Elements of Physics
Motion, Force, and Gravity

Producer/Director
Wendy Loten

Animation and Graphics
Wesley Cudlip

Educational Consultants
Daniel Coté, MSc

Dr. David Harrison
University of Toronto
Physics Department

Editor
Gina Binetti

Writer/Researcher
Bill Freeman, Ph.D.

Teacher's Guide
Bill Freeman, Ph.D.

Distributed by..

united learning
1560 Sherman Avenue | Suite 100 | Evanston IL 60201 | 800.323.9084 | FAX 847.328.6706 | www.unitedlearning.com

800.323.9084 | FAX 847.328.6706 | www.unitedlearning.com

Table of Contents

CC This video is closed captioned.

CLASSROOM/LIBRARY
CLEARANCE NOTICE

This program is for instructional use. The cost of each program includes public performance rights as long as no admission charge is made. Public performance rights are defined as viewing of a video in the course of face-to-face teaching activities in a classroom, library, or similar setting devoted to instruction.

Closed Circuit Rights are included as a part of the public performance rights as long as closed-circuit transmission is restricted to a single campus. For multiple locations, call your United Learning representative.

Television/Cable/Satellite Rights are available. Call your United Learning representative for details.

Duplication Rights are available if requested in large quantities. Call your United Learning representative for details.

Quantity Discounts are available for large purchases. Call your United Learning representative for information and pricing. Discounts, and some special services, are not applicable outside the United States.

Your suggestions and recommendations are welcome. Feel free at any time to call United Learning at 1-800-323-9084.

Elements of Physics Series
Motion, Force, and Gravity
Grades 9 to 12
Viewing Time: 20 minutes

INTRODUCTION

Motion, Force, and Gravity is part of the ***Elements of Physics Series***, a six-part series of programs to help students understand fundamental concepts of physics. The attractive images and engaging narration of the program have been designed by educators and filmmakers to help students understand the sometimes difficult and obscure scientific explanations of our physical world.

The study of motion has led to some of the greatest insights into our physical world. Out of these studies came an understanding of gravity, the movement of heavenly bodies, and the motion of objects on Earth, and it also has been important in the development of architecture and engineering. This program focuses on the way that physicists understand motion, force, and gravity and provides a comprehensive introduction to this fascinating area of science.

LINKS TO CURRICULUM STANDARDS

Elements of Physics Series, is based on the "National Science Educational Standards" for "Physical Science," grades 9-12, (Content Standard B).

STUDENT OBJECTIVES

After viewing the program and participating in the various follow up activities, students should be able to do the following:

• Describe the experiment Galileo conducted to determine the speed of falling bodies of differing weights and summarize his findings.

• Explain why Galileo is sometimes called the "father of science."

• Describe Galileo's formula for the speed of falling bodies: $v = gt$.

• Explain the importance of mathematical formulas in expressing ideas in physics and other sciences.

• Describe the work of Copernicus and Kepler.

• Define what is meant by the term, "First Revolution in Physics."

• Explain the three laws of motion and their significance.

• Give a general description of vector analysis and its importance.

• Describe how Newton derived his law of gravity from the second law of motion.

• Explain the difference between weight and mass.

• Outline Newton's law of gravity either mathematically or with a verbal explanation.

• Explain why Newton provided the reason, which had eluded Galileo, as to why things fell to Earth.

• Give a brief explanation of Einstein's general theory of relativity.

• Explain what Einstein meant by space-time.

• Name the forces in nature: gravity, electromagnetism, and the strong and weak nuclear forces.

SUMMARY OF THE PROGRAM

The motion of objects has long been a fascination, but it was the Italian physicist Galileo who first began a scientific inquiry into the behavior of moving objects. He studied the speed of falling bodies and determined all objects fell at the same rate of speed regardless of their weight.

Isaac Newton, the great English physicist in the seventeenth century, built on the work of Galileo and others. Newton worked out the "three laws of motion" governing the movement of all objects at all times and in all circumstances. The first law states that an object's natural tendency is to continue what it is doing. It is known as the "principle of inertia." The second law describes how an object accelerates or changes direction when a force is applied to it, and Newton's third law of motion states that for every action there is an equal and opposite reaction.

Physicists have applied these three laws to many different types of movements. Vector analysis, the study of forces, is widely used in various branches of engineering and architecture. But perhaps the greatest insight they have led to is the explanation of gravitational forces.

The second law states that an object accelerates or changes direction when a force is applied to it. Newton was able to use this law to explain how the gravitational force of the Earth's mass held the moon in its orbit. In the same way the planets are held in their orbits by the gravitational force of the sun.

For over 200 years, scientists used Newton's explanation of gravity, but in 1915, Albert Einstein published his general theory of relativity, which provided a radically different way of understanding gravity. Einstein held that the mass of an object distorts space-time. Planets orbit the sun because they are moving through the distortions of space-time that have been created by the gravitational field of the sun.

