Review

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and the reviewers of the Second Report.

Introductory Physical Science 8th edition with Formative Assessment by Haber-Schaim, Gendel, Kirksey, and Pratt and published by Science Curriculum Inc., Belmont, MA 02478

Force, Motion, and Energy by Haber-Schaim, Cutting, Kirksey, Pratt, and Stair and published by Science Curriculum Inc., Belmont, MA 02478

(Note: Teacher materials, a Newsletter, and workshops are all available.)

Together, these two books have fewer than 375 pages. They represent a full year course at the 8th or 9th grade level. The first title (IPS) has been around for over 40 years. The second title followed in 2002 to fashion a more complete course, meeting state and national standards. Obviously, the authors believe in the “less is more” philosophy, i.e., choosing to cover fewer topics in depth, rather than covering many topics cursorily.

Scientists will see these books as ideal for getting students to more fully appreciate the scientific approach. Future teachers of chemistry and physics will appreciate the thorough grounding in their subjects of the students completing this course.

Accuracy:
Of all the books that we looked at, these were the most consistently accurate. For example, “These texts get very high marks for accuracy. I found no errors, false impressions, claims, or misleading statements.” Very basic Physics concepts are presented to students who are probably very unfamiliar with the vocabulary and concepts in a way that relates to real world phenomena that the students are very familiar with. Experiments are presented to students in a way that says to the student, “I know you have seen this before. This is how and why it works.” When the authors address average speed, they clearly state that the relationship does not give specific information about speed at any point. Not too serious, but I would prefer recognizing that "force" is a vector quantity, and not using the phrase, "force vector," a redundancy. For a first course, I would like to see expressions such as "distance covered," "distance traveled," "time taken," and so on rather than simply "distance" and "time" in formulas as students quickly take on the bad habit of forgetting that all measurements are not made from some zero value. The authors have avoided a familiar problem by using "thermal energy" rather than "heat" as a noun.

Readability:
These texts present the material in a very casual style. They are conversational, which should help engage many readers. They are succinct; there is no extraneous information included. It appears from the student introduction that the student’s previous experience (or lack thereof) in reading science texts is taken into account. My own reading (and that of my 8th and 6th grade children) indicated that the use of language is sophisticated enough so as not to “talk down” to the student, yet easy enough for an inexperienced student to understand. The text cleanly addresses common applications of the material presented. There is no need to wade through unrelated images or text searching for the subject to be studied. Images and graphs are used judiciously throughout the text. Each image and graph directly relates to the content presented in the text. These texts, the reading, graphical methods, labs, and mathematical problem solving questions are appropriate for any 8th and 9th grade class. The clear writing style should be helpful to all students. If one is looking for an honors text, this text would still be a good choice due to its clear writing and fine presentation of data collection, graphical methods and other scientific processes, but as an honors text, the staff would have to supplement materials for mathematical rigor. Similarly, as a text for the ELL and Special Education populations, the staff would have to supplement some questions and perhaps expand on a few of the ideas. With one exception all reviewers felt that most students would (or did) find the textual material quite readable.

Age and Sex Appropriateness:
While there are many diagrams and pictures of experiments, there are few pictures of actual students doing experiments. I believe that this lack of pictures is a benefit, because it does not limit the class based on “This is a boy’s [or girl’s] book.” It also prevents a younger class from being intimidated by pictures of older students, or an older class looking on it as a “baby” text because of pictures of younger students. The text uses real-world applications of physics principles to present physics content that would be of interest to these students. For example, the text uses Earth-quakes to introduce longitudinal and transverse waves and wave speed. Petroleum products are used to address filtering and the separation of mixtures.

I believe that the text is well suited to 8th or 9th grades.

As I [BHF] read the book [FM&E], I kept thinking that this would be a superb way for elementary and middle school science teachers to learn how to learn science. I’ve heard that some teachers and many students get “turned off” science at an early age in life, probably because it was not interesting, was not fun, or was made too hard for them. There is nothing about this book that is threatening, the authors encourage students to get data first, make sense out of the data, talk to other student teams, draw general conclusions when possible, and extrapolate to new situations. So although the book may be designed for the 8th or 9th grade, I think it would be a good learning source for just about anyone wanting to learn more about forces, motion, and energy, right up through college.

I [JLH] look at the two books by Haber-Schaim et. al. as a one-year course. I am a fan of "less is more" and do not mind a selection of topics, especially when I see that students who take these books do so well later.

What it "covers" it does very thoroughly... maybe too thoroughly.

