fast enough to win. You are going to follow your coach's recommendation and start slowly and then sprint as fast as you can for the last quarter of the race.

❶ Map out a straight "track" and mark a starting and stopping point.

❷ Take the compass and find out the direction you will be running in. Record this direction on the chart in the *Results* section.

❸ Measure the distance between the starting point and the stopping point by walking heel-to-toe and counting each step as one "foot." Record the distance here.

Length of track in "feet" ______________________________

4. Take your measurement of the length of the track and divide it into fourths. Record the distances to the points at which you will time your run. Each time point distance is measured from the previous time point.

   Time point 1: $\mathbf{d_1}$ (1/4 mark) ______________________

   Time point 2: $\mathbf{d_2}$ (1/2 mark) ______________________

   Time point 3: $\mathbf{d_3}$ (3/4 mark) ______________________

   Time point 4: $\mathbf{d_4}$ (Finish) ______________________

   Now record distances $\mathbf{d_1}$-$\mathbf{d_4}$ on the chart in the Results section.

5. On the track, measure with your feet the distance between each time point and mark time points $\mathbf{d_1}$, $\mathbf{d_2}$, and $\mathbf{d_3}$. [$\mathbf{d_4}$ (Finish) is already marked.]

6. Pick one person to run the stopwatch. Have a second person use the chart in the *Results* section to record your time at each of the time points.

7. Get ready! **Set! GO!**

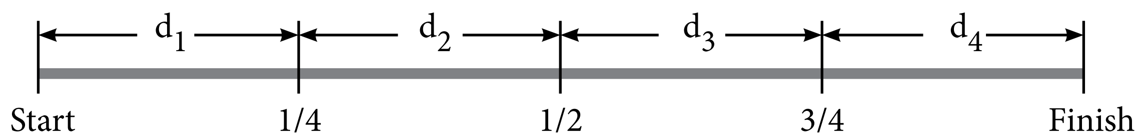
8. Repeat three or four times or until you are too tired to continue.

Results

1. For each trial, use the formulas provided in the following chart to calculate the velocity at each time point. Space is provided for calculations. Record your results in the chart.

2. For each trial, use the formulas provided in the chart to calculate the acceleration between each time point. Record your results in the chart.

Time Trial Results



Direction ____________________

Distance (in "feet")

d_1 __________ d_2 __________ d_3 __________ d_4 __________

Time (seconds)

	t_1	t_2	t_3	t_4
Trial 1	__________	__________	__________	__________
Trial 2	__________	__________	__________	__________
Trial 3	__________	__________	__________	__________

Velocity

	$v_1 = \frac{d_1}{t_1}$	$v_2 = \frac{d_2}{t_2}$	$v_3 = \frac{d_3}{t_3}$	$v_4 = \frac{d_4}{t_4}$
Trial 1	__________	__________	__________	__________
Trial 2	__________	__________	__________	__________
Trial 3	__________	__________	__________	__________

Acceleration*

	$\mathbf{a}_1 = \left(\frac{\mathbf{v}_2 - \mathbf{v}_1}{\lvert t_2 - t_1 \rvert}\right)$	$\mathbf{a}_2 = \left(\frac{\mathbf{v}_3 - \mathbf{v}_2}{\lvert t_3 - t_2 \rvert}\right)$	$\mathbf{a}_3 = \left(\frac{\mathbf{v}_4 - \mathbf{v}_3}{\lvert t_4 - t_3 \rvert}\right)$
Trial 1	__________	__________	__________
Trial 2	__________	__________	__________
Trial 3	__________	__________	__________

***Note:** For acceleration, time is always a positive number. In the acceleration formula, the change in time (Δt) is written as $\lvert t_f - t_i \rvert$ to show that the result is expressed as a positive number.

A Place for Your Calculations

III. Conclusions

A. Questions

❶ Which segment did you run with the fastest velocity? Why?

❷ Which segment did you run with the slowest velocity? Why?

❸ What can you notice about your acceleration in the different trials?

❹ In how many segments was your acceleration positive? negative? Which ones? Why?

B. Conclusions

Compare your trials. How was your performance in each? Were you faster or slower on the third trial? Explain your observations and results.

IV. Why?

By measuring the time it takes you to run between different points of known distance, you can calculate your velocity and acceleration. If you were training for the Olympics, by knowing how much energy you have and how fast you can go for how long, you could monitor how well you are doing in each run. You might notice that if you start out the run with a fast pace and accelerate too much near the beginning of the race, you are likely to run out of energy and slow down, decelerating near the finish line. Running out of energy before the end of the race won't help you to win, but you can learn how to start more slowly, run at a steady pace, and then accelerate at the finish.

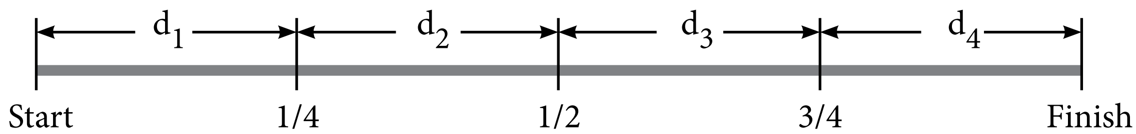
V. Just For Fun

Run every day for a few weeks, recording the date and length of time. Then repeat the experiment. Record your results in the following chart. Have your times improved? What changes have you made in how you run a race? Use additional paper for observations such as the route you follow, weather, etc.

Date and Length of Time for Each Run

Date	Time	Date	Time	Date	Time

Time Trial Results



Direction ____________________

Distance (in "feet")

d_1 __________ d_2 __________ d_3 __________ d_4 __________

Time (seconds)	t_1	t_2	t_3	t_4
Trial 1	__________	__________	__________	__________
Trial 2	__________	__________	__________	__________
Trial 3	__________	__________	__________	__________

Velocity	$\mathbf{v}_1 = \frac{d_1}{t_1}$	$\mathbf{v}_2 = \frac{d_2}{t_2}$	$\mathbf{v}_3 = \frac{d_3}{t_3}$	$\mathbf{v}_4 = \frac{d_4}{t_4}$
Trial 1	__________	__________	__________	__________
Trial 2	__________	__________	__________	__________
Trial 3	__________	__________	__________	__________

Acceleration*	$\mathbf{a}_1 = \left(\frac{\mathbf{v}_2 - \mathbf{v}_1}{\lvert t_2 - t_1 \rvert}\right)$	$\mathbf{a}_2 = \left(\frac{\mathbf{v}_3 - \mathbf{v}_2}{\lvert t_3 - t_2 \rvert}\right)$	$\mathbf{a}_3 = \left(\frac{\mathbf{v}_4 - \mathbf{v}_3}{\lvert t_4 - t_3 \rvert}\right)$
Trial 1	__________	__________	__________
Trial 2	__________	__________	__________
Trial 3	__________	__________	__________

***Note:** For acceleration, time is always a positive number. In the acceleration formula, the change in time (Δt) is written as $\lvert t_f - t_i \rvert$ to show that the result is expressed as a positive number.

There is space for calculations on the following page.

A Place for Your Calculations

Focus On

Grades 5-8

Middle School Physics

Teacher's Manual

3rd Edition

Rebecca W. Keller, PhD

Real Science-4-Kids

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A Note from the Author

This curriculum is designed to engage middle school level students in further exploration of the scientific discipline of physics. The *Focus On Middle School Physics Student Textbook–3rd Edition* and the accompanying *Laboratory Notebook* together provide students with basic science concepts needed for developing a solid framework for real science investigation into physics.

The experiments in the *Laboratory Notebook* allow students to expand on concepts presented in the *Student Textbook* and develop the skills needed for using the scientific method. This *Teacher's Manual* will help you guide students through the laboratory experiments.

