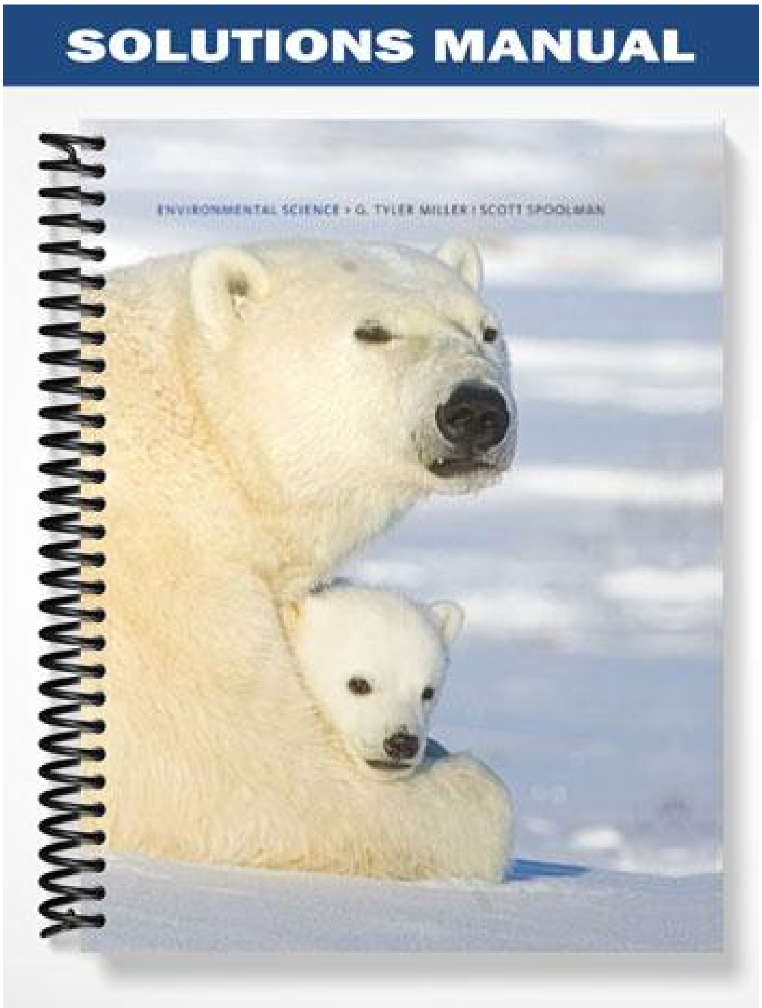
SOLUTIONS MANUAL
ENVIRONMENTAL SCIENCE • G. TYLER MILLER | SCOTT SPOOLMAN

CHAPTER 2
SCIENCE, MATTER, AND ENERGY

Objectives

1. Briefly describe how science works. State the questions science tries to answer. Summarize scientific methods.

2. Distinguish between science and technology, and between frontier science and consensus science.

3. Define *environmental science.* Describe two problems that arise when science is used to address environmental problems. Define *model.* Explain the conditions under which mathematical models are particularly useful to environmental science.

4. Draw a simple, generalized system. Include accumulations, flows, and feedback loops. Distinguish between positive and negative feedback loops. Give examples of each.

5. Define *matter*. Distinguish between forms of matter and quality of matter. State the law of conservation of matter. Discuss the properties of pollutants.

6. Define *energy*. Distinguish between forms of energy and quality of energy.

7. Distinguish among physical, chemical, and nuclear changes. Distinguish between nuclear fission and nuclear fusion.

8. State the first and second laws of energy.

9. Describe the implications of the laws of matter and energy for a long-term sustainable-Earth society.

10. Distinguish among high-waste, matter-recycling, and low-waste societies.

Key Terms {(Terms are listed in the same font style as they appear in the text.)}