When I [JLH] think about what is important to teach younger science students (8th or 9th grade) what comes to mind is learn how to think like a scientist. Learn that the experimental method of discovery is exciting and if repeatable, tells us something about nature and how the world ticks. I think that the book **Force, Motion, and Energy** does exactly that, it puts the student in the driving seat and guides the student through a number of very well designed experiments to discover some very basic laws of physical science.

In the authors' words: "the purpose of the program is to give students in eighth- or ninth-grade an understanding of some of the basic ideas of physics, and an insight into the way scientific knowledge is acquired." The Preface to the book states that every major concept in FM&E is introduced with a laboratory investigation that is a fully integrated part of the program – not an optional add-on. The format suggested for the class is cooperative learning in small groups with each group doing experiments and comparing their results with others, encouraging dialogue. Students keep personal laboratory journals with their data and their findings. A point that I really liked, from a teaching perspective, is that the texts present opportunities for short essays. This extends the student's abilities in expository writing.

Mathematics Requirements: The math used is approachable for any student. The quantitative problems are typically the plug-n-chug variety. Students are given all but one variable of a mathematical model and they are to calculate the single missing value. Mathematical relationships are not the highlighted points of priority in this text. As a result, if the text is to be used as an honor text for 8th or 9th graders, staff would need supplemental materials. Very little math is required. The equations are all simplified to $a=b*c$. Graphing data sets is also required. Linear fit is done by estimation, an excellent practice!

I'm not sure what I expected when I began to investigate this book. My primary experience is teaching 11th grade physics for high-standard to honors students. My only experience teaching 9th grade physics was a Physical Science course for students not yet ready for the regular freshman biology course. That book was on an extremely basic level, so I guess I expected a similar level of language usage and mathematical requirements from FM&E. What I found instead was a book very well suited to an honors level 9th grade course. The use of mathematics is kept to a very basic level, three variable equations and graphing of data sets. There is really no linear algebra required. However, the use of language and the expectation that the student is not just reading the text, but actually participating in the text was what surprised me. Because of all the experimentation involved, this text appears to be well suited to an independent/group study course, rather than a standard lecture course.

The companion book **Introductory Physical Science** is written in the same style, with frequent experiments. It appears that either book can be used first, since neither relies on the material from the other.

Despite the fact that there are so many authors, the writing as a whole does not suffer. There are none of the distractions that interfere with the narrative found in many of the commonly used books at this level. There is no wasted space showing how this material meets some set of standards — it will! There is no space wasted discussing careers that might not even exist when these children graduate, but children who take a course with these two books will be well-prepared for future science courses and even if they choose not to take other science courses, they will have an excellent understanding of the scientific approach.

Lastly, in a more positive vein, I would like to see a 15-cm ruler and compass introduced with the study of vectors to ensure a solid kinesthetic experience with vectors.

There are several good suggestions for themes to be written, especially concerning common words that have a special meaning in physics. The notion of "calibration," often ignored, is very well handled. The number of questions and problems is just right. A chart, accompanying the Teacher's Guide, presents several options for a course sequence with and without **Introductory Physical Science,** the companion volume. The laboratory items called for (motion detector and associated software being the most expensive) do not require a heavy expenditure of funds as the materials can be used in several ways. I (JLH) strongly recommend this book as well as its companion for a full year course at the 8th or 9th grade level.

The text includes labs directly within each unit. If instructors choose to do different labs, or skip the labs presented, students will NOT get the full value of the text. Additionally, students would likely wonder why the instructor is not doing all of the labs that are featured so predominantly in the text. The text does not present relativity, modern physics, or any more sophisticated topics. Rather, it concentrates on hands-on phenomena. That is not to say that the book is old-fashioned. It uses high-tech lab equipment (motion detectors linked to computers) and calls for investigations on the Internet. It might be ideal to use the labs included in the text and add additional labs as cumulative assessments.

I can't see taking a few days of laboratory work to derive the KE proportional to mv2 formula using a bicycle wheel and calorimetry, if the text never mentions watts or power, or calories, or Coulomb's Law, etc. Hey... acceleration and inertia are never mentioned! Newton's 2nd Law is about the most basic concept in Mechanics... and it is not mentioned in FM&E. I'd love to have heard the discussion years ago as to what topics FM&E would cover. If a main purpose of 9th Physics is to prepare students for 10th Chemistry and then 11th Biology... (not the only purpose) then I think it would be a mistake to cover IPS (basic chemistry) and FM&E in 9th grade as a full year, just because of the topics left out. I [JLH] agree that these may be important issues for some, but feel that the authors' handling of Newton's 1st and 2nd Laws and the Conservation of Energy through induction are more likely to remain with the student much longer and will make for an easy transition to these as deductive principles.