There are several sections in each chapter of the *Laboratory Notebook*. The section called *Think About It* provides questions to help students develop critical thinking skills and spark their imagination. The *Experiment* section provides students with a framework to explore concepts presented in the *Student Textbook*. In the *Conclusions* section students draw conclusions from the observations they have made during the experiment. A section called *Why?* provides a short explanation of what students may or may not have observed. And finally, in each chapter an additional experiment is presented in *Just For Fun*.

The experiments take up to 1 hour. Materials needed for each experiment are listed on the following pages and also at the beginning of each experiment.

Enjoy!

Rebecca W. Keller, PhD

Materials at a Glance

Experiment 1	Experiment 2	Experiment 4	Experiment 5	Experiment 7
tennis ball paperclip yarn or string (about 3 meters [10 ft]) marble bouncing ball, 1 (or 2 or more of different sizes) **Optional** penknife, ice pick, awl, or other sharp tool pliers	electronic circuit kit (see next page Other) **Experiment 3** Slinky several paperclips 1-2 apples 1-2 lemons or limes 1-2 oranges 1-2 bananas spring balance scale or food scale meterstick, yardstick, or tape measure tape	small to medium size toy car stiff cardboard wooden board, smooth and straight (more than 1 meter [3 feet] long) straight pin or tack, several small scale or balance one banana, sliced 10 pennies meterstick, yardstick or tape measure tape	student-selected materials several sheets of paper **Experiment 6** several glass marbles of different sizes several steel marbles of different sizes cardboard tube, .7-1 meter [2.5-3 ft] long scissors black marking pen ruler letter scale or other small scale or balance	stopwatch compass an open space large enough to run (park, schoolyard, playground, backyard, etc.) 5 markers of students' choice to mark distances blank paper a group of friends

Experiment 8	Experiment 9	Experiment 10	Experiment 11	Experiment 12
pencil or pen marking pen thumbtack or pushpin 3 pieces of string — approximate sizes: 10 cm [4 in.]; 15 cm [6 in.]; 20 cm [8 in.] tape ruler (metric) large piece of white paper (bigger than 30 cm [12 in.] square — students may need to tape several sheets of paper together) firm surface at least as large as the paper and that a thumbtack can be pinned into	10-20 copper pennies (pennies made before 1982 have more copper and work best) aluminum foil paper towels salt water: 30-45 ml (2-3 Tbsp.) salt per 240 ml (1 cup) water voltmeter* 2 plastic-coated copper wires, each 10-15 cm (4"-6") long duct tape (or other strong tape) scissors wire cutters fine steel wool, plain (no soap), 1 pad 9 volt battery ovenproof pan or dish heatproof pad or surface **Optional** wire stripping tool bucket of water	small glass jar with lid aluminum foil (small piece) paperclip duct tape (or other strong tape) plastic or rubber rod (or balloon) silk fabric (or can use hair with a balloon) scissors ruler awl or other tool to make a hole several thin, bendable plastic straws (thick straws may not work well) paper tissues (Kleenex) or cloth made of silk or wool small piece of paper small piece of aluminum foil 1 or more books — thin pages preferable 1-2 plastic combs plastic cup shallow bowl or a plate	(2) D cell batteries and battery holder (2) 3.7 volt light bulbs and sockets (1) switch (4) alligator clip connectors (2) 5 ohm, 1/4 watt resistors (1) DC motor with propeller Materials are available as a kit from Home Science Tools (as of this writing): Product #: EL-KITBASC http://www.hometrainingtools.com/	metal rod (e.g., large nail 8.9 cm [3.5"] long, 16d flathead—or an unmagnetized screwdriver) electrical wire, .3-.6 meter (1'-2') 10-20 paperclips 6v or larger battery (12v battery if a screwdriver is used) electrical tape or 2 alligator clips scissors wire cutters bar magnet small plastic baggie small flat-bottomed clear plastic container with lid [about 5 cm x 8 cm x 1.5 cm (2" x 3" x 1/2") — a box straight pins come in would work) clear Karo syrup spoon 2 pencils or other props **Optional** wire stripping tool iron filings**

* An inexpensive voltmeter can be purchased at any store that supplies electrical equipment. Make sure the voltage scale is low enough to detect small voltages. A typical penny-cell produces about 0.5v.

** Available from Home Science Tools CH-IRON, http://www.hometrainingtools.com/

Materials

Quantities Needed for All Experiments

Equipment

alligator clip connector (2)[1]
awl or other tool to make a hole
ball, bouncing, 1 (or 2 or more of different sizes)
ball, tennis
battery, 6v or larger (12v battery used with a screwdriver)
battery, 9 volt
battery, D cell (2) and battery holder[1]
bowl, shallow, or a plate
compass
container with lid, small flat-bottomed clear plastic [about 5 cm x 8 cm x 1.5 cm (2” x 3” x 1/2”) — a box straight pins come in would work)
jar, small, glass with lid
light bulb, 3.7 volt (2), and sockets (2)[1]
magnet, bar
marble, glass, several of different sizes
marble, steel, several of different sizes
meterstick, yardstick, or tape measure
motor, DC, with propeller[1]
pad or surface, heatproof
pan or dish, ovenproof
pennies, 10
pennies, 10-20 copper (pennies made before 1982 have more copper and work best)
resistor, 5 ohm, 1/4 watt, (2)[1]
rod, metal (e.g., large nail 8.9 cm [3.5”] long, 16d flathead—or an unmagnetized screwdriver)
ruler
ruler (metric)
scale, letter, or other small scale or balance
scale, spring balance or food
scissors
Slinky
spoon
stopwatch
switch, electric[1]
toy car, small to medium size
voltmeter*
wire cutters

Optional

bucket
penknife, ice pick, awl, or other sharp tool
pliers
wire stripping tool

Materials

aluminum foil
baggie, small plastic
board, wooden, smooth and straight (more than 1 meter [3 feet] long)
book, 1 or more — thin pages preferable
cardboard, stiff
cardboard tube, .7-1 meter [2.5-3 ft] long
comb, plastic, 1-2
cup, plastic
fabric, silk (or hair and a balloon)
markers of students’ choice to mark distances, 5
materials, student-selected
paper, large piece, white (bigger than 30 cm [12 in.] square — can tape several sheets of paper together)
paper, several sheets
paper towels
paperclips, 10-20
pen, black marking
pencil or pen
pencil, (2) or other props
rod, plastic or rubber (or balloon)
salt water: 30-45 ml (2-3 Tbsp.) salt per 240 ml (1 cup) water
steel wool, fine, plain (no soap), 1 pad
straws, plastic, thin, bendable, several (thick straws may not work well)
string, 3 pieces— approximate sizes: 10 cm [4 in.]; 15 cm [6 in.]; 20 cm [8 in.]
tack or straight pin, several
thumbtack or pushpin
tissues, paper (Kleenex) or cloth made of silk or wool
tape
tape, duct (or other strong tape)
wire, electrical, .3-.6 meter (1’-2’)

wire, plastic-coated copper wires, 2 pieces, each 10-15 cm (4”-6”) long
yarn or string (about 3 meters [10 ft])

Optional

iron filings[2]
tape, electrical

Foods

apple, 1-2
banana, 2-3
Karo syrup, clear
lemon or lime, 1-2
orange, 1-2

Other

electronic circuit kit (choose one):
Snap Circuits: http://www.snapcircuits.net/
Snap Circuits Jr. 100 Kit
Little Bits: http://littlebits.cc/intro
Base Kit: http://littlebits.cc/kits/base-kit
Note: If these products are no longer available, do an internet search on children’s electronic circuit kits to find a kit suitable for this experiment.

group of friends

open space large enough to run (park, schoolyard, playground, backyard, etc.)
surface, firm, large, that a thumbtack can be pinned into

[1] Electrical materials are available as a kit from Home Science Tools (as of this writing): Product #: EL-KITBASC http://www.hometrainingtools.com/
[2] Available from Home Science Tools CH-IRON, http://www.hometrainingtools.com/

Contents

Experiment 1

It's the Law!

