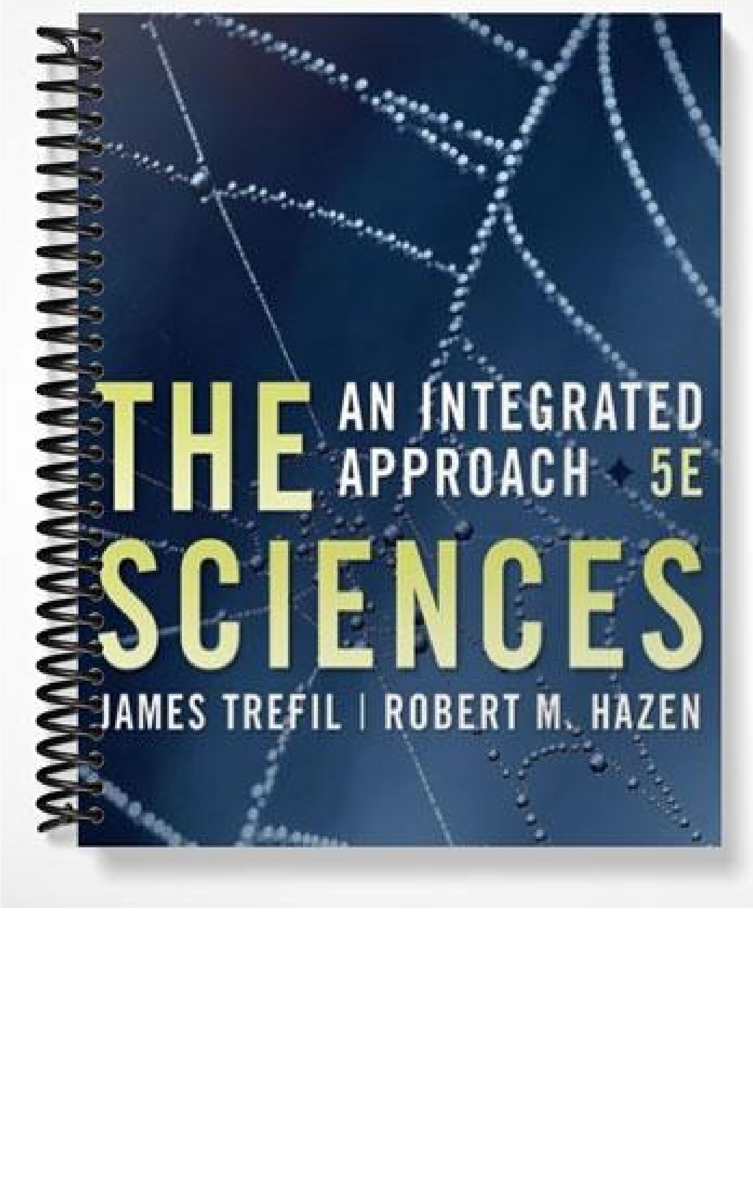
SOLUTIONS MANUAL



Chapter 2: The Ordered Universe

Key Terms

Mechanics
Speed
Velocity
Acceleration
Newton's laws of motion
Uniform motion
Force
Mass
Gravity
Newton's law of universal gravitation
Weight

In-Class Activities:

Instructor Notes for Out of Class Activity 1

Title: History of Science
Time: 60 minutes or more depending on student interest out of class
30 minutes in class to briefly discuss chosen scientists
Materials: Biographies of early and present day scientists, internet biographies
Handouts: See below
Procedures: Particularly if you have students who are going to be teachers, it is important for people to have an understanding of how the nature of science works. One way to help your students understand the nature of science it to have them study the history of science. The text does an excellent job of introducing aspects of the history of science that reflect the nature of science, discussions about Newton's Laws in chapters 2 and 7 for example. This activity allows students to investigate the history and nature of science in more depth while they learn about the lives of scientists and their work.

Have the students read chapters that talk about the experiments conducted by scientists from their biographies. Students will then write a brief overview of the information they have gathered about the scientist, his/her experiments, and what the results of the work were. You will choose selected scientists' work to discuss in class based on what the students have found. Your particular job is to explain to students whether that experimental evidence is still supported by current experimental evidence and to discuss, if the students don't, any controversy regarding the results.

Student Instructions: You will read biographical information about the scientific research of the scientist you are assigned. There are books on reserve in the library or you can use the internet to find information about the actual experimentation your assigned scientist did/does. If possible, you should try to find out if the experimentation that you read about is still supported by the current research. Use the handout provided to complete your report. Be prepared to discuss what you learned in class.