One of the reasons my school said we would adopt a Physics First 9th grade curriculum was to enhance the three year sequence integration and so we asked our Chemistry teachers what topics (in 9th Physics) would be helpful to them next year. And so we came up with a list and we try our best to cover that list. Certainly conservation of momentum and conservation of energy are key concepts that we cover well, but omit certain others like calorimetry which the Chemistry course will teach.

Certainly circular motion, Coulomb's Law, basic wave ideas are a key to a better understanding of the atomic model. What about conduction, convection, radiation and the electromagnetic spectrum? FM&E dwells on Newton's Third Law and completely omits the First and Second Law... why?

FM&E is a fascinating book and one that would challenge the best 8th - 9th graders.

It, however, gives no history of physics and gives no historical connections. What it sets out to do it does very well - to guide the student through a series of experiments in order to see some of the fundamental relationships in physical science. Teachers are always free to “fill in the missing historical gaps” if so desired, but for a textbook to omit so much of history is a tragedy of sorts.

There are seven chapters in FM&E: Forces, Pressure, Forces Acting in Different Directions, Distance, Time, & Speed, Waves, Heating and Cooling, and Potential Energy & Kinetic Energy. There are also four Appendices: Proportionality, Graphing, Conversion of Units, and Histograms.

There are ten chapters in IPS: Volume and Mass, Mass Changes in Closed Systems, Characteristic Properties, Solubility, The Separation of Mixtures, Compounds and Elements, Radioactivity, The Atomic Model of Matter, Sizes and Masses of Molecules and Atoms, and The Classification of Elements: The Periodic Table

I started reading immediately as many folks have wondered about topics for 8th and 9th grades that were "missing" from **Introductory Physical Science** by the same authors that we have enthusiastically endorsed. The endorsement continues.

A Closer Look:

Experiment: Hooke’s Law
As an example of the authors’ style, I (BHF) will lead the reviewer through the first few activities students will do. The book takes an unusual approach by NOT beginning with a study of motion, leading towards an understanding of speed, velocity, and acceleration. Most physics texts start with motion to give the reader a deeper understanding of acceleration, so that when Newton’s Second Law is approached in the form $F = ma$, the reader is already familiar with what acceleration means and how to measure it. FM&E takes a different approach, starting with forces in chapter one and the first lab. In the first laboratory exercise students study the stretching behavior of a simple short spring (Hooke’s Law). Students learn that the stretch of a small spring is “linear” (up to a point) using known weights, plot their data on X, Y axes, and then examine the shape of their graph.

The suggestion of a linear graph (through the origin) indicates that the spring stretches by equal lengths for equal additions of weight. Then, the standard unit of weight, the newton is introduced. The newton in this first chapter is not defined in the traditional way; the force needed to accelerate one kilogram by one meter per second squared, so the reader is missing an important connection of force and motion right from the start. The authors do compare newtons to the more familiar English unit, pounds, but leave it at that.

Math requirements are pretty stiff right from the start, as students graph total stretch of the spring (Y) vs. weight hanging from the spring (X). The book has no general description or discussion of X,Y (Cartesian) graphs, scaling of axes, labels, or the mathematics of a straight line ($Y = mX + b$) so one would hope that students have learned something about graphing in their mathematics class prior to this lesson. If that is not the case, the science teacher would need to do a considerable amount of mathematics instruction. So in the first experiment students will be exposed to some fairly complex mathematics about interpreting their data in graphical form. Students are asked to calculate the stretch per unit weight, or the slope; what the authors call the “proportionality constant”. The books ask “does the graph of spring stretch vs. weight represent proportionality and if so, what is the proportionality constant?” This is fairly sophisticated language for the typical 8th grader who may or may not have been exposed to rise/run or slope or what it means to be “directly proportional”. I (JLH) favor this approach as a great way to match kinesthetically physics and mathematics and do not see it as burdensome for an 8th grader.