Materials Needed

- tennis ball
- paperclip
- yarn or string (about 3 meters [10 ft])
- marble
- bouncing ball, 1 (or 2 or more of different sizes)

Optional

- penknife, ice pick, awl, or other sharp tool
- pliers

Objectives

In this experiment students will be introduced to the concept of *physical laws*—a fundamental concept in physics.

The objectives of this lesson are for students to:

- Use the scientific method to observe the physical world.
- Explore Newton's First Law of Motion.

Experiment

I. Think About It

Read this section of the *Laboratory Notebook* with your students.

Ask the students what a law is, such as a law against driving too fast or a law against stealing. Ask if these laws can be broken and, if so, why they can be broken.

Explain that laws in physics differ from the kinds of laws that govern our country. In physics a law is an overall principle or relationship that remains the same and is not broken.

Ask the students to describe several observations they have made about how objects behave in the physical world. Encourage them to discuss as many observations as they can think of. There are no "right" answers, and at this point, it is not important to know the reasons why something happens.

Ask questions such as the following:

- *What happens when you put on the brakes while riding a bicycle? Do the tires stop immediately? Do they skid?*
- *What happens when you throw a ball into the air? Does it reach the clouds? Does it come down in the same spot?*
- *What happens when you turn on a flashlight? How far can you see the light? Can you see the beam from a flashlight in the daytime?*
- *Have you ever thrown a ball and had it not come down (except when it gets stuck somewhere like in a tree)?*
- *Does ice always float?*
- *Does the Sun always come up in the morning?*

II. Experiment 1: It's the Law!

Read this section of the *Laboratory Notebook* with your students.

In this experiment students will discover Newton's First Law of Motion by observing the movements of a tennis ball and a marble. Newton's First Law of Motion can be stated as:

> *A body will remain at rest or in motion until it is acted on by an outside force.*

The objective is provided. Have the students read through the experiment and then write a hypothesis based on the steps of the experiment.

Part I

❶ Students are to observe how a ball travels through the air. They should notice that the ball will go up and come down in some kind of arc every time they throw it. The arc can be shallow or sharp depending on how they throw the ball.

Challenge them to throw the ball so that it won't come down.

Ask them if they can get the ball to go up and down in a pattern different from an arc.

❷ Have the students follow the directions to use a paperclip to attach the string to the tennis ball. It is somewhat difficult to puncture the tennis ball with the paperclip, so have students take care while doing this. You may want to first put a small hole in the tennis ball with a penknife, ice pick, or awl before having the students insert the paperclip.

Alternatively, a longer string can be used, wrapped several times around the ball, and secured with tape. It is harder to get the string to stay attached to the ball using this method.

❸ With the string attached, the trajectory of the tennis ball will be different. When the string has reached its full length, the ball will abruptly stop and fall to the ground.

Have the students throw the ball several times. Ask them if they can change how the ball falls to the ground. They should notice that if they shorten the string, the ball does not travel as far as when the string is longer. They should also notice that if they do not throw the ball very far and it does not reach the end of the string, the ball will travel almost as if there were no string attached to it.

Have them record their results.

Part II

❶ Students will roll a marble several times on a smooth surface and record their results.

❷ Students will roll a marble several times on a rough surface and record their results.

III. Conclusions

Have the students review the results they recorded for Part I and Part II of the experiment. Have them draw conclusions based on the data they collected.

IV. Why?

Read this section of the *Laboratory Notebook* with your students.
Discuss any questions that might come up.

V. Just For Fun

In this experiment students will play with a bouncing ball and observe how the amount of force used changes the way the ball bounces. With more force, the ball will bounce higher and more times.

If bouncing balls of different sizes are available, have the students repeat the experiment and observe whether the size of the ball affects the outcome.

Experiment 7

Accelerate to Win!

Materials Needed

- stopwatch
- compass
- an open space large enough to run (park, schoolyard, playground, backyard, etc.)
- 5 markers of students' choice to mark distances
- blank paper
- a group of friends

Objectives

In this experiment students will explore using basic math in physics formulas.

The objectives of this lesson are for students to:

- Learn how to calculate velocity and acceleration.
- Observe how velocity and acceleration vary over several trials.

Experiment

I. Think About It

Read this section of the *Laboratory Notebook* with your students.

Ask questions such as the following to guide open inquiry.

- *How fast is the fastest human?*
- *How fast is the fastest animal?*
- *How fast do you think you can run?*
- *Do you think you can train to run faster? Why or why not?*

II. Experiment 7: Accelerate to Win!

Have the students read the entire experiment before writing an objective and a hypothesis.

Objective: Have the students think of an objective for this experiment (What will they be learning?).

Hypothesis: Have the students write a hypothesis. The hypothesis can restate the objective in a statement that can be proved or disproved by their experiment. Some examples include:

- *I can run at a steady pace (velocity).*
- *I can accelerate at the end of each trial.*
- *My average velocity will increase with each trial.*

EXPERIMENT

❶ Help the students create a running track that is straight and has a manageable length. Have them mark a starting point and an ending point for the distance they will run. Make sure that when the total length of the track is divided into fourths, there will be enough time during the run for a timer to record the time of each segment of the run (one-fourth of the total track length).

❷ Have the students use a compass to determine in which direction they will be running and then record this direction in the chart in the *Results* section.

❸ Students will measure the length of the track using their own feet, walking heel-to-toe from the starting point to the finish with each step being one "foot." In the space provided, have them record the distance they measure.

❹ Using their measurement of the total distance to be run, students will calculate the distance of one-fourth of the track and then record this result for each of the time points $\mathbf{d_1}$-$\mathbf{d_4}$. This is the distance they will run for each of the four segments of the track.

❺ Have the students use their feet to measure the distance between the time points and mark each time point on the track in a way that the timer can see the mark as the runner is passing it.

❻-❼ One person will use a stopwatch to clock the times. Have them stand in a position where they will be able to see all the time points as the runner passes them. A second person will record the times in the *Laboratory Notebook.* Have your students run from the starting point to the finish line with the time keeper recording the time at each time point.

❽ Have the students run three or four times or until they are too tired to continue.

Results

❶-❷ Have your students calculate the velocity of each segment for each time trial and the acceleration between time points for each trial. Formulas are provided in the chart where students will record their answers. An example of calculations is included on the following page in this *Teacher's Manual.*

Space is provided for doing the calculations, but extra paper may be needed. If students use extra paper, have them fasten it in the *Laboratory Notebook* when they have completed the experiment.

