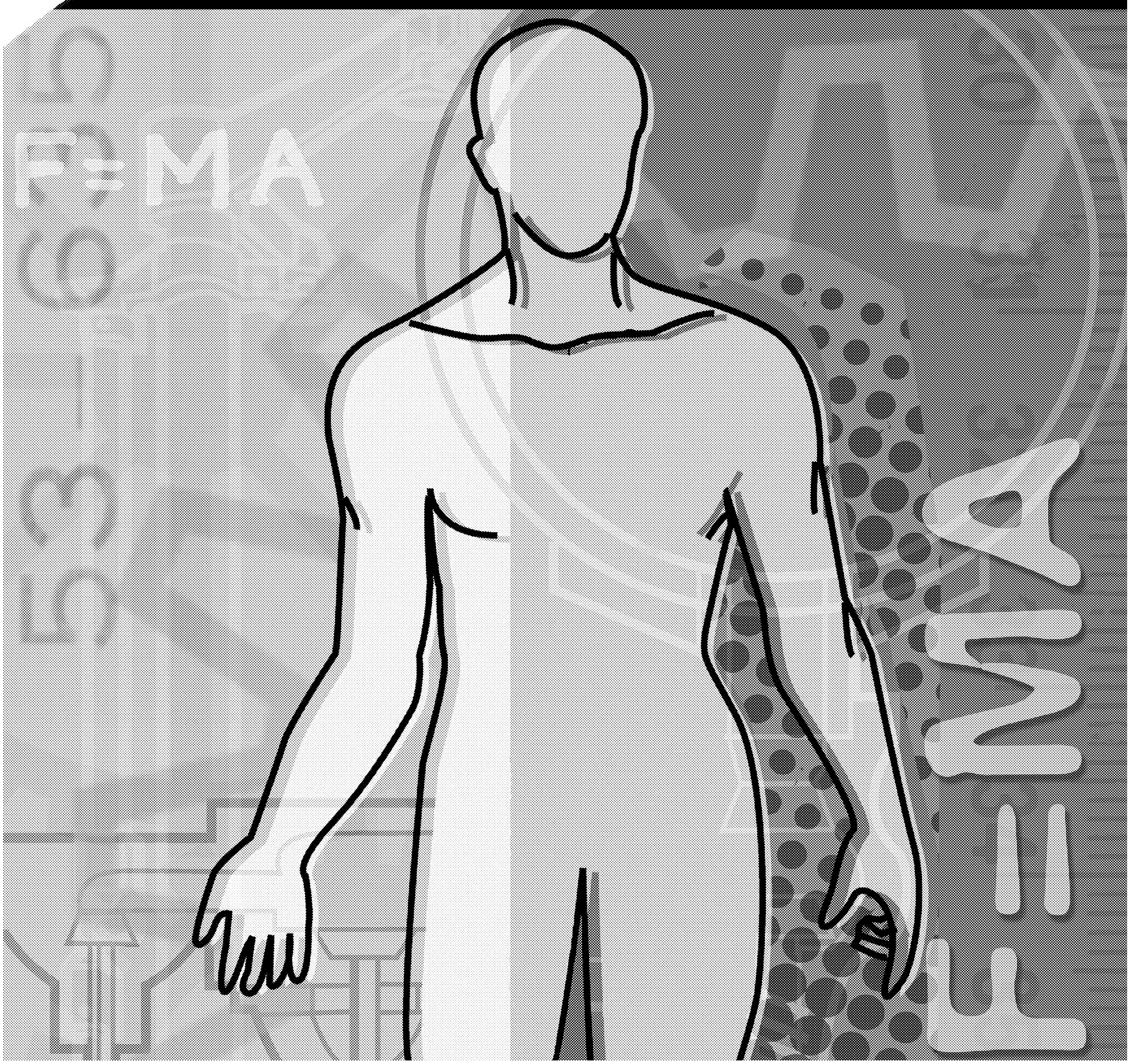
J. WESTON
WALCH
PUBLISHER
Portland, Maine

topSHELF
PHYSICS



Gina Hamilton

Contents

National Science Standards for High School

The goals for school science that underlie the National Science Education Standards are to educate students who are able to

- experience the richness and excitement of knowing about and understanding the natural world;
- use appropriate scientific processes and principles in making personal decisions;
- engage intelligently in public discourse and debate about matters of scientific and technological concern; and
- increase their economic productivity in their careers through using knowledge, understanding, and skills they have acquired as scientifically literate individuals.