Experiment: Magnetic Force
In the second experiment students study the magnetic force, something typically not done until much later in more traditional textbooks. Students measure the force of attraction of two magnets separated by known distances with their spring scale, which is calibrated to 0 - 5.0 N with a precision of about ± 0.1 N. Students graph the measured force of attraction vs. distance between magnets and discover that the graph is a curved line, not a straight line. The authors suggest that students “draw a smooth curve that fits the data.” The authors do not suggest why force decreases with distance, nor do they mention words like “inverse square” shape graph, but students do see that the force falls off very quickly with distance. The authors simply ask: “what happens to the magnetic force as the distance between the magnets gets larger?” Students are asked to use their graphs to make some interpolations without referring to the mathematical relationship between force and distance.

Experiment: Friction
In the third experiment frictional forces are investigated. Friction is clearly defined as a kind of force, and therefore, a vector. In a clever way the authors state “The frictional force is a strange force. It does not appear until some other force is present and, up to a point, its strength depends on the strength of that other force.” This has always been a difficult concept for young (and seasoned) physics students to grasp. The frictional force opposes the motion, and hence its strength (and direction) depends on the force which is applied to an object. Sometimes friction is to be avoided (bicycle wheel bearings) to continue motion but sometimes you need friction to get started moving (bicycle tires on a road).

The authors cleverly guide the student through a number of exercises measuring how the force of friction is affected by surface area, weight, and surface composition, leading carefully to the understanding (through the data) that the force of friction is **independent of surface area**, but does depend on weight and the nature of the surfaces in contact, described by the “coefficient of friction”. Students graph their data for force of friction (Y) vs. normal force (X) and the data show a linear relationship. The authors then ask again “what is the constant of proportionality” suggesting that students can determine this from individual data pairs, or by the slope of their graph. The authors do ask an interesting question on page 15.

Q #14 “Why do some motorists keep sand in the trunk of their car for winter driving?” However, most cars these days are “front wheel” drive and so sand in the trunk (rear) of the car would not help with traction on snow or ice.

Experiment: Newton’s Third Law
Another experiment goes on to examine Newton’s Third Law. At this point there is no mention of inertia, acceleration, or Newton’s First or Second Law; again an unorthodox and novel way of introducing a new idea – equilibrium and net force. Through a series of clever measurements with their spring scales, students are guided to discover that forces occur in pairs of

equal size and directed oppositely.

At this point in the text the authors suggest that the weight of an object is the force with which that object is being pulled to the earth. In all subsequent discussions (BHF & JLH) would prefer if Earth were spelled with a capital E, rather than a lower case "e" as this is the proper name (noun) of our planet. Likewise, in all further discussions, Moon should be spelled with a capital M and not as moon, referring to our Moon in orbit around the Earth. The textbook is inconsistent in this, sometimes Earth and sometimes earth, sometimes Moon and sometimes moon. Unless you are talking about the soil (earth) you should spell it Earth.

Mass and Weight
One might think at this point the authors would discuss Newton's First or Second Law, but the book then goes on to examine pressure in Chapter 2. The text describes in a somewhat awkward way the difference between mass and weight on p. 22, awkward because there has been no mention of inertia, Newton's First Law, or acceleration. The authors then introduce a major idea with no experimental evidence, the weight of an object is less (1/6th) if on the Moon without any reason for this. (JLH suggests that this might be expected from previous discussion qualitatively.) Then mass is defined in terms of **what you can measure on an "equal-arm balance**", shown on p. 23, not what the spring scale reads. There is no mention of inertia at this point. Mass is simply introduced as **the amount of material** in an object. The textbook does introduce the standard metric unit for mass, the kilogram, as the "mass of a platinum cylinder kept in Sèvres, France, just outside Paris" but there is no mention of the original metric kilogram being based on the mass of one liter of water at 4 degrees Celsius, missing a very nice historical connection of mass and volume (length). Students are reminded, however, that mass can be used as a verb as well as a noun, so you can "mass an object".

The authors describe how the weight of a kilogram changes at different locations or elevations on Earth, and that the constant connecting mass (kg) and weight (N) is called "g". At this point, students are not aware that "g" is also the free-fall acceleration of all objects ignoring air drag, so again, a connection is missed. (JLH does not like to make that connection.) The authors do discuss that the mass of any object is proportional to its weight at any location, so supermarkets do "weigh" food on a spring scale or electronic scale similar to the spring scale the students calibrated. However, we still buy meat in America by the pound, not by the kilogram and certainly not by the newton.