A Place for Calculations (Calculations for example on next page)

Velocity

Trial 1: v_1 $$v_1 = \frac{d_1}{t_1} = \frac{150 \text{ ft.}}{11 \text{ sec.}} = 13.6 \text{ ft./sec.}$$

Trial 1: v_2 $$v_2 = \frac{d_2}{t_2} = \frac{150 \text{ ft.}}{12 \text{ sec.}} = 12.5 \text{ ft./sec.}$$

Trial 1: v_3 $$v_3 = \frac{d_3}{t_3} = \frac{150 \text{ ft.}}{11 \text{ sec.}} = 13.6 \text{ ft./sec.}$$

Trial 1: v_4 $$v_4 = \frac{d_4}{t_4} = \frac{150 \text{ ft.}}{9 \text{ sec.}} = 16.7 \text{ ft./sec.}$$

Acceleration*

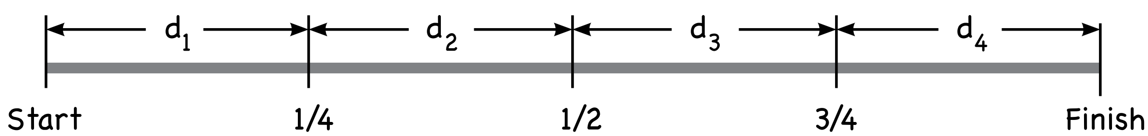
Trial 1: $$a_1 = \left(\frac{v_2 - v_1}{|t_2 - t_1|}\right) = \frac{12.5 - 13.6}{|12-11|} = \frac{-1.1 \text{ ft./sec.}}{1 \text{ sec.}} = -1.1 \text{ ft. sec.}^2 \text{ (squared)}$$

Trial 1: $$a_2 = \left(\frac{v_3 - v_2}{|t_3 - t_2|}\right) = \frac{13.6 - 12.5}{|11-12|} = \frac{1.1 \text{ ft./sec.}}{1 \text{ sec.}} = 1.1 \text{ ft. sec.}^2 \text{ (squared)}$$

Trial 1: $$a_3 = \left(\frac{v_4 - v_3}{|t_4 - t_3|}\right) = \frac{16.7 - 13.6}{|9-11|} = \frac{3.1 \text{ ft./sec.}}{2 \text{ sec.}} = 1.55 \text{ ft. sec.}^2 \text{ (squared)}$$

***Note:** For acceleration, time is always a positive number. In the acceleration formula, the change in time (Δt) is written as $|t_f - t_i|$ to show that the result is expressed as a positive number.

Time Trial Results (Example—answers will vary)



Direction *north*

Distance (in "feet")

d_1 *150* d_2 *150* d_3 *150* d_4 *150*

Time (seconds)

	t_1	t_2	t_3	t_4
Trial 1	*11*	*12*	*11*	*9*
Trial 2				
Trial 3				

Velocity

	$v_1 = \frac{d_1}{t_1}$	$v_2 = \frac{d_2}{t_2}$	$v_3 = \frac{d_3}{t_3}$	$v_4 = \frac{d_4}{t_4}$
Trial 1	*13.6 ft./sec.*	*12.5 ft./sec.*	*13.6 ft./sec.*	*16.7 ft./sec.*
Trial 2				
Trial 3				

Acceleration*

	$a_1 = \left(\frac{v_2 - v_1}{\lvert t_2 - t_1 \rvert}\right)$	$a_2 = \left(\frac{v_3 - v_2}{\lvert t_3 - t_2 \rvert}\right)$	$a_3 = \left(\frac{v_4 - v_3}{\lvert t_4 - t_3 \rvert}\right)$
Trial 1	*-1.1 ft. sec.^{2}*	*1.1 ft. sec.^{2}*	*1.55 ft. sec.^{2}*
Trial 2			
Trial 3			

***Note:** For acceleration, time is always a positive number. In the acceleration formula, the change in time (Δt) is written as $\lvert t_f - t_i \rvert$ to show that the result is expressed as a positive number.

III. Conclusions

Have the students review the results they recorded for the experiment, answer the questions, and then draw conclusions based on their observations. Have them note if their conclusion supports or does not support their hypothesis.

IV. Why?

Read this section of the *Laboratory Notebook* with your students.
Discuss any questions that might come up.

Discuss with your students how they can measure their own velocity and acceleration by using time and distance. Explain how knowing these numbers can help a coach train an athlete for the Olympics. Have them discuss how this information might help them in a sport they participate in or how it might be used by participants in a sport they're interested in.

V. Just For Fun

Have the students run every day and record the date and amount of time they spend on each run. A chart is provided. They may find it interesting to create their own chart on a separate piece of paper that has a schedule for the runs and space to record the date and length of time of each run along with observations including how difficult or easy each run was, their route and its characteristics, the weather, etc. Do they notice a difference between the first and last training runs? What factors affect their runs?

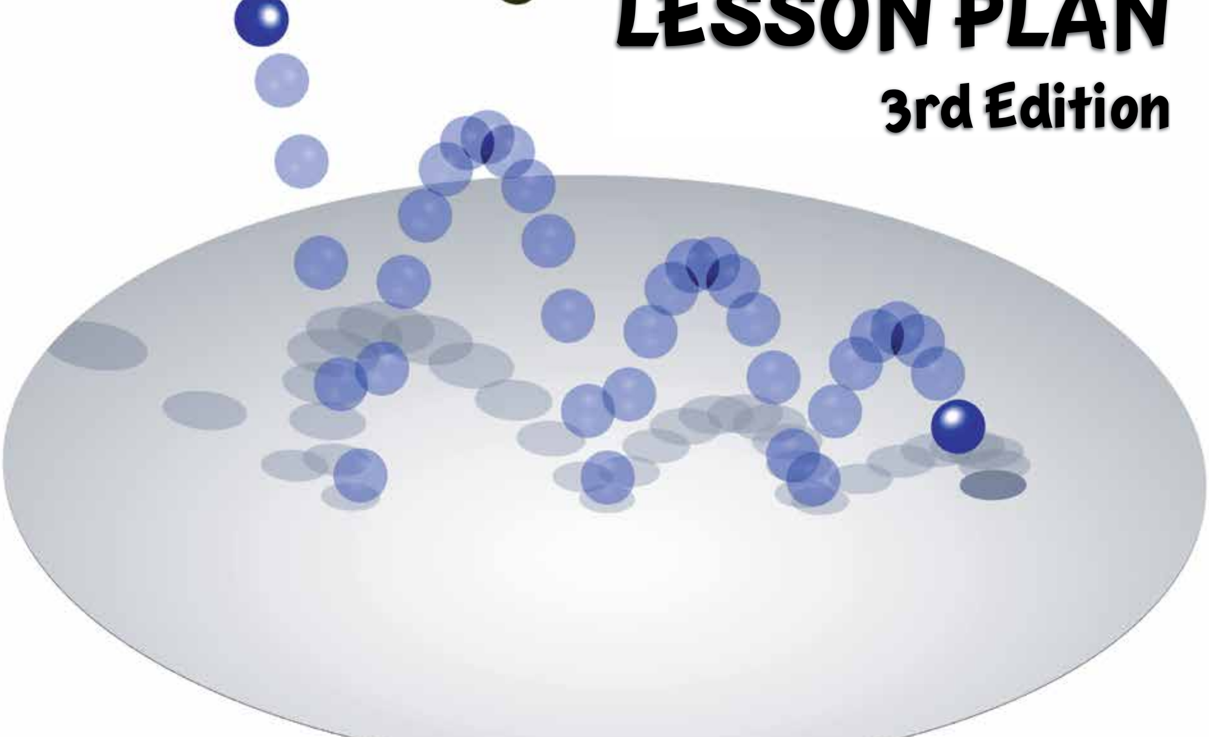
After a few weeks have them repeat the experiment. Have them record and calculate their results and compare them to the first set of trials. What differences in the trials can they notice? Do they think running every day for a few weeks made a difference in the results? Has using the physics in this experiment helped them better understand how to run a race? Has it helped them observe a difference in their fitness? What conclusions can they draw?

Grades 5-8

Focus On Middle School Physics

Lesson Plan

3rd Edition



Rebecca W. Keller, PhD

Real Science 4 Kids

Real Science-4-Kids

Focus On Middle School Physics Lesson Plan— 3rd Edition

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LESSON PLAN INSTRUCTIONS

This *Lesson Plan* accompanies *Focus On Middle School Physics Student Textbook*, *Laboratory Notebook,* and *Teacher's Manual—3rd Edition*. It is designed to be flexible to accommodate a varying schedule as you go through the year's study. And it makes it easy to chart weekly study sessions and create a portfolio of your student's yearlong performance. The PDF format allows you to print pages as you need them.