The study of motion remains central to scientific inquiry and continues to have an important impact on such diverse fields as astronomy, architecture, engineering, rocketry, automobile design, and many other areas.

PRE-TEST AND POST-TEST

Blackline Master #1, Pre-Test, is an assessment tool intended to gauge student comprehension prior to viewing the program. Remind your students that these are key concepts upon which they should focus while watching the program.

Blackline Master #7, Post-Test, can be compared to the results of the Pre-Test to determine the changes in student comprehension after participation in the activities and viewing the program.

TEACHER PREPARATION

Before presenting this program to your students, we suggest that you preview the program and review this guide and accompanying Blackline Master activities in order to familiarize yourself with the content. Feel free to duplicate any of the Blackline Masters and distribute them to students.

As you review the materials presented in this guide, you may find it necessary to make some changes, additions or deletions to meet the specific needs of your class. We encourage you to do this. Only by tailoring this program to your class will your students obtain the maximum instructional benefits afforded by the materials.

We suggest that you first show the program in its entirety to your students. This is an introduction to the complex subject of motion, force and gravity, and at this stage it is helpful that students gain an overview of the concepts and material in the program. A number of lesson activities will grow out of the content of the program and, therefore, the presentation should be a common experience for all students.

After the introduction the program is divided into units with the following titles:

- **About Falling Things**
- **The First Revolution in Physics**
- **Newton's Three Laws of Motion**
- **Forces and Vectors**
- **Gravitation**
- **Einstein's Theory of General Relativity**

These chapters vary in length from two to four minutes. After the students have seen the entire program, lessons could be designed around these different chapters. A chapter could be shown at the beginning of the class, and the balance of the class time and subsequent classes, could be spent examining the subject matter in the program in greater depth.

STUDENT PREPARATION

It is important that students work through the material and familiarize themselves with the vocabulary, concepts, and theories that scientists use to understand this field.

If the students have a textbook that they are following, assign the relevant reading before the lesson. As students work through the material, they will encounter a number of unfamiliar words and concepts. Most of these words are highlighted in the program. An additional list of words is provided in **Blackline Masters #2a-c, Vocabulary Definitions and Activities**.

The program concludes with a 10-question Video Quiz that may be used to gauge students' comprehension immediately after the presentation of the program. **Blackline Master #6, Video Quiz**, is a printed copy of the questions, which may be reproduced and distributed to the students. The answers to the questions appear in the answer key of this Teacher's Guide.

DESCRIPTION OF BLACKLINE MASTERS

Blackline Master #1, Pre-Test, should be given to students before viewing the program. When these answers are compared to the Post-Test results, it will help you gauge student progress.

Blackline Master #2a, Vocabulary Definitions, will introduce students to unfamiliar words and concepts used in this program. **Blackline Master #2b: Use the Right Word**, and **Blackline Master #2c: Word Match**, are activities designed to help reinforce key concepts and vocabulary.

Blackline Master #3, Connected/Not Connected, will help students identify their knowledge of key vocabulary terms and the context these words may be used.

Blackline Master #4, Crossword Puzzle

Blackline Master #5, Creative Writing Story Ideas, will allow students to think creatively while incorporating scientific principles and vocabulary covered in this program.

Blackline Master #6, Video Quiz, is a printed version of the Video Quiz that appears at the end of the video.

Blackline Master #7, **Post-Test**, may be used to evaluate student progress after completing this lesson.

ANSWER KEY

Blackline Master #1, Pre-Test

1. false
2. true
3. true
4. false
5. true
6. true
7. false
8. false
9. false
10. true

Blackline Master #2b, Use the Right Word

1. velocity
2. gravity
3. friction
4. acceleration
5. mass
6. force
7. vector
8. inertia
9. calculus
10. space-time

Blackline Master #2c, Word Match

calculus	type of mathematics developed by Newton
Einstein	showed the universe had four dimensions

F = ma	formula that expresses the second law of motion
friction	resistance to the motion of an object
gravity	universal force of the attraction of the mass of an object
mass	total quantity of an object's matter
motion	movement of an object
Newton	his synthesis is said to be the "first revolution of physics"
v = gt	formula for velocity
velocity	rate of motion in a particular direction

Blackline Master #3, Connected/Not Connected

1. mass	gravity
2. calculus	Aristotle
3. velocity	v = gt
4. inertia	interacting
5. falling objects	Galileo
6. F = ma	friction
7. vector	stress
8. First Law	opposing
9. Einstein	space-time
10. light	matter

Blackline Master #4, Crossword Puzzle

										1 M						
							2 V	E	L	O	C	I	T	Y		
										O						
					3 M	O	T	I	O	N						
					A											
4 C					T						5 T		6 E			
O		7 M			H			8 G			H		I			
P		9 A	C	C	E	L	E	R	A	T	I	O	N			10 N
E		S			M			A			R		S			E
R		S			A			V			D		T			W
N			11 F		T			I					E			T
12 I	N	E	R	T	I	A		T		13 G	A	L	I	L	E	O
C			I		C			Y					N			N
U			C		S											
S			T													
			I													
			O													
			N													

