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Chapter One 1

Motion

Physics is the science that explores how energy acts on matter. Everything in the universe that we can experience with our senses is made of matter and energy. The Bible recognized this fact in Genesis 1:1–3. After God created earth (matter), He said, "Let there be light [energy]."

Matter has weight and occupies space. Energy can put matter in motion or change it in some way. Physics is sometimes described as the study of matter in motion. But physics is far more than that because physics includes exploring not only motion, but also sound, heat, light, electricity, magnetism, and nuclear energy.

Physics goes far back in time. Aristotle, an ancient Greek scientist, lived more than 2,000 years ago. The Greeks made an effort to gain knowledge through observation and reasoning. However, they seldom did experiments, which are observations that can be repeated under

PROBLEM

1. How do modern scientists test new ideas?
2. What discovery helped clocks keep better time?
3. How did Galileo slow the motion of falling balls?

Can You Propose Solutions?

controlled conditions. Without experiments, they could not repeat what they observed to test their conclusions.

For instance, suppose they saw a leaf fall from a tree and later saw an apple fall from a tree. They might speculate as to why the apple appeared to fall more quickly than the leaf, but they would not think to pick up an apple and a leaf and drop them together.

In addition, measurement is essential to good science. Scientists must be able to measure quantities such as weight, distance, time, temperature, electric current, and light intensity. But ancient people had few accurate scientific instruments, so they could noteasily measure what they observed. Ancient scientists could only state what they discovered as general conclusions rather than precise scientific principles.

For example, they might see a heavily loaded cart roll down a hill and conclude that it gained speed. From one moment to the next it rolled faster and faster. However, they had no accurate clocks, so they could not time the cart and measure its actual speed.

The first person to make real progress in understanding physics was Galileo, a scientist who lived in Italy almost 500 years ago. Like the Greeks, he had a brilliant and inquiring mind. In addition to thinking and observing, he was willing to experiment. Experiments are a way to collect scientific information and test new discoveries.

Galileo entered the University of Pisa in 1581 to study medicine. Europe at that time was coming out of a period known as the Middle Ages. The Middle Ages were sometimes called the Dark Ages in Europe because learning had been in a deep decline. Most people—including leaders of countries—could neither read nor write.

In these dark days, scholars held in high regard the confident writings of Aristotle and other Greeks who lived almost 2,000 years earlier. People of the 1500s turned to ancient books as final authority on scientific matters. They saw no reason to question Aristotle's books or test his statements.

During his first year at the university, Galileo discovered an important principle that ancient Greeks had completely overlooked.

Students at Pisa began their day by going to chapel. One morning Galileo knelt and said his prayers in the dark chapel. He arose to watch a lamplighter light the candles in a lamp which was hanging 30 feet from the high ceiling.

Aristotle taught his students to learn through observation and reasoning.

Lighting the candles caused the lamp to move in a slow back and forth motion. As its motions died down, it seemed to take as long to make a small swing as a large one. Galileo timed the chandelier swing with his pulse.

Galileo returned to his room to try other pendulums. Experiments showed that the time for a complete swing was the same whether the arc was a small one are a large one.

Galileo's discovery is known as the principle of the pendulum. A principle is a law of science. In this case, Galileo had found that two pendulums of the same lengths would swing at the same rate regardless of how wide or shallow

Aristotle

Aristotle (Greek Philosopher, 384–322 B.C.) was a great thinker of the ancient world. He attended school at Plato's Academy in Athens, Greece. It was one of the best schools in the world. Aristotle learned to observe carefully, poise insightful questions, and use reason to form conclusions. He did not, however, learn to do experiments to reveal new facts. Doing an experiment required work with the hands, but Greek thinkers thought manual labor was the work of servants.

Aristotle stayed in Athens for 20 years, first as a student and then as a teacher. He returned to his home country of Macedonia and served as the private tutor of the young man who would become Alexander the Great. Alexander the Great grew up to become the greatest military general of the ancient world.

Aristotle and Alexander the Great became good friends. Alexander the Great gave Aristotle money to start his own school in Athens. Aristotle called his school the *Lyceum*. Aristotle lectured as he walked about in the garden with his students. He encouraged his students to test their observations with common sense and clear thinking.

Aristotle wrote a book about the systems of laws that govern countries. He believed education was essential to the survival of a nation. Aristotle said, "All who have meditated on the art of governing mankind are convinced that the fate of empires depends on the education of youth."

About 50 of Aristotle's books were preserved. Errors in his books are minor considering the vast number of subjects he discussed. However, scholars in Europe during the Middle Ages believed his books contained no errors and all knowledge could be found in them. Medieval scholars made few important new discoveries in science. Aristotle would have been appalled that people used his books as the final word on scientific questions.

Aristotle tutoring Alexander the Great

their arcs. Only by making the string longer could he lengthen the time needed to make one back and forth swing.

Ancient Greeks had not mentioned this discovery in any of their books. The 17-year old Galileo had made a discovery they had completely overlooked. Galileo realized that the ancient Greeks did not have all of the answers.

Galileo's discovery of the principle of the pendulum turned out to have a useful application. In Galileo's time, only length and weight could be measured with any accuracy. Merchants sold cloth, ribbon, and rope by length. They sold grain, potatoes, and coal by weight. They had developed accurate scales and rulers for measuring these quantities. But other tools of science, especially a way to accurately measure time had not yet been invented.

Short intervals of time were especially difficult to measure. The best clocks of Galileo's day had only hour hands. They could not keep time accurate to the minute or second.

The regular back and forth motion of the pendulum would eventually regulate a clock so time could be measured to the second. However, attaching a pendulum to a clock would not occur until 30 years after Galileo died.

Galileo's experiments with pendulums set him thinking about other forms of motion. Almost everything taught about motion came from the books of Aristotle.

Aristotle claimed that heavy objects fall more rapidly than light ones. A ball ten times as heavy as a lighter one would fall ten times faster. A rumor sprang up that Galileo dropped different size iron balls from the tower of Pisa. It was the Leaning Tower of Pisa even then. Both heavy and light iron balls that Galileo dropped struck the ground at the same time.

He may not have done this experiment, but he did do other ones that convinced him that all objects would fall at the same speed.

Everyone knew that a feather would fall more slowly than a lump of lead. Galileo had to explain this everyday observation. He believed that air resistance caused differences

Falling Objects

Try this experiment testing the speed of falling objects.

Test whether light and heavy objects fall at same or different speeds. Place a dime and a quarter in the palm of your hand. Stand where the floor is hardwood, tile, or other solid surface that is not covered with carpet or a rug. Quickly lower and pull away your hand so the two coins start falling to the floor at the same instant. Listen for their impact.

A quarter is about 2½ times as heavy as a dime. If Aristotle were correct, it would strike the floor well before the dime. However, sounds of the coins show that they strike the floor at nearly the same instant.