atom (p. 28)
atomic number (p. 29)
atomic theory (p. 29)
chemical change (p. 31)
chemical formula (p. 30)
chemical reaction (p. 31)
chlorinated hydrocarbons (p. 31)
compounds (p. 28)
data (p. 25)
electromagnetic radiation (p. 33)
electrons (p. 29)
elements (p. 28)
energy (p. 33)
energy efficiency (p. 35)
energy productivity (p. 35)
energy quality (p. 33)
experiments (p. 25)
first law of thermodynamics (p. 34)
frontier science (p. 26)
heat (p. 33)
high throughput (high-waste) economies (p. 35)
high-quality energy (p. 33)
high-quality matter (p. 31)
hydrocarbons (p. 31)
inorganic compounds (p.30)
ions (p. 29)
isotopes (p. 29)
kinetic energy (p. 33)
law of conservation of energy (p. 34)
law of conservation of matter (p. 32)
low-quality energy (p. 33)
low-quality matter (p. 31)
low-throughput (**low-waste**) **economy** (p. 36)
mass number (p. 29)
matter (p. 28)
matter-recycling economy (p. 35)
model (p. 25)
molecule (p.30)
natural law (p. 25)
natural radioactive decay (p. 32)
neutrons (p. 29)
nuclear fission (p. 32)
nuclear fusion (p. 32)
nucleus (p. 29)
organic compounds (p. 30)
peer review (p. 25)

pH (p. 30)
physical change (p. 31)
potential energy (p. 33)
protons (p. 29)
science (p. 24)
scientific hypotheses (p. 25)
scientific law (p. 25)
scientific theory (p. 25)
second law of thermodynamics (p. 34)
simple carbohydrates (p. 34)

Outline

2-1 What Is Science?

- A Science is an endeavor to discover how the natural world works. It assumes that events in the natural world follow orderly patterns and that, through observation and experimentation, these patterns can be understood.
  1. Scientists collect facts or scientific data.
  2. Based on observations, scientists form a scientific hypothesis—an unconfirmed explanation of an observed phenomenon.
  3. Scientists test these hypotheses by designing experiments, making predictions, and collecting data.
  4. Important features of the scientific process are skepticism, reproducibility, and peer review.
- B A scientific theory is a verified, believable, widely-accepted scientific hypothesis or a related group of scientific hypotheses supported by extensive evidence.
- C A scientific/natural law describes events/actions of nature that reoccur in the same way, over and over again.
- D Testing is a fundamental part of science and is used to establish reliability of scientific tools and conclusion.
  1. Results that have not been widely tested or are not widely accepted are often called tentative science.
     a. At this stage, disagreement among scientists is common and leads to advancement.
  2. Reliable science consists of widely tested and accepted results that have been scrutinized by experts in that field.
- E Science has limitations.
  1. Scientists can disprove facts, but can never prove things absolutely because of inherent uncertainty in measurements, observations, and models.
     a. Scientists attempt to establish high probability of truth to their statements.
  2. Being human, scientists are not free of bias, although they do attempt to minimize this effect.
  3. Because the natural world is so complex, there are many variables that cannot be controlled for.
  4. Scientists often use statistical analysis to describe the natural world. This inherently limits accuracy.
  5. The scientific process is limited to understanding the natural world. Therefore, it cannot be applied to answer moral or ethical questions.

2-2 Matter

- A Matter is anything that has mass and takes up space, living or not. It comes in chemical forms as an element or a compound.
  1. An element is the distinctive building block that makes up every substance; chemically, elements are represented by a one- or two-letter symbol.
  2. Compounds are combinations of two or more different elements bound in fixed proportions.
- B The building blocks of matter are atoms, ions, and molecules.
  1. An atom is the smallest unit of matter that exhibits the characteristics of an element.
     a. Each atom consists of subatomic particles. They are the positively charged protons, uncharged neutrons, and negatively charged electrons.

b. Each atom contains a nucleus of the subatomic particles.
   1) Each element has an atomic number that is equal to the number of protons in the nucleus of its atom.
   2) The mass number of an atom is the total number of neutrons and protons in its nucleus.
   3) Isotopes are forms of an element that have the same atomic number, but different mass numbers.