Blackline Master #6, Video Quiz

1. true
2. acceleration
3. false
4. inertia
5. true
6. false
7. net
8. true
9. false
10. space-time

Blackline Master #7, Post-Test

1. per second
2. mathematics
3. accelerates
4. gravity
5. false: Aristotle believed objects fell to Earth at rates of speed

dependent on their weight. It was Galileo who determined that all object fell at the same rate of speed in a vacuum.
6. false: The third law of motion states that for every action there is an equal and opposite reaction. Opposing forces often do not balance out.
7. true
8. false: Gravitation is a universal force that affects all objects within the gravitational field.
9. false: Newton's theory of gravity holds that objects with mass are affected by gravity. Light has no mass, and therefore, light is unaffected by gravity. Einstein showed that the effect of gravity was to distort or warp space itself. Light follows this distortion and therefore is affected by gravity.
10. Weight is a useful measurement on the surface of the Earth because the gravitational field of the Earth pulls equally on all objects. In space, however, all objects are weightless. A more useful concept is mass because it is the total quantity of the object's matter, and objects never lose their mass.
11. Newton was the first to understand that the moon was held in place by the gravitational pull of the Earth. The Earth's gravitational force pulls on the moon just enough to change the moon's direction, but the Earth is a sphere. Its curvature is such that as the moon falls towards the Earth, it never gets closer and stays in orbit.
12. Einstein explained that the mass of the object, like the sun, bends the space and time around it and in the process space-time is warped. Planets orbit the sun because they are moving through the distortions of space-time that have been created by the gravitational field of the sun.

DISCUSSION QUESTIONS

1. <u>Why did people find it difficult to accept the fact that all objects fall to Earth at the same rate of speed?</u>
Common sense suggests that lighter objects fall more slowly than heavier objects, just as common sense suggests the world is flat or the Earth is the center of the universe. Science often challenges these "common sense" notions to determine what is the reality behind appearances.

2. Why is verification and experimentation so important in science?
Verification is the foundation of science. In the realm of scientific inquiry, until an idea is confirmed by some form of rigorous empirical research, it is only an unsubstantiated opinion. The process of science is to first develop ideas about why things behave the way they do. These untested ideas are called hypothesis. The next stage is to test the validity of a hypothesis in the empirical, or real, world. In the physical sciences these tests are usually in the form of controlled experiments. The social sciences use survey research, interviews or some other technique. Only when a hypothesis has been objectively verified, and often verified a number of times, can it be accepted as valid.

3. If Newton's first law of motion states that an object's natural tendency is to continue what it is doing - the principle of inertia - then why do objects not continue in the same direction forever?
In the vacuum of space, once an object is set in motion it will carry on forever unless another force, such as gravity, intervenes. On Earth, gravity is always a factor that influences the motion of objects. For example, when a ball is thrown it falls to Earth because of gravity. There is another factor that often determines the motion of objects on Earth, friction. A hockey puck sliding along the ice will ultimately slow and stop because of the friction between the ice and the puck. The friction of air is another factor that often distorts the motion of an object. Today automobiles are carefully designed to minimize the influence of air currents on the motion of cars.

4. The third law of motion states that for every action there is an equal and opposite reaction. Does the same law work for human beings?
All of the laws apply to the motion of physical objects, not human emotion. It does not mean, for example, for every person who is loved there is another who is hated. The world of human beings, fortunately, does not have the same level of predictability as physical objects.

5. Newton and Einstein both provided explanations of gravity. Can they both be right?
Curiously, the answer to this question is yes, but the reason is that they looked at different things. Newton was explaining how the gravitational force of one object affected the motion of another. Einstein looked at the question, what was the effect of the gravitational force of an object on the shape of space-time? He always said that he was building on Newton's theory, not contradicting it. Both theories provide precise mathematical calculations for the influence of gravity on objects. The theory of relativity provides a more accurate calculation, but astronomers and scientists at space agencies usually use Newton's formula because the calculations are easier to use and the margin of error is miniscule.

EXTENDED LEARNING ACTIVITIES

The following activities and projects might prove useful to students studying the subject of motion, force, and gravity.

1. Write a report on the life of Galileo. Why did the church feel that it was so important that he recant his views? What ultimately happened in this confrontation?

2. Replicate Galileo's experiment of falling bodies to determine whether heavier objects fall more rapidly than lighter objects. First, write your hypothesis as clearly as possible; second, conduct your experiment using two different types of methods to determine the speed of the falling bodies; and third, write a report on your findings.