These goals define a scientifically literate society. The standards for content define what the scientifically literate person should know, understand, and be able to do after 13 years of school science. Laboratory science is an important part of high-school science, and to that end, we have included several labs in each volume of *Top Shelf Science*.

The four years of high-school science are typically devoted to earth and space science in ninth grade, biology in tenth grade, chemistry in eleventh grade, and physics in twelfth grade. Students between grades 9 and 12 are expected to learn about modeling, evidence, organization, and measurement, and to achieve an understanding of the history of science. They should also accumulate information about scientific inquiry, especially through laboratory activity.

Our series, *Top Shelf Science,* addresses not only the national standards, but also the underlying concepts that must be understood before the national standards issues can be fully explored. National standards are addressed in specific tests for college-bound students, such as the SAT II, the ACT, and the CLEP. We hope that you will find the readings and activities useful as general information as well as in preparation for higher-level coursework and testing. For additional books in the *Top Shelf Science* series, visit our web site at walch.com.

Safety and Ethical Issues

The *Top Shelf Science* series contains several laboratory experiments. Special care must be taken to ensure student safety when these experiments are performed. Experiments involving living organisms should be done carefully, and the health of the living specimen should be kept in mind. Here are some guidelines for general safety issues in a laboratory setting:

- Wear proper safety equipment at all times. This includes an apron, a smock, or a lab coat; safety goggles; and gloves. Do not wear open-toed shoes, such as sandals, during lab experiments.
- Do not eat or drink anything in the lab.
- Be sure to turn off heat sources when not in use.
- Perform any chemical experiments involving gas emissions within a chemical fume hood or in a well-ventilated room.
- Before disposing of chemical ingredients, be certain that they are neutralized; then dispose of them in proper containers.
- Establish a location for the disposal of sharp objects, such as broken glass or nails.
- Use extreme caution when heating solutions.
- Animals, plants, and other life forms deserve respect. Treat living specimens with care and, when possible, release them or replant them outdoors.
- Use care when using electrical appliances of any sort. Know how to recognize a short circuit or a blown fuse.
- Keep fire extinguishers on hand and properly charged, and know how to use them. Be sure that you have an ABC-rated extinguisher, as well as a Halon™ extinguisher for electrical fires.
- Follow all local, state, and federal safety procedures.
- Have evacuation plans clearly posted, planned, and actually tested.
- Label all containers and use original containers. Dispose of chemicals that are outdated.
- Be especially aware of the need to dispose of hazardous materials safely. Some chemistry experiments create by-products that are harmful to the environment.
- Take appropriate precautions when working with electricity. Make sure hands are dry and clean, and never touch live wires, even if connected only to a battery. Never test a battery by mouth.
- When using lasers, never look directly into the beam, and make sure students are conversant with the dangers of laser light.

Safety precautions unique to a given laboratory will be provided within the lab write-up itself. These safety precautions are provided as a guide only. They may be incomplete. Use common sense when working with any chemicals, electricity, or living organisms.

Parent/Teacher/Student Guide

Dear Parents, Teachers, and Students,

Thank you for choosing the *Top Shelf Science* series to help you better understand some of the difficult ideas in high-school science. We are confident that our books will help students who have a greater knowledge of the subject matter being studied; they can also be used to provide a lab-based program for students learning at home.