This Lesson Plan file includes:

- Weekly Sheets
- Self-Review Sheet
- Self-Test Sheet
- Sticker Templates

Materials recommended but not included:

- 3-ring binder
- Indexing dividers (3)
- Labels—24 per sheet,1.5" x 1.5" (Avery 22805)

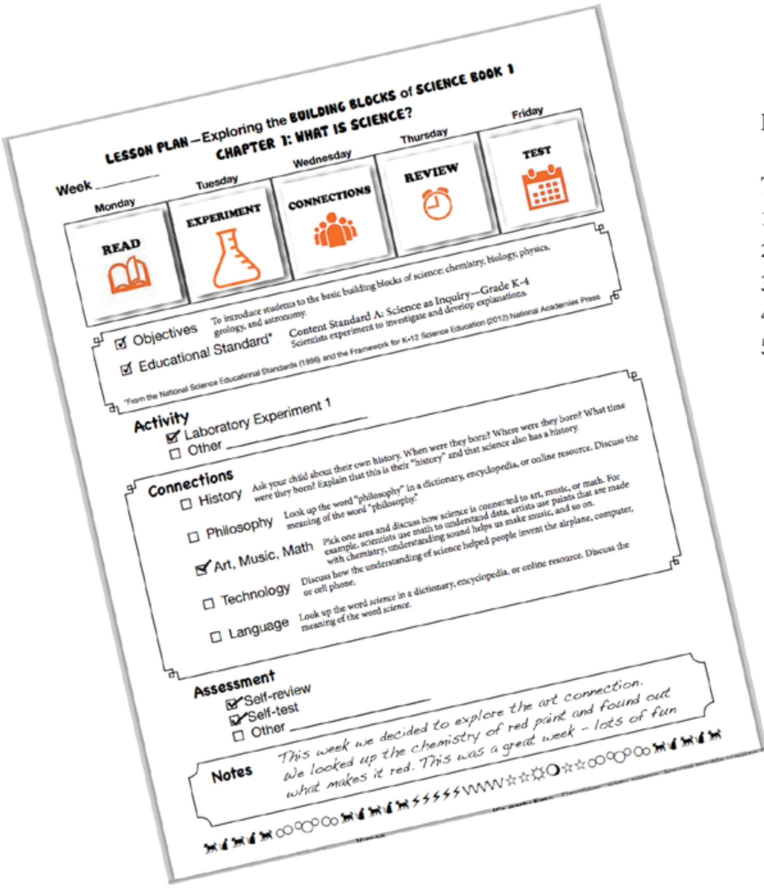
Use the Weekly Sheets to map out daily activities and keep track of student progress. For each week you decide when to read the text, do the experiment, explore the optional connections, review the text, and administer tests. For those families and schools needing to provide records of student performance and show compliance to standards, there is a section on the Weekly Sheets that shows how the content aligns to the National Science Standards.

To use this Lesson Plan:

- Print the Weekly Sheets
- Print Self-Review Sheets
- Print Self-Test Sheets
- Print the stickers on 1.5" x 1.5" labels
- Place all the printed sheets in a three-ring binder separated by index dividers

At the beginning of each week, use the squares under each weekday to plan your daily activities. You can attach printed stickers to the appropriate boxes or write in the daily activities. At the end of the week, use the *Notes* section to record student progress and performance for that week.

WEEKLY LESSON PLAN SAMPLES


LESSON PLAN – Exploring the BUILDING BLOCKS of SCIENCE BOOK 1
CHAPTER 1: WHAT IS SCIENCE?

Week ______

Monday	Tuesday	Wednesday	Thursday	Friday
READ	EXPERIMENT	CONNECTIONS	REVIEW	TEST

☑ Objectives — To introduce students to the basic building blocks of science: chemistry, biology, physics, geology, and astronomy.

☑ Educational Standard* — Content Standard A: Science as Inquiry—Grade K-4. Scientists experiment to investigate and develop explanations.

*From the National Science Educational Standards (1996) and the Framework for K-12 Science Education (2012) National Academies Press

Activity
☑ Laboratory Experiment 1
☐ Other ______

Connections
☐ History — Ask your child about their own history. When were they born? Where were they born? What time were they born? Explain that this is their "history" and that science also has a history.
☐ Philosophy — Look up the word "philosophy" in a dictionary, encyclopedia, or online resource. Discuss the meaning of the word "philosophy."
☑ Art, Music, Math — Pick one area and discuss how science is connected to art, music, or math. For example, scientists use math to understand data, artists use paints that are made with chemistry, understanding sound helps us make music, and so on.
☐ Technology — Discuss how the understanding of science helped people invent the airplane, computer, or cell phone.
☐ Language — Look up the word science in a dictionary, encyclopedia, or online resource. Discuss the meaning of the word science.

Assessment
☑ Self-review
☑ Self-test
☐ Other ______

Notes This week we decided to explore the art connection. We looked up the chemistry of red paint and found out what makes it red. This was a great week – lots of fun

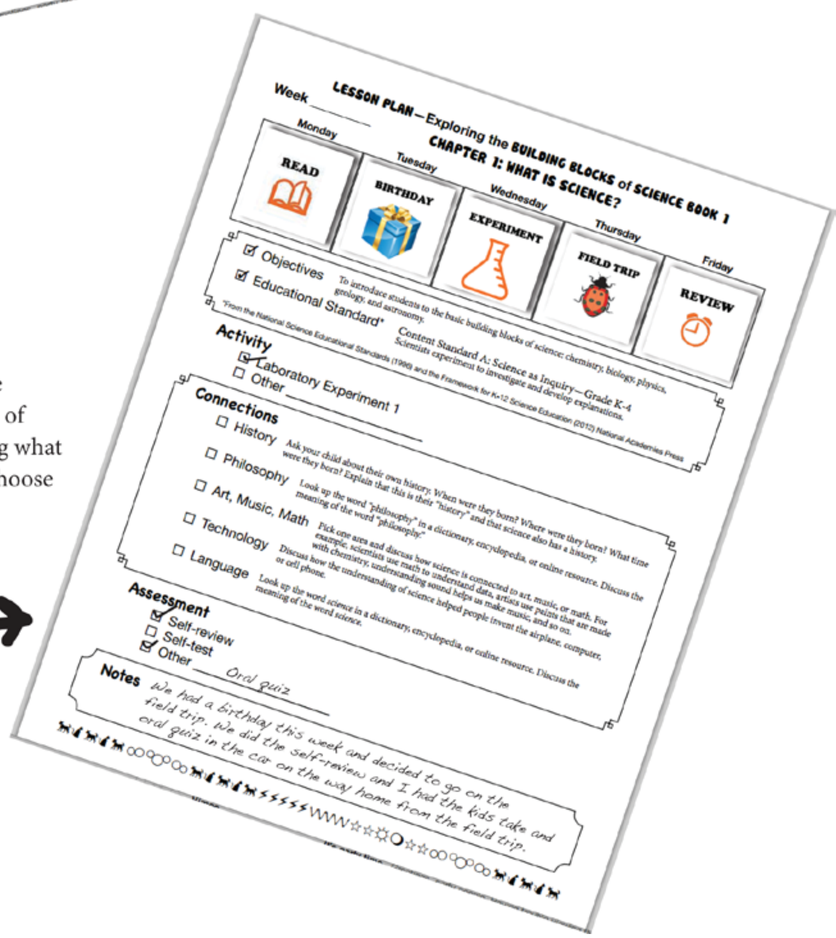
Here is a sample of a normal week.

The recommended sequence is
1 - Read the student textbook on the first day.
2 - Do the laboratory experiment on the second day.
3 - Pick one or more connections to explore on the third day.
4 - Do the self-review sheet on the fourth day.
5 - Administer the self-test or another exam on the fifth day.

