

SET 1

MOTION AND FORCES

1.1. THE LAW OF FALLING BODIES

DO HEAVIER BODIES FALL FASTER THAN LIGHTER ONES? The way that Galileo arrived at an answer to this question was as revolutionary as the answer itself. Although Galileo could not create a vacuum, he could imagine one, and so he realized that in a vacuum all bodies fall with the same constant acceleration. In this video, Galileo's investigation of the law of falling bodies is presented with an emphasis on scientific methods. Galileo's pioneering work in quantifying empirical data earned him the title of "The Father of Modern Science."

Running Time: 13:49

1.2. THE LAW OF INERTIA

HOW CAN THE MOTION OF A FALLING OBJECT APPEAR THE SAME ON A MOVING EARTH AS ON A STATIONARY EARTH? In defending the Copernican system, Galileo discovered that the description of motion of objects on earth demanded an understanding of inertia quite different from the prevailing Aristotelian conception. He realized that the tendency of an object was not, as Aristotle thought, to reach a state of rest, but rather to continue moving without any propelling force. In this video, the methods Galileo used to arrive at the law of inertia and its immediate consequence, the relativity of motion, are examined. Through his persevering work in mechanics and astronomy, Galileo drove the last nail in the coffin of the Aristotelian world view and firmly established the validity of the Copernican system.

Running Time: 18:11

1.3. NEWTON'S LAWS

WHAT ARE THE CAUSES OF MOTION? Galileo's laws of falling bodies and inertia describe how objects move. However, they do not explain why. In this video, Newton's great work of completing Galileo's kinematics with dynamics—a theory of the causes of motion—is described. Not only did Newton's three laws introduce a new order to the chaos of scientific thought, they opened up questions about force and mass which remain central questions of physics even today.

Running Time: 15:45

1.4. MOVING IN CIRCLES

HOW DO WE DESCRIBE THE CIRCULAR MOTION OF HEAVENLY BODIES? The stars, said Plato, represent eternal, divine, unchanging beings that move at uniform speed around the earth in the most regular and perfect of all paths—an endless circle. Plato accepted motion in a circle with constant speed—uniform circular motion—as so simple and natural an idea that it needed no explanation. In this video, the kinematics of circular motion is explored; the relationships between radius, velocity, and acceleration are developed. When Newton's universal law of gravitation is incorporated as the driving force, the circular motion of planets, and much more, is revealed.

Running Time: 7:00

SET 2

GRAVITY

2.1. KEPLER'S LAWS

HOW CAN THE MOTIONS OF THE PLANETS BE DESCRIBED? Although Copernicus had proposed that the earth is not the center of the universe, an accurate description of the motions of the planets was not developed until the pioneering work of Johannes Kepler. No seventeenth century astronomer searched more for order in the heavens and had a life filled more with turmoil than he. This video depicts the momentous effort Kepler made to find a mathematical description for the motion of the planets, in particular Mars. The three laws Kepler subsequently formulated provided the essential groundwork for Isaac Newton's later development of the universal law of gravitation.

Running time: 14:52

2.2. THE APPLE AND THE MOON

HOW IS THE MOTION OF THE MOON AROUND THE EARTH LIKE THAT OF A FALLING APPLE? Newton's answer to the question came to be known as his law of universal gravitation. Galileo had described the law of falling bodies—gravity on earth, and Kepler had described planetary orbits—gravity in the heavens. In this video, how the universal law of gravitation emerged from Newton's efforts to reconcile Galileo's new kinematics with Kepler's new astronomy is explored. Together with Newton's three laws of motion, the law of universal gravitation provides the basis for Newton's coherent view of how the universe works.

Running Time: 12:43

2.3. NAVIGATING IN SPACE

HOW DO YOU GET FROM EARTH TO VENUS? Interplanetary travel is introduced as an application of the celestial mechanics of Kepler and Newton. In this video, important principles of classical mechanics are reviewed through an exciting application. The ideas behind transfer orbits, launch opportunities, launch windows, and gravity assists are explained through a conceptual development.

Running Time: 18:04

2.4. CURVED SPACE AND BLACK HOLES

WHY DO ALL BODIES FALL WITH THE SAME CONSTANT ACCELERATION? Newton realized that the law of falling bodies was a consequence of the equality between inertial mass and gravitational mass of an object. Einstein realized that that equivalence stemmed from a more fundamental feature of nature—the inability to distinguish solely by experiments done within a single reference frame whether that frame is undergoing uniform acceleration or is in free fall. In this video, the principle of equivalence and its consequences—curved space and black holes are introduced and explored.

Running time: 12:36

SET 3

CONSERVATION

3.1. CONSERVATION OF ENERGY

WHAT DOES CONSERVATION OF ENERGY MEAN? Galileo's fertile experiments with balls rolling down inclined planes indicated that some quantity was conserved. Not until the nineteenth century did the law of conservation of energy emerge from experiments exploring the relationships between heat, work, and energy. In this video, an overview of mechanical energy is presented. The connections between work, kinetic energy, potential energy, and heat energy are woven together in the law of conservation of energy.