Each volume of the *Top Shelf Science* series is designed for a particular course of study. Within each volume, concepts build sequentially, and it is recommended that students begin with the first section and move forward.

Each book has sections that are thematically designed. The laboratory exercises associated with each section are specific to a deeper understanding of the overlying concept. In Appendix II, you will find a list of materials that are necessary to conduct the lab exercises, as well as a list of science equipment dealers who may help you acquire things you need in the course of the lab exercise; we have tried to keep the materials list small, as well as provide lab lessons in which materials are readily accessible. Therefore, we have also provided alternatives, where possible, to the lab glassware and other large pieces of equipment that may not be located in your kitchen cabinet or small classroom.

In Appendix I, you will find answers to the questions in each unit, as well as a suggested grading rubric for essays and lab reports. Share these rubrics with students so that they can correct areas that need to be corrected before the next assignment. In keeping with the national science standards, we have also included a time line of the history of each discipline. Each volume also contains an index and a glossary.

Whether you are using our product as the basis for a home school experience, a new and fresh way of supporting textbook material, or as preparation for a college placement test, we are confident that *Top Shelf Science* can meet your needs.

Thank you!

The authors and editors of *Top Shelf Science*

BACKGROUND

Thermodynamics and Entropy

The study of heat and how it is transformed to mechanical energy is called the theory of **thermodynamics.** The foundation of thermodynamics is the concept of conservation of energy, and the fact that heat flows from a warmer body to a colder one. Thermodynamics provided the underlying theory for the successful development of heat engines, such as the steam engine, and heat pumps, which led to refrigeration.

In theory, there is no upper limit for temperature.

Remember that absolute zero is the lowest limit of temperature. In theory, there is no upper limit for temperature, although we haven't witnessed anything above 100,000,000 degrees Kelvin (100,000,000 K)—the temperature of ground zero of a hydrogen bomb. Even the centers of stars aren't as hot as this. Every hot body, like a star, is working furiously to achieve a thermal equilibrium with its surroundings, and whenever heat is added to such a system, it transforms to an equal amount of some other form of energy. That is, heat from our Sun strikes our planet and transforms into kinetic energy (in the form of wind); photosynthetic energy, which in turn drives the biomass on the planet; and so on. This is also the idea behind steam engines, which even today power every power plant on Earth except for solar plants.

This concept is the First Law of Thermodynamics, which, you'll note, is not dramatically different from the conservation of energy that we looked at in the section on energy. This law applies to closed systems; otherwise, heat may indeed be lost (or gained) to or from other areas. A solar system is not a closed system; heat escapes into deep space. Still, it is a useful starting place for understanding events in Earth's atmosphere, such as wind, weather, and cloud formation.

As we have learned, heat never, of itself, flows from a cold object to a warm object. This, too, is one of the laws of thermodynamics. If we place a hot roll into a thermally insulated basket with a lot of cold rolls, the hot roll will cool, while the cold ones will warm a little.

According to the Second Law of Thermodynamics, not only does heat flow from hot to cold exclusively, but the heat that is gained by the colder body is also lost to further useful work. This heat loss can be a huge issue in engines and other machines. It means that, even under ideal circumstances, machines are startlingly inefficient—only about 56% efficient in the best cases.

Entropy

According to the First Law of Thermodynamics, energy is conserved, but according to the Second Law of Thermodynamics, much of that energy becomes useless. This means that natural closed systems tend to proceed toward a state of increasing disorder, or **entropy.** In a closed system, entropy always increases. The condition of the universe includes blocks of matter (such as planets and dead stars, for instance) that receive more energy from outside than they process into usable energy. In the early universe, however, each subatomic particle was highly energized. From then until now, entropy has been increasing, but we have to remember that if it weren't, we couldn't possibly be here.

However the universe ends, it will not occur for many billions of years.

