Integrated Physics & Chemistry

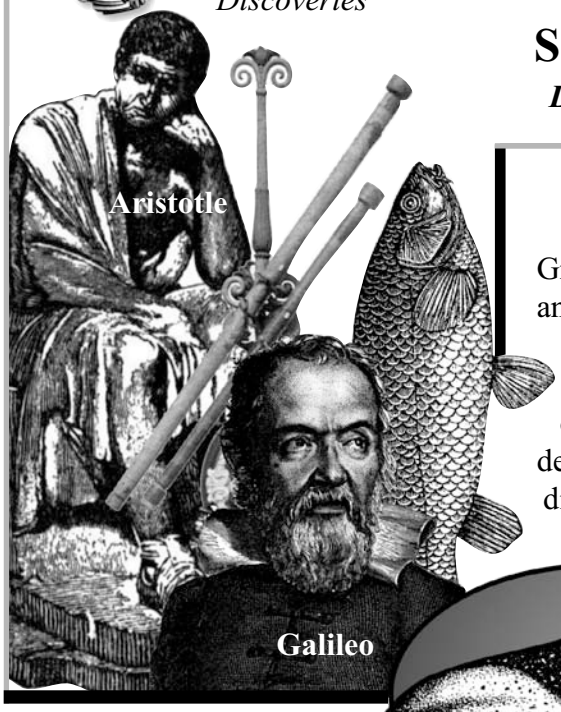
Chapter 2

Lesson 1
Inventions & Discoveries

Section 1

Lessons 1-5

GALILEO AND THE PENDULUM



Physics began during the time of the Greeks more than 2,000 years ago. The Greeks attempted to gain knowledge through reasoning and observation. Greeks who studied the natural world were known as natural philosophers. ***Philosophy*** is a Greek word that means *love of learning.* A "Doctor of Philosophy"(Ph.D.) is an advanced university degree. The Greeks did not separate science into different areas of study. Greek philosophers studied natural science and called it physics. An individual could not be an expert in all areas of science. Scientists specialized in various areas of science, such as biology, geology, chemistry and others. Biology is the study of life and living organisms. Geology is the study of the Earth. Chemistry involves the study of composition and structure of matter.

After biology, geology, chemistry and others are removed from physics, much remains. Physics includes the study of motion, sound, heat, light, electricity, magnetism and nuclear energy. Physics is the study of matter and energy and their interaction. ***Matter*** has weight and occupies space. ***Energy*** can put matter into motion or bring about a physical change.

Aristotle is one of the earliest known scientists. He was born in Macedonia in 384 B.C. At the age of 17, Aristotle's father sent Aristotle to the best school in the world, Plato's Academy, in Athens, Greece. At Plato's Academy, Aristotle learned to observe, pose questions and use reason to arrive at conclusions.

Aristotle stayed in Athens for twenty years and taught at Plato's Academy. After Plato died, Aristotle returned to Macedonia.

VOCABULARY

Philosophy: love and pursuit of wisdom or learning
Matter: anything that occupies space and has weight
Energy: capacity to make a change in matter, to heat, to move, or to change its physical form
Arc: part of a circle
Period: interval of time between two occurrences of a repeating event
Experiment: an observation under controlled conditions

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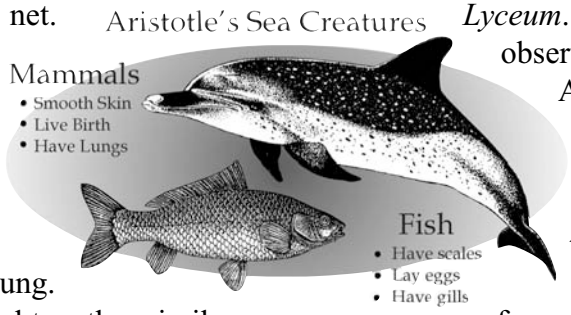
Aristotle especially enjoyed studying animals that lived in the sea. The Greeks gave the name "fish" to all sea life. Greeks believed that all creatures in the sea differed slightly from one another. Aristotle could see differences among the things he caught in his net. For instance, some sea creatures had scales, and others did not. Some gave live birth to their young. Aristotle grouped together similar creatures.