Specific Suggestions: Particularly good scientists to use include: Isaac Newton - although his work and the refutation of certain parts of it in particular situations is well described in the text, Edwin Hubble – whose theory of galaxy shape being related to the life cycle was refuted by a telescope named for him, Lamarck – whose research technique was found faulty as we learned more about the world, Walter Alvarez – whose theory about the extinction of dinosaurs is still under scrutiny, Charles Darwin – who waited to publish the results of his work.

Objectives: Explain the nature of science using historical examples.
Analyze research and describe evidence that supports a hypothesis or theory and evidence that refutes them.

<u>Out of Class Activity 1: Handout:</u>

<u>History and Nature of Science</u>

You will read biographical information about the scientific research of the scientist you are assigned. There are books on reserve in the library or you can use the internet to find information about the actual experimentation your assigned scientist did/does. If possible, you should try to find out if the experimentation that you read about is still supported by the current research. Use the handout provided to complete your report. Be prepared to discuss what you learned in class.

1. Describe the scientist you are studying including area of research, background, and other interesting tidbits that catch your eye.

2. Choose one particular research area, set of experiments, or concepts with which your scientist worked. Describe the research as far as methodology, purpose, and conclusions including any technical problems and controversies either within the scientific community or within the greater community that arose.

3. If you can find this information, is the research you read about still supported today? If so, why is that? If not, why not?

Instructor Notes for In-Class Activity 2

Title: What Property is That?

Time: 15-20 minutes

Materials: Ramp; various cans of food items including: cream of mushroom soup, sliced peaches, peach halves, tomato soup, broth; stopwatch; balance (or have the cans pre-massed)

Handouts: NA

Procedures: Roll the cans of food down the ramp. Have a student time how long it takes for them to roll down the ramp. Calculate the speed of the items and compare the speed of cans of different masses. Roll each can at least three times. The students will begin to note that the cans with solid contents tend to behave a little differently. Question the students about what is different about the cans. Ask them to define the property that makes the difference. Some examples that I have heard are the “sloshiness factor,” “floppiness,” and “bumping around.”

This factor is slightly related to torque because the center of mass is moving around within some of the cans. Asking students to find and define a property, helps them to participate in the development of a definition which is what this chapter is about. It is also a nice lead in for the next activity which is very simple and could be done the same day or the next class period.

Student Instructions: NA

Specific Suggestions: It is best if one of the cans containing only liquid has a similar mass as the cream of mushroom and sliced peaches. Also, generic sliced peaches or pears work better while brand name cream of mushroom works better for comparison purposes.

Objectives: Define properties of different systems.
Use data to develop definitions.

Instructor Notes for In-Class Activity 3

Title: A Hard-boiled Mystery
Time: 10 minutes
Materials: 1 egg, 1 hard boiled egg and a surface upon which to spin them
Handouts: NA
Procedures: If you'd like you can make up a story about grabbing a couple of hard boiled eggs from the refrigerator for lunch, but you just got a call from home saying that you must have taken one hard boiled and one raw egg.

Ask the students how you differentiate a hard boiled egg from a raw egg. Let students hold the eggs (both should have been refrigerated). They may try to hold them up to the light. Depending on the light levels in your classroom you may or may not decide to allow that. Ask students to list the ways that a hard boiled egg is different inside from a raw egg. List their comments and ask how they might use this information (if necessary refer them to the previous activity if you chose to do it) to design a method to differentiate the two. There are several websites that discuss both spinning eggs to determine their cooked or uncooked state and the idea that it is theoretically possible for an egg to switch to spin on its end.

Student Instructions: NA

Specific Suggestions: Some students may already know about this method of determining the state of the inside of an egg because they either cook or know someone who cooks. Ask them to explain why they think spinning the eggs will differentiate them based upon what they have learned in class.

The eggs should be fresh as older hard boiled eggs form an air pocket at the end that can make a difference when holding the egg.

Make links between "common" knowledge and scientific knowledge. How does one become the other, etc.?

Specific Questions:

1. How do you differentiate a hard boiled egg from a raw egg? What explanations do you have?
2. Here hold these eggs, can you tell which is which by feel?
3. What are the properties of the inside of a raw egg? Of a hard boiled egg?
4. How can we use this list of properties to develop a method to test (to explain the method if someone has already told people how it is done) eggs?
5. What is it about spinning the eggs that differentiates the two?
6. What concept have we learned about that describes this phenomenon?