Running time: 15:06

3.2. CONSERVATION OF MOMENTUM

IF THE UNIVERSE FOLLOWS PURELY MECHANICAL LAWS, WHAT KEEPS IT TICKING UNTIL THE END OF TIME? The idea of a mechanical universe was set forth by René Descartes, who postulated that the total "quantity of motion" in the universe is constant. Newton later identified the quantity of motion as momentum. In this video, how Newton's laws of motion, taken together, lead to the fundamental law of conservation of momentum is illustrated. Not only does conservation of momentum aid in understanding what keeps the mechanical universe ticking, but also it provides a powerful principle for analyzing collisions, even at a local pool hall.

Running Time: 13:34

3.3. ANGULAR MOMENTUM

WHAT DO THE MOTIONS OF A SPINNING ICE SKATER AND OF AN ORBITING PLANET HAVE IN COMMON? Kepler's second law of planetary motion, the equal areas law, is rooted in a much deeper principle—the law of conservation of angular momentum. In this video, the ideas of angular momentum and torque are developed through applications to planetary motion, whirlpools, tornadoes, and spinning ice skaters. Along with the laws of conservation of energy and of momentum, conservation of angular momentum remains among the deepest mysteries of nature.

Running Time: 8:20

SET 4

HEAT, VIBRATIONS, AND WAVES

4.1. TEMPERATURE AND THE GAS LAWS

WHY DO GASES EXPAND WHEN HEATED? The connection between temperature and energy emerged after a series of investigations into the behavior of gases undertaken by Boyle, Charles, and other scientists. In this video, the observable properties of gas, such as temperature and pressure, are tied to microscopic events, such as gas molecules striking container walls. Through the use of computer-animated sequences, the difference between heat and temperature is formulated and the ideal gas law is developed.

Running time: 16:42

4.2. HARMONIC MOTION

WHY DO SOME MOTIONS REPEAT THEMSELVES REGULARLY? A dramatic application of the success of Newton's second law in explaining physics on the earth is simple harmonic motion. In this video, simple harmonic motion is presented as a model which illustrates the scientific process of extracting simple, underlying physical principles from complex behavior.

Running Time: 12:21

4.3. INTRODUCTION TO WAVES

WHAT MAKES A WAVE? Water waves, shock waves, sound waves, and waves on a spring are all examples of mechanical waves. In this video, the generation and characteristics of mechanical waves are introduced and explored. The oscillatory motion of balls linked by springs-coupled oscillators—provides a model of the way such waves travel. This model is extended to describe sound and water waves.

Running Time: 10:20

SET 5

ELECTROSTATICS

5.1. ELECTRIC FIELDS AND FORCES

HOW DOES THE ELECTRIC FORCE ACT? Coulomb suggested that the electric force, like gravity, is a force acting at a distance obeying an inverse square law. The idea of a force being transmitted without bodies in contact with one another was difficult for most eighteenth and nineteenth century scientists to accept, despite the fact that the same idea was inherent in Newton's visualization of gravitational forces acting through empty space. In the mid-nineteenth century, Michael Faraday helped resolve this dilemma by introducing the concept of an electric field. His powerful insight provided a qualitative description of the behavior of electric forces—which has since been mathematically interpreted.

Running time: 15:10

5.2. EQUIPOTENTIALS AND FIELDS

WHAT IS THE DIFFERENCE BETWEEN ELECTRIC POTENTIAL AND ELECTRIC FIELD?

This video explore the relationships between electric potentials and electric fields. Contour lines of a landscape are mapped as an analogy for mapping the contours of electric potentials in an electric field. Electrical discharges are also discussed along with the relationships among energy, voltage, and charge.

Running Time: 11:14

5.3. POTENTIAL DIFFERENCE AND CAPACITANCE

HOW CAN ELECTRIC CHARGE BE STORED? Benjamin Franklin performed many experiments in electricity and as a result formulated a theory of electric charge. In his theory he recognized that electric charge is not created, but is simply transferred from one body to another—a fundamental principle known today as conservation of electric charge. A triumph of Franklin's theory was that it could describe how a device used to store electric charge, the capacitor, works. In this video Franklin's experiments in electricity are correlated with an understanding of modern capacitors and how they work.

Running time: 15:11

5.4. THE MILLIKAN EXPERIMENT

HOW DOES SCIENCE PROGRESS? The experimental work of Robert A. Millikan indicates that science progresses through painstaking care in measurements, extraordinary diligence in eliminating errors, and creativity in improving existing methods. In this video, the spirit of scientific discovery is conveyed through Millikan's work in determining the charge of the electron. The jottings in Millikan's laboratory notebooks reveal an interesting relationship between scientific judgment and experimental apparatus.

Running Time: 15:06

SET 6

CIRCUITS AND MAGNETISM

6.1. SIMPLE DC CIRCUITS

WHAT IS ELECTRIC CURRENT AND HOW DOES IT BEHAVE? Electric current, resistance and their effects in series and parallel circuits are the topics of this video. The video uses the analogy of water flow to correlate ideas between water flow and electric current. Ohm's law is explored to illustrate the relationship among current, voltage, and resistance.