Here is a sample of a week with other activities

1- Find at least one day to READ the text.
2 - Find a day to perform the EXPERIMENT.
3 - Find a day to do the REVIEW or TEST.

Any activity that is missed can be rescheduled for the following week. However, keep to the main sequence of reading the text, doing the experiment, and reviewing what has been covered. If an activity needs to be missed, choose the CONNECTIONS or SELF-TEST.


LESSON PLAN – Exploring the BUILDING BLOCKS of SCIENCE BOOK 1
CHAPTER 1: WHAT IS SCIENCE?

Week ______

Monday	Tuesday	Wednesday	Thursday	Friday
READ	BIRTHDAY	EXPERIMENT	FIELD TRIP	REVIEW

☑ Objectives — To introduce students to the basic building blocks of science: chemistry, biology, physics, geology, and astronomy.

☑ Educational Standard* — Content Standard A: Science as Inquiry—Grade K-4. Scientists experiment to investigate and develop explanations.

*From the National Science Educational Standards (1996) and the Framework for K-12 Science Education (2012) National Academies Press

Activity
☑ Laboratory Experiment 1
☐ Other ______

Connections
☐ History — Ask your child about their own history. When were they born? Where were they born? What time were they born? Explain that this is their "history" and that science also has a history.
☐ Philosophy — Look up the word "philosophy" in a dictionary, encyclopedia, or online resource. Discuss the meaning of the word "philosophy."
☐ Art, Music, Math — Pick one area and discuss how science is connected to art, music, or math. For example, scientists use math to understand data, artists use paints that are made with chemistry, understanding sound helps us make music, and so on.
☐ Technology — Discuss how the understanding of science helped people invent the airplane, computer, or cell phone.
☐ Language — Look up the word science in a dictionary, encyclopedia, or online resource. Discuss the meaning of the word science.

Assessment
☑ Self-review
☐ Self-test
☑ Other Oral quiz

Notes We had a birthday this week and decided to go on the field trip. We did the self-review and I had the kids take and oral quiz in the car on the way home from the field trip.

Week ________

CHAPTER 1: WHAT IS PHYSICS?

Monday	Tuesday	Wednesday	Thursday	Friday

☑ Objectives To introduce students to the scientific discipline called physics.

☑ Educational Standard* **Content Standard 5-PS1-2**
Science assumes consistent patterns in natural systems.

*From the Next Generation Science Standards (NGSS)

Activity

- ☐ Laboratory Experiment 1
- ☐ Other ____________________

Connections

- ☐ History Look up Sir Isaac Newton and discuss how his ideas contributed to modern physics.
- ☐ Philosophy Explore how our ideas about the physical world have changed since Aristotle's time.
- ☐ Art, Music, Math Explore how physical bodies follow rules, like math follows rules, and how some rules in physics change as we learn more.
- ☐ Technology Look up Newton's cradle and discuss how it works.
- ☐ Language Look up the word *physics* in a dictionary, encyclopedia, or online resource and discuss its meaning.

Assessment

- ☐ Self-review
- ☐ Self-test
- ☐ Other ____________________

Notes

Week __________

CHAPTER 7: LINEAR MOTION

Monday	Tuesday	Wednesday	Thursday	Friday

☑ Objectives To examine the nature of linear motion.

☑ Educational Standard* **Content Standard MS-PS2.A**
The motion of an object is determined by the sum of the forces acting on it.

*From the Next Generation Science Standards (NGSS)

Activity

☐ Laboratory Experiment 7
☐ Other ______________________

Connections

☐ History Look up Isaac Newton and discuss his First Law of Motion and how it applies to linear motion.

☐ Philosophy Explore whether or not philosophy shaped Newton's ideas about motion.

☐ Art, Music, Math Explore the equations for velocity and acceleration and discuss how math is used to understand motion.

☐ Technology Discuss the types of technology used to explore motion.

☐ Language Look up the word *acceleration* in a dictionary, encyclopedia, or online resource and discuss its meaning.

Assessment

☐ Self-review
☐ Self-test
☐ Other ______________________

Notes

SELF-REVIEW

Think about all of the ideas, concepts, and facts you read about in this chapter. In the space below, write down everything you've learned.

Date ____________________ Chapter ____

SELF-TEST

Imagine you are the teacher and you are giving your students an exam. In the space below, write 5 questions you would ask a student based on the information you learned in this chapter.

Date ________________ Chapter ____

READ	READ	READ	READ
REVIEW	REVIEW	REVIEW	REVIEW
EXPERIMENT	EXPERIMENT	EXPERIMENT	EXPERIMENT
CONNECTIONS	CONNECTIONS	CONNECTIONS	CONNECTIONS
TEST	TEST	TEST	TEST
READ	READ	READ	READ

HOLIDAY

HOLIDAY

HOLIDAY

HOLIDAY

FIELD TRIP

FIELD TRIP

FIELD TRIP

FIELD TRIP

BIRTHDAY

BIRTHDAY

BIRTHDAY

BIRTHDAY

REST DAY

REST DAY

REST DAY

REST DAY

REST DAY

REST DAY

REST DAY

REST DAY

SICK DAY

SICK DAY

SICK DAY

SICK DAY

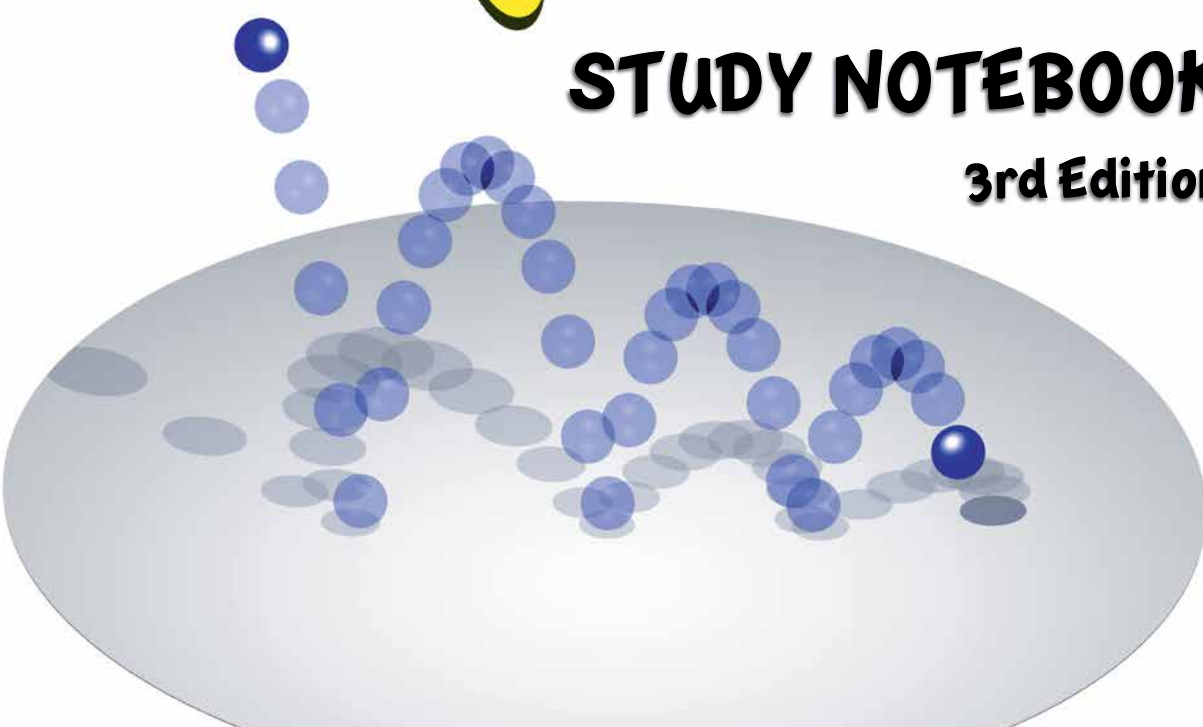
Focus On

Grades 5-8

MIDDLE SCHOOL PHYSICS

STUDY NOTEBOOK

3rd Edition



Rebecca W. Keller, PhD

Illustrations: K. Keller

Focus On Middle School Physics Study Notebook—3rd Edition

Published by Gravitas Publications Inc.
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www.gravitaspublications.com

Welcome to your study notebook

This notebook is your place to record anything you want as you learn about force, energy, work, inertia, different types of energy, electrostatics, electrodynamics, motion, and all the other amazing facts and concepts we call physics.