Chapter 2

Objectives: Explaining science with everyday phenomena

Lecture Lead-Ins

In the broadest sense, this chapter states an assumption so fundamental to science that we often overlook it: there is order in the universe. We believe that the universe behaves in a regular, ordered fashion. We believe that we can discover the regularities and perhaps with sufficient insight even explain why they occur. Even primitive cultures were capable of discerning complex cycles of the stars and Moon. This requires motivation, careful observation, good records, and patience. It is fairly simple and instructive to have the class model this process.

Ask the students to discern patterns and predict the next letter in a series such as ababcabcd . . . . Patterns can be simple or complex. Stopping at various points in the pattern, you can ask the class to predict what comes next. Of course, we don't always have enough information to deduce the correct answer. For example, given the series 1, 2 . . . , students might correctly deduce that 3 is the next member. But even that correct prediction doesn't ensure that we've correctly deduced the full pattern of 1, 2, 3, 3, 2, 1, 2, ... Students will appreciate that the more complex or subtle the pattern, the longer one must observe and the greater the need for accurate record keeping.

Currently popular are the sudoku logic-based placement puzzles. The sudoku puzzle has a unique solution that can be reached logically without guessing. The pattern involves entering digits from 1 to 9 into every row and every column. In looking more carefully at the pattern that the puzzle presents, one sees that each 3x3 square also will contain the digits 1-9. An early variant of the puzzle was influenced by the Swiss mathematician Leonhard Euler who repopularized Latin Squares. Latin Squares were engraved in ancient architecture as numerological talismans. Euler made no changes to their rules. Here is a sample Sudoku:

			3		9		7	
				2			6	1
7		1				3		
4			2					
	8	9	4		5	2	3	
					1			8
		6				4		5
8	9			7				
	1		6		2			

Another example of ancient architecture is Stonehenge. The positions of the rocks at Stonehenge clearly show that ancients were able to deal with some very complex astronomical patterns. The work of Brahe and Kepler adds a certain subtlety, moving from circular to elliptical paths.

Mechanics can be introduced by asking students to predict or explain behavior. For example, which of several objects do they think will strike the floor first if dropped? Many will believe that heavier objects fall faster. You might then try dropping some objects to see what does happen. You might also introduce Aristotle's views of natural and violent motion. Many students will find these reasonable descriptions of the way objects in motion behave. Basically Aristotle believed in four elements: air, water, earth, and fire. According to Aristotle, rocks naturally fell when released because they were made of earth and were seeking that level. Heavier rocks fell faster because they were made of more earth. A feather fell very slowly because it was composed of part air and part earth. Violent motion resulted from the continuous application of force, something that Aristotle believed was necessary to keep an object in motion. Of course, Aristotle did no experiments. Galileo's work directly contradicted Aristotle's statements concerning both types of motion.

Active Learning Ideas

Circle vs. Ellipse

To gain an appreciation for the subtle difference between circular and elliptical orbits for planets, you can trace these out on a board or allow teams of students to trace their own on paper. To trace an ellipse, tie a closed loop of string. Tape it to the board or a sheet of paper in two spots representing the foci as seen in Figure 2-5. (Thumbtacks make better foci if you are working on an appropriate surface.) To approximate the Earth's orbit, use a 20.7 cm loop of string and place the foci 0.7 cm apart. Mars' orbit is more eccentric. It can be approximated with a 32.8 cm loop and foci 2.8 cm apart.

Falling objects

The surest way to convince students that all objects fall at the same rate when air resistance can be ignored is to have them drop some objects for themselves. You can choose many objects such as books of similar dimensions but clearly different masses, or two crumpled balls of aluminum foil with a marble in the middle of one. Have students do the experiment, drop the objects from a height and judge when they hit the floor. Take care to test your objects ahead of time. If the mass is too low compared to surface area (as in a feather) air resistance becomes important.

Newton's Third Law

Equal and opposite forces can be illustrated nicely by putting students on skateboards. Put two students on separate skateboards and have them push off of each other. It is safer to have the students sit rather than stand on the boards. You can choose students of varying masses and also let them vary the method of pushing off (both push hand to hand, only one pushes, etc.).