3. Roll a ball down an inclined plane; for example, a piece of plywood leaning against a chair. With a stopwatch, measure the time it takes for the ball to roll the first two feet and then the second two feet. (Do it several times to verify your observations.) Calculate the rate of acceleration of the ball on the basis of your observations.

4. Research the term "Copernican Revolution." Why were these ideas so revolutionary?

5. Write a report on the reasons why there was an explosion of scientific thought in Europe during the seventeenth century.

6. Why is mathematics such a useful tool for physics? Give some examples of formulas used by physicists and show why they are more useful than written explanations.

7. Conduct two simple experiments that demonstrate the principle of inertia. In a report on your experiments describe the outcome with precision and explain why they validate the principle.

8. Draw a vector analysis showing the effect of three forces on the motion of a baseball. The three forces might be the force of the player throwing the ball, gravity, and the wind.

9. Draw an image showing how the gravitational field of a sun affects the space-time around it. Write an explanation of how a planet circling the sun and light from a distant star are influenced by this distortion.

10. Einstein is viewed as the greatest physicist of the twentieth century. Write a report that justifies or criticizes this point of view.

REFERENCE LIST

There are many excellent books and websites dealing with motion that are appropriate for students and available in libraries. The following is a short list.

Books:

Physics, A Practical Approach, Hirsch, Alan J., Second Edition, New York: John Wiley and Sons, 1991.

Physics, Huber-Schaim, Uri, John H. Dodge, James A. Walter, Fifth Edition, Lexington, Mass.: D.C. Heath and Co., 1981.

Basic Physics: A Self-Teaching Guide, Kuhn, Karl F., Second Edition, New York: John Wiley and Sons Inc., 1996.

Internet Sites:

http://www.aapt.org
This is the website of the American Association of Physics Teachers, an organization of physics high school teachers. They also publish a magazine called The Physics Teacher.

www.physicsclassroom.com
This excellent site for high school physics students provides tutorials on interesting topics and multi-media animations to help students visualize major physics topics.

www.physicscentral.com
This is the website of the American Physical Society, which has some 42,000 physicists as members. The site is written in a non-technical way appropriate for high school students. It features news, describes research, and also answers questions from students.

www.bbc.co.uk/history/historic_figures/newton
This is a site of the British Broadcasting Corporation (BBC). It provides an interesting biography of Newton, providing historical information and details on his contributions in science and other fields.

http://csep10.phys.utk.edu/astr161/lect/history/newtongrav.html
This amusing site deals with motion, Newton, and many other issues in physics. Their description of gravity is particularly interesting.

SCRIPT OF NARRATION

Humans have always attempted to understand the physical world. The ancient Greeks, over 2,300 years ago, arrived at insights, which continue to shape the way we understand things. But it has been the discoveries of physics in the last 400 years that has truly revolutionized the way we understand our physical universe.

Perhaps the most remarkable thing about physics is that some of the greatest insights have come from attempts to understand the simplest and most common everyday events. Who would have believed that our understanding of the solar system, stars, galaxies, and much more would come out of an attempt to understand why things fall?

ABOUT FALLING THINGS

Aristotle, one of the greatest of the Ancient Greek thinkers, believed that heavy objects fell to Earth faster than lighter objects. Drop a stone and a feather at the same time and watch which one reaches the ground first. For almost 2000 years Aristotle's belief about falling things was accepted as fact.

In the early 17th century, an Italian named Galileo wondered if it was true. Legend has it that an assistant climbed to the top of the Leaning Tower of Pisa and dropped two stones of differing weights while Galileo stayed on the ground to observe what happened. He found that both stones hit the ground at exactly the same time.

Whether Galileo actually dropped stones from the Tower of Pisa or not, he tested his idea by experimentation and observation, a process that is fundamental to science. For this reason alone he is often credited with being the "father of science."

Galileo was able to calculate important information about falling bodies. He determined that as objects fall, the speed at which they fall changes at a constant rate. During the first second, the speed is 9.8 meters per second and after the next second, the object falls at a rate of double that, or 19.6 meters per second, and so on. So the rate of acceleration, or change in velocity, per unit of time, is a constant, 9.8 meters per second, per second. He went on to reduce his observations to a mathematical formula. The formula is: $v = gt$, or change in velocity equals acceleration multiplied by time.

Galileo's explanation of the speed of falling bodies was a remarkable achievement, but one important element was missing. He did not know how to explain the force that was making this happen.

THE FIRST REVOLUTION IN PHYSICS

Galileo's use of a mathematical formula to express his ideas is very significant. Mathematics has become the major analytical tool of physics and virtually all of the significant insights in the discipline are expressed as formulas.

In 1530 Nicolaus Copernicus, a Polish astronomer, studied the solar system, and using mathematics, he concluded that the sun, rather than the Earth, was the center of the universe.

Johannes Kepler, working around the time of Galileo used mathematics to calculate the orbits of the planets around the sun. He discovered that their orbits were elliptical, rather than circular, and went on to work out a detailed set of laws that described the behavior of the planets.