There are questions and suggestions. Some are serious and some are whimsical. If you don't like them, cross them out and create your own.

Just explore what you think about all the topics you are learning and try not to get too worried about writing down the "right" answers. This is an opportunity for you to explore what YOU like.

There are places in this notebook that are unscripted and have little instruction. There are also questions that just dangle on the edges of the page. That's OK. Just record, draw, or paste images that you think apply. Add extra pages as you like. Answer the questions and suggestions in a way that makes the most sense to you. Most of real science is unscripted and making discoveries has no set of instructions. Just play with it. You'll be fine and you might find out something unexpected and amazing.

This notebook is not meant to be graded. So parents and teachers, just let it go. Don't grade this notebook or make your student "turn it in." If your student wants to share all they are learning great! If not, let that be OK too.

day month year

CHAPTER 1

How do the laws of physics affect the way humans build things? Consider a bridge.

Why is a bridge necessary?

Using your knowledge of physics and the laws that govern nature, explain why a bathtub is designed the way it is. Describe everything from its shape to its material.

What holds water?

Galileo

Newton

Challenge: Use Isaac Newton's equation for gravitational force to explain an object's motion in physical space.

$$F=G\frac{m_1m_2}{r^2}$$

what is space?

day month year

CHAPTER VII

Define the word magnitude.

How does this word help define the concept of a scalar quantity?

Write a story in which something moves at constant speed in completely linear motion.

Pick one of the equations from Chapter 7 and attempt to apply it to a situation in your life.

$= \div \ast \, !$

Name ___________________________ Date __________________

Focus On Middle School Physics 3rd Edition - Midterm 1
Chapters 1-6, 18 questions, 10 points each

1. Physical laws... (10 points)
   - ◯ Can be easily broken and changed.
   - ◯ Were determined without scientific investigation.
   - ◯ Are statements about how the physical world works.
   - ◯ Were ignored by Galileo and Isaac Newton when they did their experiments.
   - ◯ Are similar to laws such as those that tell us the speed limit on a highway.

2. Newton's law of universal gravitation is a law of physics that... (10 points)
   - ◯ Explains that the physical world behaves in unpredictable and unreliable ways.
   - ◯ Explains why two balls of different weights that are dropped at the same time will land at different times.
   - ◯ Tells us that science is to be taken seriously.
   - ◯ Shows mathematically why two falling objects will reach the ground at the same time even if one is heavier than the other.
   - ◯ Shows that scientific investigation doesn't work well for discovering the laws of physics.

3. The laws of physics are scientists' best guesses about how things behave. (10 points)
   - ◯ True
   - ◯ False

Focus On Middle School Physics 3rd Edition - Midterm 2
Chapters 7-12, 18 questions, 10 points each

1. Some terms used to describe motion are... (Check all that apply.) (10 points)
   - ☐ Speed.
   - ☐ Acceleration.
   - ☐ An airplane.
   - ☐ A voltmeter.
   - ☐ A bicycle.
   - ☐ Velocity.

2. Match the term with its definition. (10 points)

______ Speed	a. The motion of any object traveling in a straight line.
______ Acceleration	b. When velocity changes over time.
______ Scalar	c. The rate at which an object covers a given distance in a given amount of time.
______ Linear motion	d. Describes an amount or magnitude.
______ Velocity	e. Speed + direction (the rate at which an object changes its position).

3. If you wanted to ride your bike at a constant speed, you would need to avoid... (Check all that apply.) (10 points)
   - ☐ Big hills.
   - ☐ Stop signs.
   - ☐ Traffic jams.
   - ☐ Traffic lights.
   - ☐ Cold weather.
   - ☐ Chocolate milk.

Focus On Middle School Physics 3rd Edition - Final
Chapters 1-12, 24 questions, 10 points each

1. One of the great discoveries of Newton's time is that... (10 points)
   - ☐ Two balls dropped at the same time will land at different times.
   - ☐ Mathematics can be used to describe events that happen in nature.
   - ☐ Speed limits can be changed.
   - ☐ Laws of physics can be broken and reassembled.
   - ☐ Galileo dropped balls off a building to see what would happen.

2. In physics it can be said that because the mass of Earth is so huge, the gravitational force on any two objects is the same as long as each object has a mass that is much smaller than the mass of Earth. Therefore, two balls dropped at the same time will land at the same time. (10 points)
   - ○ True
   - ○ False

13. Speed can be calculated by dividing distance by time. (10 points)
   - ○ True
   - ○ False

14. Speed is the rate at which an object moves, and velocity is the rate at which an object changes its position. (10 points)
   - ○ True
   - ○ False

Answer Sheet

Focus On Middle School Physics 3rd Edition - Midterm 1
Chapters 1-6, 18 questions, 10 points each

1. Are statements about how the physical world works.
2. Shows mathematically why two falling objects will reach the ground at the same time even if one is heavier than the other.
3. True

Focus On Middle School Physics 3rd Edition - Midterm 2
Chapters 7-12, 18 questions, 10 points each

1. Speed., Acceleration., Velocity.
2. c, b, d, a, e
3. Big hills., Stop signs., Traffic jams., Traffic lights.

Focus On Middle School Physics 3rd Edition - Final
Chapters 1-12, 24 questions, 10 points each