Density
The next experiment in Chapter 2 examines the relationship among mass, volume, and density. Students use a graduated cylinder (and a discussion of meniscus) to measure the volume of four metal cylinders and after measuring mass in grams, plot a graph of mass (Y) vs. volume (X). The authors ask again, "Does the graph you drew represent proportionality? If so, what is the proportionality constant and what are its units?" Students then come to understand that the mass per unit of volume, or the slope of the mass-volume graph, represents a constant called the **density** of the substance. There is a table on page 28 which shows the density of common materials but in units of grams per cubic centimeter. There is no discussion about why atoms have different densities, again missing an important model of the atom which might lead to a discussion of what students will learn in chemistry courses to follow.

Pressure
The authors then move to discuss the concept of pressure showing some common situations like shoulder bags' straps and wires melting through ice, mentioning the idea that "distributing the weight over a large area will reduce the pressure". Pressure is defined as force per unit area, but the units used are newtons per square centimeter, rather than the more common newtons per square meter. There is no mention of pascals as the metric unit of pressure. A table of weight and area (footprint) asks students to calculate the pressure caused by the feet of elephant, horse, human, and cat.

The next experiment is to look at the pressure caused by a fluid. Two open cylinders of different diameter are connected by a rubber hose, and by measuring and adjusting the heights of the fluid, pressures are changed and measured. The authors ask the student to compare the pressure in the large and in the small cylinder. Pressure is further developed as a model of the weight of a column of liquid, developing the idea that the pressure is the weight per unit volume times the depth of the liquid. A graph on p. 36 shows the pressure vs. depth for water, candle oil, and mercury. The authors ask a great question at this point: "is the pressure in a liquid limited only to the downwards direction?" A clever experiment then suggests that students measure the pressure in a beaker of water with three open glass tubes of equal length, but with the opening facing downwards, then upwards, and one sideways. The tubes, filled with air, are then read and clearly show that pressure is independent of direction. What a clever demonstration (page 38)!

The authors next tackle the issue of buoyancy and Archimedes' Principle with another clever experiment showing that the weight of a submerged metal cylinder is reduced by an amount equal to the weight of the water that it displaces. A thoughtful question then asks students "will an object that sinks in water on Earth also sink in water on the Moon? Why or why not?" Atmospheric pressure is covered next relating pressure units of mm of mercury or inches of mercury. A graph (not student data) on p. 44 illustrates how the barometric pressure of Earth's atmosphere drops with elevation (km). Another clever question on page 44 "The atmospheric pressure in Denver (mile high city) is about 4/5 the pressure at sea level. How do you think this would affect the number of homeruns hit during a baseball season?"

Vectors
Perhaps one of the areas younger students struggle with is vectors, either with or without the complication of trigonometric equations. Ch. 3 does an excellent job looking at vectors as a graphical model (no equations) discussing how vectors add using the parallelogram method and how one can find the "net force" with two or more force vectors using the head-to-tail model. The next few pages are about as mathematical as the text gets, but with absolutely no equations, finally showing the components of forces on an inclined plane. Students place a force on a low-friction air puck by blowing air through a straw – what could be more simple and elegant?

Motion
Finally, in Chapter 4 we come to see how distance, time and speed are related. The authors discuss the "black box" (calculator, telephone, etc.) and mention that the sonic ranger (motion detector) works on a simple principle: timing the return pulse for an ultra-high pitch sound wave. Motion graphs (distance-time) are produced by students moving in a variety of conditions, beginning with constant speed. Students catch on quickly that the steepness (slope) of the D-T graph indicates how fast the object is moving, its speed. Direction clearly shows up as a positive slope or a negative slope, without mentioning the

word itself. The authors then discuss what "average speed" means and again, relate this to the rise/run on a D-T graph. Terminal speed is shown with coffee filters falling towards a motion sensor on the floor and a few simple formulas are derived relating distance, speed and time. However, throughout the entire chapter there is no mention of the word acceleration or deceleration and acceleration does not even appear in the Index to the book. I'm [BHF] not sure why the next step was not taken, but one wonders why an elementary physics textbook would not cover one of the most basic motion concepts, acceleration.

Waves

Chapter 5 is all about WAVES. The one curious thing that I noticed right away (probably because I play saxophone) is that the picture of the band on page 83 has been printed reversed (left to right). It is impossible to play a saxophone with the horn on your left side, and the left hand is always on top, the right hand controls the lower notes. The player either just posed for the picture and does not know how to play a saxophone, or the picture was just printed incorrectly. Does anyone catch errors like these in a textbook? You can play a trumpet left or right-handed, but it is impossible to play a saxophone the way the picture is printed.