Lecture Extenders

Air Resistance

Two objects dropped simultaneously will fall with the same velocity as long as we can neglect air resistance. Air resistance becomes a significant consideration, however, when an object's mass is small in comparison to its surface area (e.g., a feather), or eventually for all objects when velocity gets large enough. Air resistance is essentially caused by the object running into air molecules. The larger the surface area presented by an object, the more air molecules it will hit. This is why skydivers fall quickly if curled into a ball but slow down if they fall spread-eagle or open a parachute with large surface area. Also the faster an object moves, the more the air in its path resists that motion. At 60 mph, the drag on a car is almost five times as great as the drag on that same car moving at 30 mph.

If we drop an object, its velocity is initially quite small and air resistance may be neglected. As the object picks up speed, however, air resistance increases. Eventually, the retarding force of the air resistance will totally cancel out the force of gravity. No net force acts on the falling object. Since there is no longer a force acting, there is no acceleration, and the object will continue to fall with a constant velocity known as its terminal velocity. $F_{\text{air resist.}} = F_{\text{gravity}} = m\,g$, so the greater the mass of the object, the greater the air resistance will need to be in order to cancel out the force of gravity. Terminal velocity for a ping-pong ball is 9 m/s, for a golf ball it is 40 m/sec. The ping-pong ball will reach its terminal velocity when dropped from heights greater than 4 m. A golf ball, however, will continue to accelerate until reaching its terminal velocity after falling 28 m.

If falling objects did not eventually reach a terminal velocity, even the smallest object falling from a great enough height would be dangerous. Raindrops or even snowflakes would strike us like bullets. Students may have more experience with water as a resisting medium. They can compare in their minds the difference between a belly flop and a graceful dive or the difference between walking and gliding in a pool.

Stop and Think! Answers

Page 45: Anything with mass must exert a gravitational attraction on every other object. If we consider the equation for this gravitational attraction, however, we can imagine circumstances in which the gravitational force is so small as to be negligible. $F = (G \times m_1 \times m_2) / d^2$ For objects with very small masses, positioned very far apart, the resulting gravitational force will be very small though never actually equal to zero.

Answers to Discussion Questions

1. Building a structure such as Stonehenge required accumulation of a great deal of information about the sky as Stonehenge was constructed to mark the passage of time. Stonehenge served as a giant calendar by which farmers would plant their crops. It was designed such that someone standing at the center could see the Sun rise directly over the heel stone on midsummer’s morning. Repeated observations revealed patterns in the movement of objects in the sky that allowed the stones to be placed in a precise orientation to reveal seasonal phases.

2. No, scientists cannot prove that ancient astronauts did not build Stonehenge. We can look for evidence of ancient astronauts, but our failure to find this evidence doesn’t prove that they didn’t exist.

3. The Earth was at the center of the universe in Ptolemy’s system because this was the viewpoint for all of the accumulated observations of earlier Babylonian and Greek astronomers. The model, with Earth unmoved at the center and concentric series of rotating spheres of stars and planets took account of careful observations and successfully predicted planetary motions, eclipses, and a host of other heavenly phenomena for almost 1500 years.

4. a) uniform motion (motion at a constant speed in a uniform direction)
   b) accelerated motion
   c) accelerated
   d) accelerated
   e) uniform / accelerated
   f) uniform

5. All objects exert a gravitational force on you.

6. a) hand on the ball / ball on the hand
   b) the bat on the ball / the ball on the bat
   c) leaf on the ground/ground on the leaf
   d) Moon attracted to Earth/Earth attracted to Moon
   e) you down on the chair/chair up on you

7. Mathematics gives us a language in which we can precisely express the laws of mechanics, and uses the laws to predict measurable outcomes.

8. Newton's world had a few laws that applied everywhere. Ptolemy described different rules for each planet. All other things being equal, science prefers the simpler explanation, one law that applies everywhere instead of a different law for each place. See “Occam's Razor.”

9. Planets do not just fly off into space because the Sun's gravity holds planets in orbit.

10. Cavendish was aware of Newton's work. He **hypothesized** that if Newton's law was correct, he should be able to observe the attraction between objects. He devised an experiment to **test the prediction**. He **observed** the attraction qualitatively and took careful **quantitative data,** which confirmed the law and allowed him to calculate the value of the constant.

11. Sir Edmund Halley predicted in 1705 that a bright comet was periodic and would make another appearance in 1758. The comet appeared as predicted and is now known as Halley’s Comet.

12. Observatories are built as far away from major cities as possible to escape light pollution and poor transparency of the atmosphere due to air pollution.