Running time: 14:04

6.2. MAGNETIC FIELDS

HOW DO MAGNETS AND MAGNETIC FORCES BEHAVE? The video examines these questions and others. Properties of magnets are discussed and magnetic lines of flux described. The interaction between a magnetic field and magnetic lines of flux are described. The interaction between a magnetic field and a moving charge is also examined. The contributions of Gilbert, Oersted, and Ampere are woven into this video. Emphasis is given to the discovery of the earth's magnetism, the aurora, and the Van Allen belts.

Running time: 17:29

6.3. ELECTROMAGNETIC INDUCTION

HOW DOES A MAGNETIC FIELD PRODUCE AN ELECTRICAL CURRENT? In 1820 Oersted discovered an electric current produces a magnetic field. This discovery led Michael Faraday on a search to find a mechanism that would cause a magnetic field to produce an electrical current. This video focuses on Faraday's law that relates induced electric fields and changing magnetic flux. The computer graphics used to portray magnetic forces, fields, and current loops help students form a mental picture of these unseen physical occurrences.

Running Time: 9:11

6.4. ALTERNATING CURRENT

WHY TRANSMIT ELECTRIC POWER USING ALTERNATING RATHER THAN DIRECT CURRENT? This video introduces alternating current and develops the rationale of using it for electric power transmission. The development includes the history of the famous dispute between Thomas Edison, the proponent of direct current, and Nikola Tesla, the proponent of alternating current. The principles behind a transformer and the importance of such a device in the transport of electric power are also discussed.

Running time: 10:09

SET 7

LIGHT AND THE ATOM

7.1. WAVE NATURE OF LIGHT

WHAT IS LIGHT? Contrary to the notion that light is a stream of particles, scientific rogues such as Huygens, Young, and Maxwell dared to describe light as a wave. The video shows details of this wave nature: properties that light shares with other kinds of waves, the unique characteristics of the electromagnetic spectrum, and the fundamental nature of the interaction between light and matter.

Instruments such as refracting and reflecting telescopes, eyeglasses, and radar devices are highlighted.

Running time: 19:42

7.2. MODELS OF THE ATOM

WHAT IS THE TRUE NATURE OF MATTER? The nature of matter has been a concern of science since the time of the ancient Greeks. Over the last 2,000 years, and particularly the last 200 years, science has developed the concept of the atom to explain matter. Because atoms are too small to be seen, scientists have developed models to assist them in their understanding. This module concentrates on the development of these models starting with Dalton's chemically combining spheres. There were several changes to the atomic models which occurred with Thomson's discovery of the electron and after Rutherford's discovery of the nucleus. Bohr was able to develop a model which combined the ideas of energy levels within atoms. Schrödinger, de Broglie, Heisenberg, and others helped develop the present quantum mechanical view of the atom which involves a nucleus surrounded by an electron cloud.

Running time: 13:15

7.3. WAVE-PARTICLE DUALITY

HOW CAN WE RECONCILE BOTH THE PARTICLE AND WAVE DESCRIPTIONS OF LIGHT AND MATTER? Why are both descriptions needed? Classical physics could not accurately describe thermal radiation or the photoelectric effect until a particle description of the behavior of light was formulated. A complementary description of the wave characteristics of matter soon followed. This wave-particle duality of light and matter is reflected in Heisenberg's Uncertainty Principle and is the foundation of quantum mechanics. This video explores in depth wave-particle duality.

Running Time: 18:38

SET 8

FORCES AND RELATIVITY

8.1. THE FUNDAMENTAL FORCES

WHAT ARE THE FUNDAMENTAL FORCES OF NATURE? Newton's mechanics clarified the role of forces in shaping the motion of all things and focused attention on identifying forces at play in the universe. In this video, a survey of how all forces are manifestations of nature's fundamental forces—gravity, electricity, the weak nuclear force, and the strong nuclear force—is presented. The unification of these forces into a common description remains to this day a beguiling quest in physics.

Running Time: 16:18

8.2. THE MICHELSON MORLEY EXPERIMENT

HOW WAS THE AETHER SHOWN TO BE NONEXISTENT? The stationary aether--the medium through which light was thought to travel in space--was every bit as important to nineteenth century scientists as the stationary earth was to the Aristotelians before Copernicus. Discarding the aether theory was not small step. The video describes how two American scientists, Michelson and Morley, performed their experiment to detect the aether and the implications of their result.

Running time: 15:31

8.3. SPECIAL RELATIVITY

WHAT DOES THE THEORY OF SPECIAL RELATIVITY DESCRIBE? The theory of relativity is clearly one of the major ideas in the development of 20th century thought. This video introduces the postulates of special relativity and how they lead to the failure of simultaneity, time dilation, length contraction, and relativistic mass. Beginning with the problem of synchronizing stationary and moving clocks using an expanding sphere of light, the video extends the argument to space-time diagrams. First Galilean relativity is considered with its assumption of absolute time. Then with the problems of synchronizing moving clocks a new slant is added to the time axis and the space-time diagram evolves. A brief consideration of relativistic mass is given through the use of an animated space billiards game.

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