By the middle of the 17th century the work of Galileo, Kepler and others had prepared the stage for the greatest scientist of the day, Isaac Newton. His synthesis has come to be called "the first revolution in physics." Like Galileo, Newton's work was the result of an attempt to understand things that could be observed every day.

NEWTON'S THREE LAWS OF MOTION

Newton built on the work of Galileo and Kepler and came to the conclusion that the motion of falling bodies, the movement of planets, and in fact the movement of any object at any time was due to being acted upon by a force, a push, or a pull. He worked out what he called the "three laws of motion," which govern the movement of all objects at all times and in all circumstances.

The first law states that an object's natural tendency is to continue what it is doing. If it is moving in a straight line at a constant speed, it will continue in a straight line unless acted upon by another force. It also states that an object at rest will remain at rest unless a force moves it. This is known as the "principle of inertia."

There are many examples of the first law. The space probe Pioneer 10 has been drifting through space for 35 years. A hockey puck sliding on the ice will keep on going. And this steel pipe won't move until "the claw" does its job.

An object's mass is a measure of its inertia. The greater the mass of an object, like the shuttle, the harder it is to move it or change its direction. Note that physicists use the term "mass," or the total quantity of its matter, rather than weight because in space, all objects are weightless but they never lose their mass.

The second law describes how an object accelerates, or changes direction, when a force is applied to it. The change depends on the magnitude of the net force. The second law also states that the acceleration due to a given force is always in the direction of the force. The mass of the object is also important. The larger the mass, the greater the force needed to make it accelerate or change direction.

The second law can be written as: $F = ma$. This formula is saying that applied force, or F, equals mass times acceleration, ma. This formula is used to describe the motion of objects under all kinds of circumstances. If a ball is thrown horizontally it will continue forever unless a force acts on it. The Earth's gravity is a force that pulls on the ball and it falls to Earth in the direction it is traveling.

Newton's third law of motion deals with interacting forces. It states that for every action there is an equal and opposite reaction. The opposing forces of these two tug of war teams balance each other. The swimmer pushes off from the floating raft propelling his body away from the raft but also pushing the raft backwards. As the law states: for every action there is an equal and opposite reaction.

A book sitting on a table remains where it sits because the table pushes back with a force equal to the book's weight. This seems like a simple minded idea but an architect or engineer designing a building had better understand the third law of motion and ensure there is enough support to carry the weight or the building will fall down.

In the building of bridges, or any complicated structure where weight must be distributed, the calculation of net force is vital because it shows where the stress will be concentrated. This is calculated through vector analysis.

FORCES AND VECTORS

Physicists use the term force in a special way to describe any action that affects the movement of an object. For example, a person paddling a canoe across a lake provides one source of force but there can be others. The wind against the hull of the canoe is a force; the waves provide another force and a current in the water yet another force. Together all of these different forces combine to make up the "net force" which determines the direction of the canoe.

A force has both a direction and a magnitude, or strength. They are analyzed using vectors such as this one. In this example there is a force from X to A, and a second force from X to B. These two forces combine to result in a net force X to C.

On the surface of the earth, friction plays an important role in influencing moving objects. Friction is a force parallel to the contacting surface between objects. If there were no friction, the balls on this pool table would roll forever. But without friction, this climber would not make it up the rock.

When laws in physics are expressed, outside forces, like friction, are ignored. Galileo did this when he ignored the influence of air resistance on the dropping stones and Newton did it when he ignored the influence of friction.

GRAVITATION

Isaac Newton made many contributions to physics, but perhaps the most important was his explanation of gravitation, one of the fundamental forces in the universe.

One story has it that he got the idea of gravitational forces when he saw an apple falling from a tree. Newton was the first to understand that gravitation was a universal force that influenced all objects and that this force accounted for a variety of phenomena, from apples falling to Earth, to the behavior of planets.

Newton's second law of motion, states that an object accelerates or changes direction when a force is applied to it, but if that force works on an apple at the top of a tall tree, could it also work on distant objects? If so, why doesn't the moon fall to Earth?

The Earth's gravitational force pulls on the moon, just enough to change the moon's direction of travel. But the Earth is a ball - a sphere - and the Earth's curvature is such that the moon never gets closer to the Earth and it stays in its orbit.

Newton had provided the explanation that had eluded Galileo as to why things on Earth fall down and why planets stay in orbit. The reason is the force called gravity.

Newton's law of gravity says that the gravitational force between two objects is proportional to the quantity of their masses and inversely proportional to the square of the distance between them. In order to solve these problems Newton developed a new mathematical tool called calculus. Using calculus Newton's followers were able to plot the motion of the planets and handle a whole new class of problems.

In the 18^{th} and 19^{th} centuries, it seemed only a matter of time before the application of Newtonian physics would reveal all of the mysteries of the universe. It took a physicist by the name of Albert Einstein in the early 20th century to shatter that optimism.