1. Mathematics can be used to describe events that happen in nature.
2. True

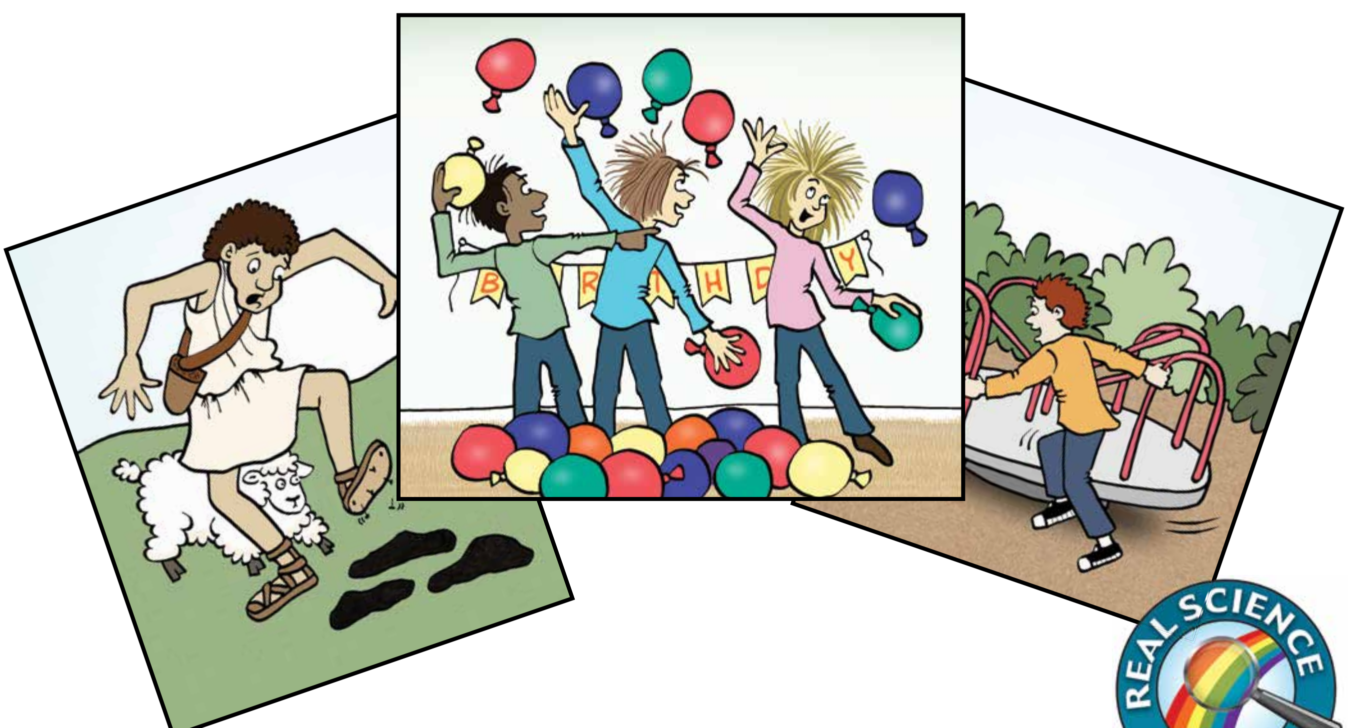
13. True
14. True

Grades 5-8

Focus On Middle School Physics

Graphics

3rd Edition



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Illustrations: Janet Moneymaker

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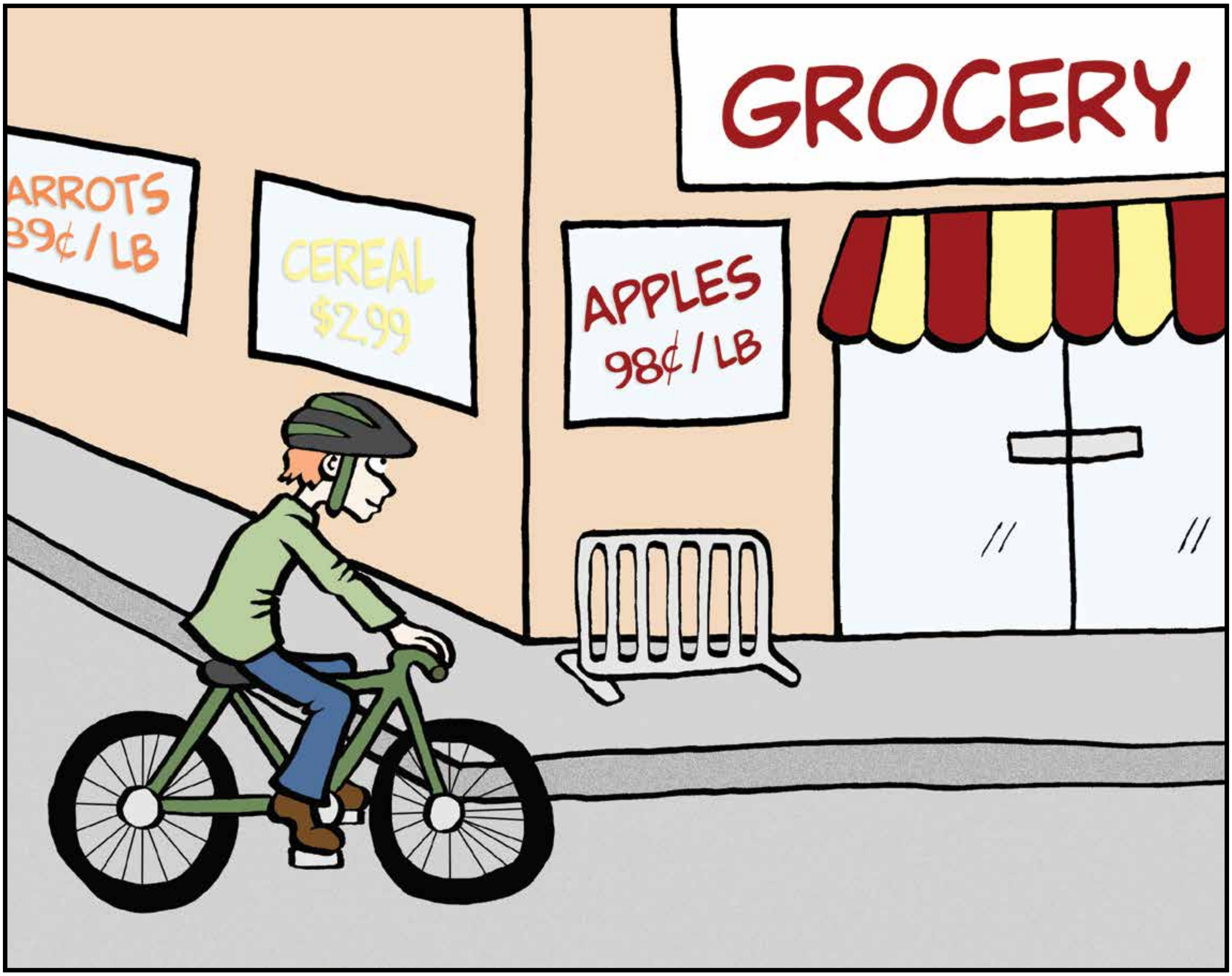
SHUFFLE
SHUFFLE
SHUFFLE


I'M SORRY, BUT YOU'VE BROKEN NEWTON'S SECOND LAW OF MOTION. YOU LEFT THE BALLPARK WITHOUT A ROCKET.
POLICE


HERE, I MADE UP THIS PHYSICS PROBLEM FOR YOU.
FUN! I'LL MAKE UP ONE FOR YOU NEXT TIME.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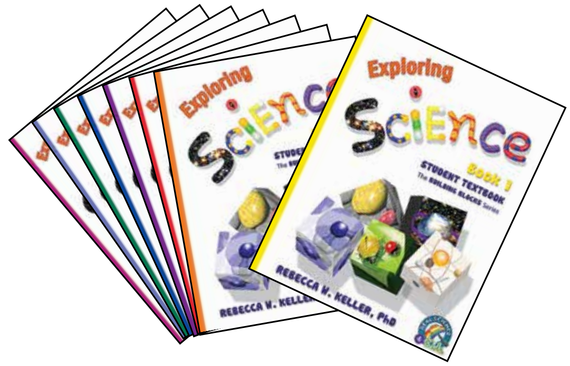
Exploring Science Book K (Activity Book)
Exploring Science Book 1
Exploring Science Book 2
Exploring Science Book 3
Exploring Science Book 4
Exploring Science Book 5
Exploring Science Book 6
Exploring Science Book 7
Exploring Science Book 8



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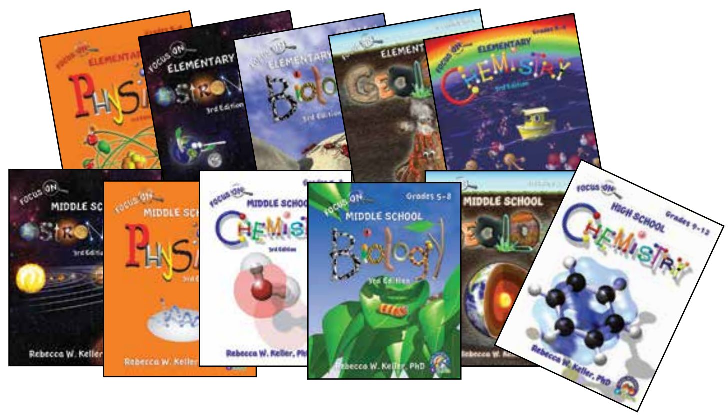

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