Entropy and thermodynamics may well allow us to predict the ultimate fate of the universe. Eventually, the material capable of making stars shine—hydrogen and helium—will be processed down into heavier materials, such as iron, that cannot undergo fusion in a star. One by one the stars will go out, either in whimpers or catastrophic explosions, and the temperature of the universe will begin to even out to a rather cold 5 or 6 degrees above absolute zero. It is difficult to imagine life, as we understand it, being able to survive such temperatures, even if there were methods to provide energy for food production other than direct or indirect starlight.

However the universe ends, it will not occur for many billions of years—our own star, the Sun, is expected to shine for another 5 billion years. And heat death is just one of several possible scenarios for the end of the universe as we know it. Entropy will play some role; how large a role remains to be seen.

EXPLORE

Exploration Activity

Write a short essay outlining the First and Second Laws of Thermodynamics, and how they describe everyday matter and energy in the universe.

All behaviors show the wave nature of light, although reflection can also demonstrate the particle nature.

Light, Color, and Vision

1. Answers may vary. Light enters the eye through the pupil and is focused on the retina. Cones on the retina provide color vision; rods are sensitive to light and dark. Impulses from these cells are transmitted along the optic nerve to the brain. The position of the optic nerve produces a blind spot that our stereoscopic vision is able to overcome.
2. Answers may vary. Most likely, you will not be able to tell the differences in colors that are of equal brightness or darkness but different hues. This is because color vision does not operate well in near darkness.
3. Additive primaries are red, green, and blue. Subtractive primaries are magenta, cyan, and yellow.

Electric Charge

1. Electromagnetism and gravitation both obey the inverse square law. Electromagnetism has both positive and negative natures, while gravitation, as far as we can tell, is positive only.
2. Coulomb's law describes the behavior of electric charges at a distance, just like gravitation. The values of C and G are very different from each other, however. G is a very small number, while C is huge.
3. When an atom is polarized, all the negative charges flow to one side.
4. The unit for electric potential is the volt. One volt is equal to 1 joule over 1 coulomb.

Electrical Currents and Circuits

1. The measurement of current
2. Current = voltage/resistance
3. Direct current flows in one direction, while alternating current flows back and forth.
4. In a series circuit, all devices are wired in a row. In a parallel circuit, each device is wired to the power source separately.

Magnetism

1. Magnetic fields are generated through the flow of electric charges.
2. No. Magnets always have both a north and a south pole. Even if you had a single atom of a magnet, the atom would have both a north and a south pole.
3. Currents are deflected in magnetic fields. This makes it possible to construct electric motors and all electrical devices known to humans.

General Relativity

1. Special relativity is useful only when an object's frame of reference is in constant velocity. General relativity is for frames that are accelerating.
2. Spacetime is the fabric of the universe that can be bent or altered by massive objects. It includes the three spatial dimensions plus the time dimension.
3. When spacetime is warped by a massive object, things fall toward that massive object. This is perceived as gravity.

Rubrics: Assessing Laboratory Reports

This book contains several student laboratory assignments for which you will produce a written report. Lab reports are important because they are a written recipe for another scientist to replicate your findings. Information should include:

- *Purpose:* Why is this lab being performed? What is the objective of the lab?
- *Hypothesis:* Given the initial level of knowledge, what do you expect to find out at the end?
- *Materials list:* A well-organized materials list makes it easier for anyone trying to replicate your results to understand what was done.
- *Procedure:* Even though a procedure is suggested in the lab write-ups, you should include the procedure you actually followed.
- *Data:* What actually took place in the lab?
- *Conclusion:* What were the results? Did your hypothesis match the data? If something went wrong, what do you think happened?