EINSTEIN'S THEORY OF GENERAL RELATIVITY

Einstein was a revolutionary thinker and his theory of general relativity brought a new understanding to the concept of gravity.

Einstein introduced the idea of a four dimensional universe. The three dimensions of space are length, width, and height and there is a fourth dimension, time. This is called the space-time continuum, one of the strangest and most difficult concepts to understand in modern physics.

Einstein theorized that the mass of an object actually distorts space-time much like the line vectors in this drawing. In his theory, planets orbit around the sun because they are moving through the distortions of space-time that have been created by the mass of the sun.

Einstein published his theory of general relativity in 1915. At that time it was believed that light had no mass and was unaffected by gravity. Einstein's theory predicted that light would be influenced by the distortion of space-time.

In 1919, during an eclipse of the sun, a group of astronomers were able to observe light from a distant star, which would normally be obscured by the sun's bright rays. The star appeared to have shifted from its regular charted position. It seemed that the light from the star had bent as it skimmed close to the sun. This confirmed Einstein's theory that the light rays simply follow the curvature of space-time caused by the mass of the sun.

Although Einstein's description of gravity is very different from Newton's, the two give almost identical results for the weak interactions of gravity at long distances. But for strong interactions, like predicting the orbit of Mercury, the planet closest to the sun, Einstein's theory is more accurate.

Einstein believed that the forces found in nature, which are gravity, electromagnetism, and the strong and weak nuclear forces are all aspects of the same force. Physicists since Einstein's day continue to try to integrate these forces into one unified theory in the belief that this will deepen our understanding of the universe.

As yet they have not been successful, but physics has come a long way from the time that Galileo measured the speed of falling bodies.

Name ____________________

ELEMENTS OF PHYSICS
MOTION, FORCE, AND GRAVITY

Pre-Test

Directions: This will help you discover what you know about the subject of motion before you begin this lesson. Answer the following true or false.

1. Aristotle believed that all objects fell to Earth at the same rate of speed. T_______ F_______.

2. Galileo expressed his observations on the rate of speed of falling objects in a mathematical formula. T_______ F_______.

3. Nicolaus Copernicus concluded the sun was the center of the universe. T_______ F_______.

4. Newton's second law of motion is called the "principle of inertia." T_______ F_______.

5. Mass is a term used by physicists to indicate the total quantity of an object's matter. T_______ F_______.

6. Newton's third law of motion states that for every action there is an equal and opposite reaction. T_______ F_______.

7. Vectors are a measure of the friction on an object. T_______ F_______.

8. Newton's law of gravity states that the attraction between two objects is only dependent on the distance between them. T_______ F_______.

9. Einstein's theory of general relativity completely repudiates Newton's law of gravity. T_______ F_______.

10. Einstein believed that all of the forces - gravity, electromagnetism, and the weak and strong nuclear force - were different aspects of the same force. T_______ F_______.

Name ____________________

ELEMENTS OF PHYSICS
MOTION, FORCE, AND GRAVITY

Vocabulary Definitions

The following words and terms used in the program may be unfamiliar to you. Try to listen for these terms while viewing the program, pay close attention so you can later include them in your scientific descriptions, observations, and creative writing assignment activities.

Aristotle - ancient Greek philosopher, 384 - 322 BC.

calculus - a type of mathematics developed by Newton and others.

Copernicus, Nicolaus - Polish astronomer, 1473 - 1543.

Einstein, Albert - German-American physicist, 1879 - 1955.

first law of motion - called the "principle of inertia."

first revolution of physics - synthesis of Isaac Newton, which was built on the work of earlier physicists.

force - to a physicist the only forces in nature are gravity, electromagnetism, and the weak and strong nuclear force. Einstein and others believed these were different aspects of the same force.

four-dimensional universe - Einstein showed that the universe had four dimensions: length, width, height, and time.

friction - resistance to the motion of an object.

Galileo, Galilei - Italian physicist and astronomer, 1564 - 1642.

gravity - universal force of the attraction of the mass of an object.

Kepler, Johannes - German astronomer and mathematician, 1571 - 1630.

mass - total quantity of an object's matter.

motion - movement of objects.

Newton, Sir Isaac - English physicist, mathematician, and philosopher, 1642 - 1727.

rate of acceleration - the change in the velocity of the motion of an object.

second law of motion - describes how an object changes direction when a force is applied to it. The formula that expresses it is: $F = ma$ (applied force equals mass times acceleration).

space-time - Einstein showed that space and time were similar and that both were influenced by gravity.

third law of motion - for every action there is an equal and opposite reaction.

three laws of motion - laws that govern the movement of all objects, at all time, and in all circumstances. These laws were formulated by Newton.

vector analysis - the analysis of the different forces on an object resulting in the calculation of net force.

velocity - rate of motion in a particular direction. The formula that expresses it is: $v = gt$ (velocity equals acceleration multiplied by time).