13. A rocket in its simplest form is a chamber enclosing a gas under pressure. A small opening at one end of the chamber allows the gas to escape, and in doing so provides a thrust that propels the rocket in the opposite direction. Newton’s third law states, “every action has an equal and opposite reaction.” A rocket can lift off from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas, and the gas in turn pushes on the rocket. The action is the expelling of gas out of the engine. The reaction is the movement of the rocket in the opposite direction. Rockets actually work better in space than they do in air. As the exhaust gas leaves the rocket engine it must push away the surrounding air; this uses up some of the energy of the rocket. In space, the exhaust gases can escape freely. In space even tiny thrusts will cause the rocket to change direction.

14. Inertia keeps the pendulum moving once it is in motion. Newton’s First law of Motion states, “an object at rest tend to remain at rest and an object in motion tends to continue in motion in the same straight line, at the same speed, unless acted upon by an outside force.” The pendulum’s inertia (an object’s resistance to changes in motion) makes it swing straight out, and the force of gravity pulls it back and down. It will continue its swing until air resistance (the outside force) eventually slows it down.

Answers to Problems

1. The bathroom scale gives weight in pounds. The known conversion factor is 1 lb. = 4.45 N, so for a 125 lb. person:

(125 lb) x (4.45 N/1 lb) = 556 N

2. Speed = distance/time, so if you run 1 mile in 10 minutes, the average speed = 1 mi/10 min = 0.1 mile/minute

Velocity has two components, speed and direction. If either changes, velocity changes, and we have an acceleration. Here direction constantly changes as you move around the oval track so there is an acceleration.

3. Acceleration = (final velocity - initial velocity)/time

= (55 mi/hr - 0 mi/hr)/6 sec
= 9.2 mi/hr/sec

If you wish to avoid two different time units in the denominator, convert mi/hr to mi/sec first. This gives an acceleration of 33000 mi/sec^2.

If you step on the brake = (0 mi/hr – 55 mi/hr)/3 sec
= -18.3 mi/hr/sec

4. The conversion between pounds and kilograms is: 1 kg ~ 2.21 lb. For a 125 lb person then:
(125 lb) x (1 kg/2.21 lb) = 56.6 kg

5. Force is defined as push, pull, or any action that has the ability to change motion. Recall from Newton's Second Law: F=ma. Force is measured in Newtons (N). One Newton is 1 kg times 1 m/s^2. If you don't want the 20 lb dumbbell to accelerate downward, you need to apply an upward vertical force to counteract gravity, so the force you apply equals the weight of the dumbbell (converted into kg) X 9.8 m/s^2 (force of gravity).

$\frac{20\text{ lbs}}{2.21\text{ kg}}$ = 9.05 kg x 9.8 m/s^2 = 88.69 N

6. Your weight = F = (G m_{you} m_{planet}) / $d^2_{\text{from center of planet}}$

Assume that your mass is 60 kg, then on Earth you would weigh 588 N, but ...

On Mars: Your weight = (6.67 x 10^{-11} Nm^2/kg^2)(60 kg)(6.42 x 10^{23} kg) / (3.39 x 10^6 m)^2
= 223 N

On Jupiter: Your weight = (6.67 x 10^{-11} Nm^2/kg^2)(60 kg)(1.90 x 10^{27} kg) / (7.14 x 10^7 m)^2
= 1490 N

7. You need a force pushing up with acceleration of 9.8 m/sec^2 so
F = ma = (100 kg) x (9.8 m/sec^2) = 9.8 x 10^3 N

8. F = (G m_1 m_2) / d^2, so $F_{\text{on baby}}$ = (G m_{baby} m_{object}) / $d^2_{\text{to object}}$

Assume that the distance between the baby and a planet is equal to the difference between the radius of Earth's orbit and the radius of the other planet's orbit. This is as close as the planets will come to each other. They will usually be much further apart, resulting in a smaller force on the baby.

$F_{\text{on baby fromVenus}}$ = (6.67 x 10^{-11} Nm^2/kg^2)(3 kg)(4.87 x 10^{24} kg) / ((150 x 10^9 m) - (108 x 10^9 m))^2
= 7.28 x 10^{-8} N

$F_{\text{on baby fromMars}}$ = (6.67 x 10^{-11} Nm^2/kg^2)(3 kg)(6.42 x 10^{23} kg) / ((228 x 10^9 m) - (150 x 10^9 m)^2
= 2.11 x 10^{-8} N

$F_{\text{on baby fromJupiter}}$ = (6.67 x 10^{-11} Nm^2/kg^2)(3 kg)(1.90 x 10^{27} kg) / ((778 x 10^9 m) - (150 x 10^9 m))^2
= 9.64 x 10^{-7} N

$F_{\text{on baby from dr.}}$ = (6.67 x 10^{-11})(3 kg)(100 kg) / (0.1m)^2
= 2.0 x 10^{-6} N

The gravitational force due to the doctor is 10 to 100 times greater than the force due to the planets.