In order to give teachers and parents a quick guide to assessing lab reports, we have constructed the following rubric:

	1	**2**	**3**	**4**
Understanding of concept	**poor**	**adequate**	**good**	**outstanding**
Methodology	**poor**	**adequate**	**good**	**outstanding**
Organization of experiment	**poor**	**adequate**	**good**	**outstanding**
Organization of report	**poor**	**adequate**	**good**	**outstanding**

Time Line of Physics

c. 2000 B.C.E.—Chinese discovered magnetic attraction.

c. 700 B.C.E.—Greeks discovered electric attraction produced by rubbing amber.

c. 530 B.C.E.—Pythagoras developed mathematical theory.

c. 500 B.C.E.—Anaximenes introduced the ideas of condensation and rarefaction.

c. 450 B.C.E.—Anaxagoras proposed the first clearly materialist philosophy—the universe is made entirely of matter in motion.

c. 370 B.C.E.—Leucippus and Democritus proposed that matter is made of small, indestructible particles.

335 B.C.E.—Aristotle established the lyceum; he studied philosophy and logic.

271—Chinese mathematicians invented the magnetic compass.

1269—Maricourt used a compass to discover that a magnet is encircled by lines that terminate at two poles.

1508–1510—Leonardo da Vinci compiled notebooks on mechanics, astronomy, anatomy, and his inventions.

1543—Copernicus formed the hypothesis that the planets revolve around the Sun.

1600—Gilbert discovered that electricity occurs in things other than amber; he also wrote a book on magnetism.

1608—Lippershey invented the telescope.

1609—Galileo built 20× telescope and discovered craters and mountains on the moon.

1609—Kepler announced his first and second laws.

1619—Kepler announced his third law.

1620—Bacon published *Novum Organum* (scientific method and inductive reasoning).

1621—Snell discovered the law of refraction.

1638—Galileo published *Discourses Concerning Two New Sciences,* summarizing the principles of mechanics.

1652—Pascal discovered laws of fluid pressure.

1666—Newton invented calculus.

1666—Newton discovered glass prism, which separates white light into a spectrum.

1687—Newton published *Principia,* describing the laws of motion.

1704—Newton published *Opticks.*

1738—Bernoulli proposed laws of fluid mechanics.

1769—Watt invented the modern steam engine.

1777—Lavoisier proposed idea of chemical compounds made of elements.

1785—Coulomb confirmed the inverse square law for electric force.

1800—Volta invented the battery.

1800—Ampere discovered properties of magnetic field produced by electric current.

Density Chart

Name	Chemical Symbol	Density (g/cm^2)
Osmium	Os	22.6
Iridium	Ir	22.4
Platinum	Pt	21.45
Rhenium	Re	21.04
Neptunium	Np	20.2
Plutonium	Pu	19.84
Tungsten	W	19.35
Gold	Au	19.32
Uranium	U	18.95
Tantalum	Ta	16.65
Protactinium	Pa	15.4
Californium	Cf	15.1
Berkelium	Bk	14.78
Americium	Am	13.67
Mercury	Hg	13.55
Curium	Cm	13.5
Hafnium	Hf	13.31
Rhodium	Rh	12.41
Ruthenium	Ru	12.37
Palladium	Pd	12.02
Thallium	Tl	11.85
Thorium	Th	11.72
Technetium	Tc	11.5
Lead	Pb	11.35
Silver	Ag	10.5
Molybdenum	Mo	10.22

Name	Chemical Symbol	Density (g/cm^2)
Actinium	Ac	10.07
Lutetium	Lu	9.84
Bismuth	Bi	9.75
Radon	Rn	9.73
Thulium	Tm	9.32
Polonium	Po	9.3
Erbium	Er	9.07
Copper	Cu	8.96
Cobalt	Co	8.9
Nickel	Ni	8.9
Holmium	Ho	8.8
Cadmium	Cd	8.65
Niobium	Nb	8.57
Dysprosium	Dy	8.55
Terbium	Tb	8.23
Gadolinium	Gd	7.9
Iron	Fe	7.87
Samarium	Sm	7.52
Manganese	Mn	7.43
Indium	In	7.31
Tin	Sn	7.31
Promethium	Pm	7.3
Chromium	Cr	7.19
Zinc	Zn	7.13
Neodymium	Nd	7.01
Ytterbium	Yb	6.9