An essential step in science is to summarize information so it is easier to understand. A scientist can summarize information by using a table or by an equation. Alternatively, the scientists can group items into categories based on how the items are alike and how they are different. Facts that apply to one member of a category are likely to apply to other members in the same category. Aristotle organized sea life into categories. He noticed that dolphins gave birth to live young and came to the surface for air. Because of this, Aristotle placed dolphins with the animals of the field like horses and cattle.

When Aristotle returned home, he became a tutor for the king of Macedonia's son, Alexander. A *tutor* is a personal teacher. The boy was thirteen years old and quite inquisitive. Alexander and Aristotle became friends.

In 336 B.C., following the death of his father, Alexander became king of Macedonia at age 20. He determined to conquer the world quickly. He conducted military campaigns all the way to India and became known as Alexander the Great. Military historians named him the greatest military general who ever lived.

Alexander the Great provided money for Aristotle to start his own school in Athens. Aristotle called his school *The Lyceum*. He encouraged his students to observe and ponder what they saw. Aristotle wrote about 170 books. Approximately, 50 of his books are still available today. Aristotle believed education was essential to the survival of a nation. He said, "All who have meditated on the art of governing mankind are convinced that the fate of empires depends on the education of youth."

The Greeks made remarkable gains in understanding the natural world. After the Greeks became weak within their military, the Romans became powerful. The Romans made fewer scientific discoveries but applied science and technology to practical problems. The Romans built roads and ships, improved mining and made useful inventions.

In mid 400 A.D., the Roman Empire began to collapse. For almost a thousand years, from the 400s to the 1400s, learning declined worldwide. People forgot most of the wonderful scientific gains made by the Greeks. Education became of little importance, and, as a result, the leaders of most countries were not capable of reading or writing. Books were few in number and became very precious. Europe fell into a period known as the Middle Ages, which was sometimes called the Dark Ages.

Starting in the late 1400s, learning began to revive. Books by Aristotle and the

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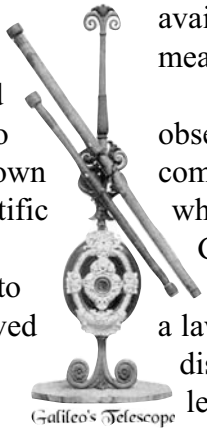
other Greek natural philosophers began to circulate. Johann Gutenberg's printing press, invented circa 1450, made possible the inexpensive production of books. This helped revive learning. Some of the first books printed were those of the ancient Greek writers. Compared to the scholars of the Middle Ages, the ancient Greek scientists seemed incredibly informed. For that reason, people of the 1500s began to think of the ancient books as the final authority on scientific matters.

Aristotle had instructed his students to observe and think. Aristotle insisted that his students test ideas with observation and clear thinking. Yet, many of the readers of his books did exactly the opposite. Aristotle had written most confidently about so many subjects, students began to view Aristotle's writings as incapable of having errors. Teachers taught their students to refer to the ancient Greek texts for answers on scientific matters. Suppose a teacher of the 1500s posed a scientific question. His students did not solve it by experimentation. Instead, they hurried to find the answer in a book by Aristotle or one of the other Greek writers.

Changing this attitude and establishing modern science required exceptional skill and personal courage. One of the founders of modern science who accepted the challenge was Galileo.

Galileo Galilei, an Italian physicist, was born in Pisa, Italy, in 1564. This was the year that the great painter Michaelangelo died and the year Isaac Newton was born. Galileo lived for 78 years and died in 1642. Galileo lived in exciting times. He is best known for his use of the telescope as a scientific instrument. Although Galileo did not invent the telescope, he was the first to use it to study the heavens. He observed the night sky and made a number of remarkable discoveries. He saw mountains and valleys on the Moon, four large satellites orbiting Jupiter and a multitude of new stars in the Milky Way. None of these sights were previously mentioned by the ancient Greeks. Although Galileo's observations of celestial bodies are important and well known, his research into the motions of bodies on Earth was as important to science.


Galileo's Telescope

Galileo's first major discovery of motion was made in 1581 while he was a young student in Pisa, Italy. He began each day by going to chapel. Early one morning, Galileo knelt and whispered his prayers in the dark chapel. He arose to watch the lamplighter at work. The lamp hung thirty feet from the high ceiling. The lamplighter pulled on a cord to bring the lamp over the balcony. After lighting it, the lamplighter released the lamp. The lamp swung back and forth in a wide ***arc***. As its motion decreased, the lamp seemed to take as long to make a small arc as a large one.