Name ____________________

ELEMENTS OF PHYSICS
MOTION, FORCE, AND GRAVITY

Use the Right Word

Directions: Find the right word from the physics vocabulary list that completes the following sentences.

1. The rate of motion in a particular direction is called ____________.

2. The universal force of the attraction of the mass of an object is called ____________.

3. The resistance to the motion of an object is ____________.

4. The change in the velocity of the motion of an object is its rate of ____________.

5. The total quantity of an object's matter is called its ____________.

6. The second law of motion describes how an object changes direction when a ____________ is applied to it.

7. The analysis of forces on an object resulting in the calculation of net force is called ____________ analysis.

8. The first law of motion is often called the principle of ____________.

9. Isaac Newton developed the mathematics called ____________.

10. Einstein's general theory of relativity explains the impact that gravitational force had on ____________.

Name ____________________

ELEMENTS OF PHYSICS
MOTION, FORCE, AND GRAVITY

Word Match

Directions: Connect the word with the proper definition.

calculus	his synthesis is said to be the "first revolution of physics"
Einstein	movement of an object
F = ma	resistance to the motion of an object
friction	formula for velocity
gravity	showed the universe had four dimensions
mass	universal force of the attraction of the mass of an object
motion	rate of motion in a particular direction
Newton	type of mathematics
v = gt	formula that expresses the second law of motion
velocity	total quantity of an object's matter

Name ____________________

ELEMENTS OF PHYSICS
MOTION, FORCE, AND GRAVITY

Connected/Not Connected

Directions: Place the following words in the proper sentences.

Aristotle	first law	interacting	space-time
calculus	friction	light	stress
Einstein	Galileo	mass	v = gt
F = ma	gravity	matter	vector
falling objects	inertia	opposing	velocity

1. __________ is connected to __________ because an object's attraction is dependent on its size.

2. __________ is NOT connected to __________ because Newton was the physicist who developed this mathematics.

3. __________ is connected to __________ because this formula is an expression of the rate of motion of an object.

4. The principle of __________ is NOT connected to __________ forces because it describes the motion of one object, not two or more objects.

5. __________ are connected to __________ because this Italian scientist studied the acceleration and rate of speed of objects as they fall.

6. __________ is NOT connected to __________ because it is a formula that measures force between objects not resistance.

7. __________ analysis is connected to __________ in buildings and bridges because this form of analysis calculates the net force on structures.

8. The __________ of motion is NOT connected to __________ forces because it is the third law that states for every action there is an equal and opposite reaction.

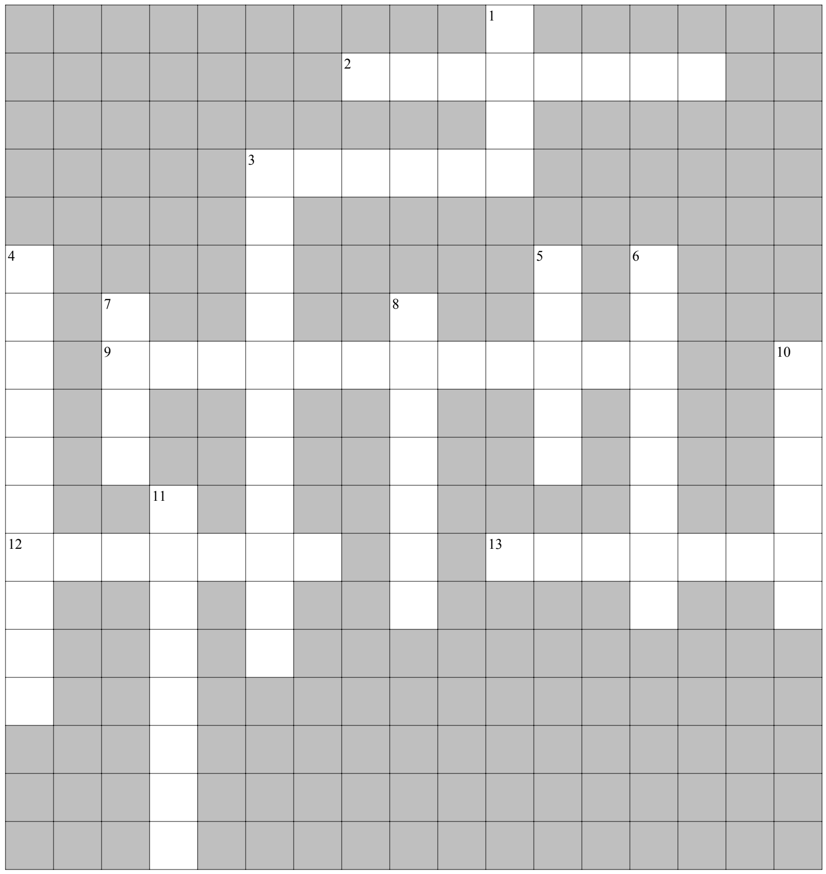
9. __________ is connected to __________ because he showed that gravity bent the fabric of space.