2. An ion is an electrically charged atom or combinations of atoms.
   a. The charge of an ion is noted by superscript beside the symbol for that atom.
3. A molecule is a combination of two or more atoms/ions of elements held together by chemical bonds.

C Chemical formulas are a type of shorthand to show the type and number of atoms/ions in a compound.
1. Each element in the compound is represented by a symbol (e.g., H = hydrogen, N = nitrogen).
2. Subscripts show the number of atoms/ions in the compound.

D Organic compounds contain carbon atoms combined with one another and with various other atoms. Only methane (CH_4) has only one carbon atom.
1. Hydrocarbons: compounds of carbon and hydrogen atoms.
2. Chlorinated hydrocarbons: compounds of carbon, hydrogen, and chlorine atoms.
3. Simple carbohydrates: specific types of compounds of carbon, hydrogen, and oxygen atoms.
4. All compounds without the combination of carbon atoms and other elements' atoms are inorganic compounds.

2-3 How Can Matter Change?

A Matter undergoes physical, chemical, and nuclear changes.
1. Physical change is a change that does not alter a samples chemical composition, but chemical changes reorder the arrangement of atoms, ions, or molecules in the sample.

B The law of conservation of matter:
1. We can never destroy the atoms involved in a physical or chemical change; just rearrange them in different patterns or combinations.

C The law of conservation of matter states that no atoms are created/destroyed during a physical or chemical change. The same is true for energy.
1. Atoms are rearranged into different patterns/combinations.
2. Atoms can have physical or chemical changes but they are never created/destroyed.

2-4 Energy

A Energy is the capacity to do work and transfer heat; it moves matter.
1. Kinetic energy has mass and velocity; wind and electricity are examples.
2. Heat is the total kinetic energy of all moving atoms, ions, or molecules in a substance.
   a. Electromagnetic radiation is a form of kinetic energy that travels as waves, a result of changes in electric and magnetic fields.

B Potential energy is stored energy, ready to be used; an unlit match is an example.

C Potential energy can be changed to kinetic energy; drop an object as an example.

D Energy quality is a measure of an energy source's capacity to do useful work.
1. High-quality matter is concentrated with great potential for usefulness and is usually found near the Earth's surface.
2. Low-quality matter is dilute and found deep underground and/or dispersed in air or water.

E Energy laws: two rules we cannot break.
1. The first law of thermodynamics states that when energy is converted from one form to another in a physical or chemical change, no energy is created or destroyed.
2. The second law of thermodynamics states that when energy is changed from one form to another, energy quality is depleted.

a. In living systems, solar energy is changed to chemical energy, then to mechanical energy. High-quality energy degraded to low-quality heat.

2-5 How Can We Use Matter and Energy More Sustainably?

A Resource-use automatically adds some waste heat/waste matter to the environment.
B Advanced industrialized countries have high-throughput (high waste) economies.
C Resources flow into planetary sinks (air, water, soil, organisms) with accumulation to harmful levels.
   1. Eventually consumption will exceed capacity of the environment to dilute/degrade wastes.
D Recycling and reusing more of Earth's matter resources slows depletion of nonrenewable resources and reduces environmental impact.
E Waste heat is added to the environment even with recycling/reuse, but it does slow the process of depletion and buys some time.
F Shifting to a more sustainable, low-throughput (low-waste) economy is the best long-term solution to environmental/resource problems. Waste less matter; live more simply; slow population growth.

Teaching Tips

Ask the students to describe what scientists "do," or how scientists expand our knowledge base. Lead the discussion to controlled experiments, namely how they develop experiments and test hypotheses. Use the discussion of controlled experiments to introduce the core case study, Hubbard Brook.

- Use the core study to solidify the students' understanding of control group, experimental group, and baseline data. Here, Borman and Likens perform the daunting task of conducting a controlled experiment in the field. Therefore, laboratory and field experiments can be compared.
- Many students have little notion of how science is "done." Considerable time should be spent discussing what science is, including the scientific method, its uses, and limitations.
- As the underpinning of all topics discussed in the course/book, the topics of matter, energy, and energy use should be emphasized.