Galileo returned to his room and experimented with pendulums of various lengths. A pendulum can be made by tying a weight to one end of a length of string. The top is fixed in place, leaving the weight at the other end free to move. Galileo pulled the weight back a short distance and released it. He measured the time required for the pendulum to swing from one side to the other and back again. Accurate clocks were not available, so Galileo used his pulse to measure the rate of the pendulum.

Galileo confirmed what he had observed in the chapel. The time for a complete back and forth swing is the same whether the arc is a small arc or 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 discovered that two pendulums of the same length would swing at the same rate

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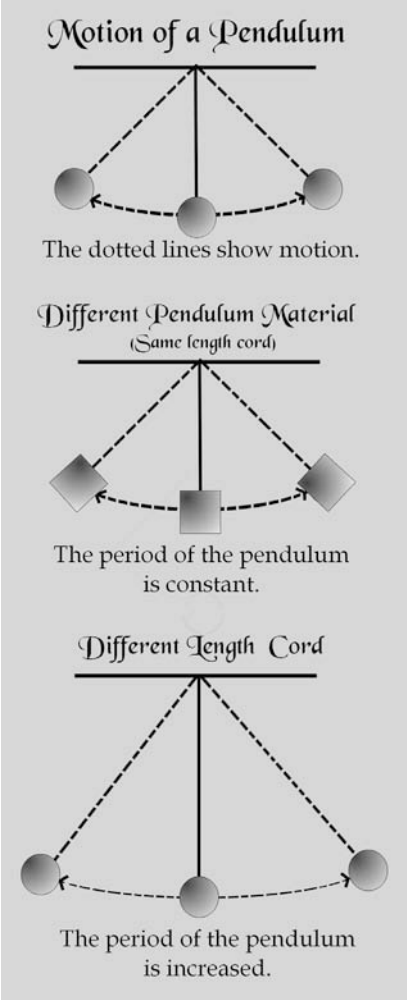
regardless of how wide or shallow their arcs.

The ***period*** of a pendulum is the time required to swing from one side to the other and then back again. This is a complete arc. A pendulum that is almost 25 centimeters long (10 inches) requires one second to make a complete arc. Its period is one second.

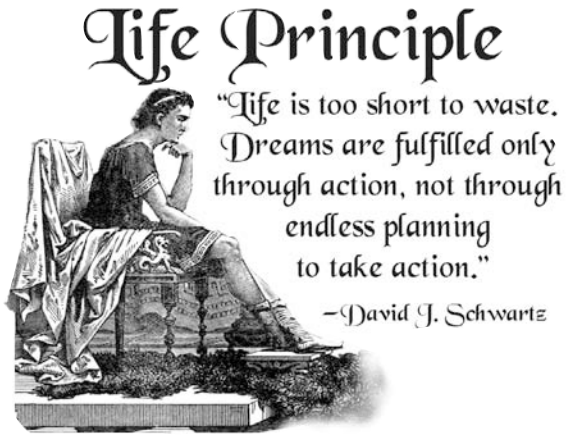
Galileo then experimented to see what would cause the period of the pendulum to change. He used different materials such as wood, glass and lead for the weight at the end of the pendulum. This change made no difference. A pendulum with a glass weight had the same period as one with a lead weight, provided the pendulums were of the same length.



The length of the cord did make a difference. When Galileo made the length of the pendulum longer, the pendulum slowed. The time for a complete arc was greater. The period increased. For instance, if the length of the pendulum was about 100 centimeters, a complete arc took two seconds. When Galileo made the string shorter, the pendulum swung more briskly. The period became shorter.

The period and the length of the pendulum are directly related because as one increases, so does the other. As one decreases, so does the other. A longer string causes the pendulum to take more time to make a swing across its arc. A shorter string causes the pendulum to take less time to swing across its arc.

Galileo's discovery of the Principle of the Pendulum was new. The Greeks had not mentioned it in any of their books. Galileo was willing to observe, think and experiment. Although the Greeks did think and observe, they seldom experimented. ***Experiments*** are better ways to reveal and test new scientific discoveries and theories.



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