10. __________ is NOT connected to the total quantity of an object's __________ because it has no mass.

Name ____________________

ELEMENTS OF PHYSICS
MOTION, FORCE, AND GRAVITY

Crossword Puzzle



Across

2. rate of motion in a particular direction
3. movement of an object
9. increase in speed
12. state of rest, or motion in a straight line
13. found all objects fell at the same rate of speed in a vacuum

Down

1. Newton showed the ____________ is held in its orbit by the Earth's gravity.
3. major tool of physics
4. astronomer who concluded the sun was the center of the universe
5. for every action there is an equal and opposite reaction is the _____________ law of motion
6. his theory showed that gravity affects light
7. total quantity of an object's matter
8. universal force of the attraction of all objects
10. his synthesis is said to be "the first revolution of physics"
11. resistance to the motion of an object

Name ____________________

ELEMENTS OF PHYSICS
MOTION, FORCE, AND GRAVITY

Creative Writing Story Ideas

Directions: Choose from one of the ideas listed below and write a story or dramatization. Include plot lines that follow scientific principles and key vocabulary terms.

1. Two Renaissance era students witness strange people dropping stones from the Leaning Tower of Pisa. Write a story from the students' point of view describing this odd event. Do they finally understand its significance?

2. Isaac Newton is a man obsessed with the motion of objects and the force of gravity. Some young people from the village drop in to visit him and he tries to describe his ideas to them. Write a dialogue of their interaction.

3. The scientist living next door has developed an anti-gravity material. You notice disturbing things going on. What do you do? The scientist argues that the anti-gravity material will be of great benefit to society. What are your conclusions?

4. A group of physicists have been sent into space to study the three laws of motion. Write a research report describing their experiments and their findings. Are the three laws validated or not?

5. "Help!" Dr. Ebenezer Rothschild, a world famous physicist, has been caught in the principle of inertia. He has been ejected from his spacecraft and according to the first law of motion he will travel in a straight line through space forever. You are aboard a nearby spacecraft and orders are given to divert your course to rescue Dr. Rothschild. What happens?

Published and Distributed by United Learning

Name ____________________

ELEMENTS OF PHYSICS
MOTION, FORCE, AND GRAVITY

Video Quiz

Directions: Answer the following true or false, or fill in the blank with the correct word to make it true.

1. Galileo is often called the "father of science" because he was the first to test his ideas by experimentation and observation. T_______ F_______.
2. Galileo studied the rate of __________, or change in the velocity of a falling object.
3. Copernicus concluded that the Earth was the center of the universe. T_______ F_______.
4. Newton's first law of motion is sometimes called the principle of __________.
5. The second law can be written as F = ma, when applied force (F) equals mass (m) times acceleration (a). T_______ F_______.
6. The third law of motion states: "For every action there is another action." T_______ F_______.
7. Vector analysis is a means of analyzing different forces on an object. Together these forces combine to make up __________ force.
8. Without friction the balls on a pool table would roll forever. T_______ F_______.
9. Newton was the first to understand that gravitation caused planets to follow irregular orbits. T_______ F_______.
10. Einstein's general theory of relativity looks at the impact of gravitational force on __________.

Name ____________________

ELEMENTS OF PHYSICS
MOTION, FORCE, AND GRAVITY

Post-Test

Vocabulary
Directions: Fill in the blank with the appropriate term from the list below.

accelerates	friction	inertia	rate
analysis	gravity	moon	sun
Aristotle	laws	motion	universe
Einstein	mass	per second	vector
force	mathematics	planets	weight

1. The rate of acceleration of falling objects is a constant, 9.8 meters __________.

2. The major analytical tool of physics is __________.

3. Newton's second law of motion describes how an object __________ when a force is applied to it.

4. Newton's law of __________ says that the gravitational force between two objects is proportional to the quantity of their masses and inversely proportional to the square of the distance between them.

True or False
Directions: Fill in the blank with True or False. If the statement is false, change it to make the statement true. Rewrite the true statement in the space provided.

5. __________ Aristotle believed all objects fall at the same rate of speed.

6. __________ The third law of motion states that opposing forces always balance out.

7. __________ The three laws of motion govern the movement of all objects at all times and in all circumstances.

8. __________ Gravitation accounts for the movement of planets but not for the motion of objects like apples falling to earth.

9. __________ Einstein's general theory of relativity explains that light is unaffected by gravity.

Essay Section
Directions: Answer the following questions in complete sentences. Use the back of this page or a separate sheet of paper if you need more space to complete your answer.

10. Explain the difference between mass and weight.

11. How did Newton explain why the moon did not fall to Earth?

12. What did Einstein mean when he said that gravity warps space?