Paper Topics

1. An evaluation of the positive and negative contributions of nuclear technologies. Nuclear weapons in World War II and the cold war; radioisotopes in research and medical technology; nuclear power plants.

2. How much are you willing to pay in the short run to receive economic and environmental benefits in the long run? Explore costs and payback times of energy-efficient appliances, energy-saving light bulbs, and weather stripping.

3. Can we get something for nothing? Explore the attempts of advertising to convince the public that we can indeed get something for nothing. Explore attempts to create perpetual motion machines. Explore the history of the *free lunch* concept.

4. Is convenience more important than sustainability? Explore the influence of U.S. frontier origins on the throwaway mentality.

5. Individual: Actions that improve energy efficiency and reduce consumption of materials.

6. Community: Enhance recycling efforts: curbside pick up versus recycling center drop-offs; high-tech versus low-tech sorting of materials; Osage, Iowa, a case study in community energy efficiency.

7. National energy policy: Evaluation of the current national energy policy proposals in light of the laws of energy and long-term economic, environmental, and national-security interests.

8. The universe: Total amounts of matter and energy in the universe; the big bang theory of the origin of the universe; the role of entropy in the destiny of the universe.

9. Low-energy lifestyles: Individual case studies, such as Amory Lovins, and national case studies, such as Sweden.

10. Nature's cycles and economics: Recycling attempts in the United States; bottlenecks that inhibit recycling; strategies that successfully enhance recycling efforts

<u>Activities and Projects</u>

1. A human body at rest yields heat at about the same rate as a 100-watt incandescent light bulb. As a class exercise, calculate the heat production of the student body of your school, the U.S. population, and the global population. Where does the heat come from? Where does it go?

2. As a class exercise, conduct a survey of the students at your school to determine their degree of awareness and understanding of the three basic matter and energy laws. Discuss the results in the context of the need for low-entropy lifestyles and sustainable-Earth societies.

3. Ask a physics professor or physics lab instructor to visit your class and, by using simple experiments, demonstrate the matter and energy laws.

4. As a class exercise, try to inventory the types of environmental disorders that are created in order to maintain a classroom environment—the lighting, space heating and cooling, electricity for projectors, and other facilities, equipment, and services.

5. Invite a medical technician to speak to your class on the beneficial uses of ionizing radiation. What controls are employed to limit the risks associated with the use of radioisotopes for diagnostic and treatment procedures?

<u>Attitudes and Values Assessment</u>

1. Do you feel a part of the flow of energy from the sun?

2. Do you feel you play a role in nature's cycles?

3. How do you feel when your home is air-conditioned? Heated?

4. How do you feel when you turn on a light? The television? Your CD player?

5. How do you feel on a sunny day? A cloudy day?

6. What right do you have to use the Earth's material resources? Are there any limits to your rights? What are they?

7. What rights do you have to the Earth's energy resources? Are there any limits to your rights? What are they?

8. Do you believe that cycles of matter and energy flowing from the sun have anything to do with your lifestyle? With your country's policies?

Laboratory Skills
(none)

Computer Skills
(none)

ABC News Videos

Stuff That We Leave Behind; Environmental Science in the Headlines, 2007; DVD; ISBN: 0495385433

Additional Multimedia Resources

Climate Puzzle (Planet Earth series); 1986; ACPB.
Gaia; 1989; 45 min.; BFF.
Life on Earth (series: Plant Under Pressure series); 44 min. (2 parts); CTC.
Radiation: Types and Effects; 22 min.; FHS.
Radiation: Origins and Controls; 27 min.; FHS.
Science and the Third World; 1994; 23 min.; challenge to science to develop solutions for third-world fecal contamination of drinking water, large-scale deforestation, and inefficient agricultural methods; FHS.
Turning Down the Heat; 2000; 46 min.; BFF.

Websites

www.thomsonedu.com/biology/miller/ Chapter 2
www.thomsonedu.com/thomsonnow
http://www.sas.upenn.edu/sasalum/newsltr/winter97/Balamuth.html
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