More Practice Questions and Problems

1. If one quantity is proportional to another quantity, does this mean they are equal to each other? Explain briefly, using mass and weight as an example.

2. An object is being pushed in a straight line by a constant force. Is it moving at constant velocity? Is it moving at constant acceleration? What would happen if the applied force were doubled? How about if the object's mass were also doubled?

3. Consider the cases below, ignoring friction and air resistance. For each, is a force being applied? Is there acceleration? If so, is acceleration constant? Is velocity constant?
   a) a ball rolls across a floor
   b) a ball rolls down a smooth ramp
   c) a ball falls off the edge of a table
   d) a ball that had been rolling across a floor now heads up a steep ramp

4. You drop a 5 lb. rock, a 3 lb. rock, and a feather from a 10-meter height on Earth then you repeat the experiment on the Moon. There are two significant differences. Describe what you should see in each case.

5. An astronaut weighs 200 lbs. on his bathroom scale at home. He experiences 3 g's during lift off. In orbit, he experiences "microgravity," essentially zero g's. On the Moon, he experiences about 1/6 g. In each of the four cases, what is the astronaut's weight and mass?

6. Imagine we try to repeat some of Galileo's experiments on the Moon. You drop a ball from the top of a tower and note that after 1 second it has fallen 0.8 meters. After 2 seconds, it has fallen a total of 3.2 meters and after 3 seconds it has fallen a total of 7.2 meters. Calculate the average velocity during the first second, during the second second, and during the third second. Is velocity constant? What is the acceleration of the ball? Is acceleration constant? What force is causing this acceleration?

7. Two ice skaters meet. One weighs 100 lbs.; the other weighs 200 lbs. From a dead stop, they use their hands to push off from each other. In which direction will each skater go? Which skater will glide further? Explain using Newton's laws.

8. One way to get traction if your car is on ice is to place the floor mats under the tires. If the car suddenly moves forward at 20 mph, what happens to the mats? Think about Newton's third law.

Connecting Back

1. Analyze the changes in our description of the solar system in the context of the scientific method identifying hypotheses, experiments, theories, and laws.

2. Great scientific advances are often connected with fresh insights on the part of a researcher and/or development of new technologies which make new types of experiments or observations possible. Which of these seems more critical to you as the description of our local solar system moved from Ptolemy to Copernicus? Copernicus to Brahe/Kepler? Kepler to today? (look at the first pages of Chapter 15) Now look back at the work of Mendeleev and Harvey described in Chapter 1. Was insight or technology more important in those cases?

Connecting Ahead

1. In this chapter we find a brief discussion of the effects of extreme acceleration on the human body. Even the 1 g acceleration that we experience constantly has important influences on the structures of large organisms in particular. Look ahead at the descriptions of flowering plants, invertebrates, and vertebrates in Chapter 20. What aspects of their structures are necessary to deal with gravity? How might these organisms be different had they evolved where the effects of gravity were much less?

Further Reading

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Chapter 2

Lecture Outline

Newton's laws of motion and gravity predict the behavior of objects on Earth and in space.

I. Science Through the Day: Cause and Effect

II. The Night Sky

Physical events are quantifiable and therefore predictable.

A. Stonehenge

B. Science in The Making: The Discovery of the Spread of Disease

C. Science by The Numbers: Ancient Astronauts

III. The Birth of Modern Astronomy

A. The Historical Background: Ptolemy and Copernicus

B. Observations: Tycho Brahe and Johannes Kepler

IV. The Birth of Mechanics

A. Galileo Galilei

B. Science in The Making: The Heresy Trial of Galileo

C. Speed, Velocity and Acceleration

D. The Founder of Experimental Science

E. The Science of Life: Experiencing Extreme Acceleration

V. Isaac Newton and The Universal Laws of Motion

A. The First Law

B. The Second Law

C. The Third Law

D. Newton's Laws at Work

VI. Momentum

A. Conservation of Linear Momentum

B. Angular Momentum

C. Technology: Inertial Guidance System

Chapter 2

VII. The Universal Force of Gravity

A. The Gravitational Constant, G

B. Weight and Gravity

C. Big G and Little g

VIII. Thinking More About the Ordered Universe: Predictability