The waves' chapter illustrates longitudinal and transverse waves and emphasizes that sound moves through air, but the air does not move along with the sound. This is always a challenge to show and to really understand. The speed of sound in air and other fluids is discussed, with a clever way of measuring the speed of sound in air using hand-clapping or wooden-block clapping near a wall with a good echo capability. I've tried this with mixed success with seniors, as it takes some good coordination and a good clean echo.

The speed of sound in air is discussed briefly, mentioning that the speed does depend on temperature and humidity (no reason given) and does NOT depend on the air pressure (no reason given). I'm not sure why a textbook would bother to mention these without some reference to an atomic model and look at possible reasons. Table 5.1 lists the speed of sound in a variety of materials (air, water, mercury) at different temperatures, but there is no follow up discussion as to why sound travels faster in water than in air. Transverse waves are shown on a spring and the fact that longitudinal and transverse waves can be transmitted in a solid, but not a fluid, is not discussed. The authors note that "for each material the speed of the longitudinal wave is greater than the speed of the transverse wave" but again, no discussion as to why this might be true. Knowing the difference in speeds of longitudinal and transverse waves through the earth allows scientists to estimate the distance from the epicenter of an earthquake, clearly shown by graphical models on p. 93.

Chapter 6 Thermal Energy

It would be difficult to imagine a basic physics course without any mention of heat and temperature and connect these to the concept of energy. The FM&E textbook however, takes this a bit further and introduces heat BEFORE any mention of work or energy in general. The authors discuss what would happen when hot and cold water mix and suggest that a change in temperature indicates a change in thermal energy (without any reference to atomic motion). The laboratory equipment accompanying FM&E uses precise high-resolution analog thermometers (mercury or alcohol?) capable of measuring within the range of 10 – 40 degrees C with a resolution or precision of 0.2 degrees. For the following laboratory exercises, one needs a thermometer capable of that kind of precision. One wonders why the authors did not choose to use the newer digital thermometers (safer and faster) with calculator or computer interface, but perhaps the technology was too new when the book was written, or the cost is considered prohibitive (temperature sensor, A/D converter, and even an older used computer can add up to hundreds of dollars).

Students first mix hot and cold water of various masses (volumes) and temperature and predict the final temperature of the mixture. No unit of energy is yet given, yet students can make correct predictions using proportions and the model of conservation of energy. Experiments next mix different ratios of water at different temperatures and students come to realize that the thermal energy transferred to/from a substance depends on both its mass and its temperature change. A table of sample data on page 102 suggests that in a mixing of hot and cold water the product of mass and temperature change is the same for the water that gained heat and the water that lost heat.

Then on page 103 the unit of energy, the joule is introduced as a thermal energy unit. It is pointed out that 4.18 joules of thermal energy are required to raise the temperature of one gram of water by one degree Celsius, and this is called the "specific heat" of water. There is no reference to James Joule and his historically significant experiments linking mechanical energy to thermal energy since mechanical energy has not (yet) been introduced to the student.

The lab suggested next is to mix a hot metal with cold water and measure the changes in energy based on mass x temperature change. Using sample data the authors show how to calculate the specific heat of aluminum. I wonder why students don't do this experiment using blocks of aluminum, iron, or brass. On page 106 Table 6.6 lists the specific heats of a number of common materials, but with no mention as to why they are different and most far less than the specific heat of water. Again, with FM&E perhaps coming after the standard IPS course, one wonders why there is no discussion of atoms per gram and how energy can be stored in an atom, linking chemistry and physics.

The chapter then goes on to discuss heat of fusion and heat of vaporization with an experiment to measure the heat of fusion of ice. One question at the end of the lab asks students to compare the heat of fusion to the heat of vaporization for the same substance, yet there is no graph for reference. One might also ask at this point why citrus fruit growers in Florida spray their orange trees with water just as a deep freeze is on the way – how does this protect the fruit?

Without reference to potential energy and kinetic energy, the authors of FM&E do an outstanding job showing characteristics of thermal energy. A final question in this chapter asks "why do eggs cook just as quickly in water at a low-boil compared to water at a rapid boil?"

Chapter 7 Potential and Kinetic Energy

Unlike most books that introduce topics in a more traditional order, with kinematics, then dynamics, and then impulse and energy, the FM&E introduces the idea of gravitational potential energy and kinetic energy with absolutely no reference to work (force x distance). The thermal energy caused by friction by a falling weight is measured (in joules) and that energy is compared to the distance a weight falls and to the size of the weight. Students measure this, with these high-precision thermometers using the temperature change of a small aluminum cylinder. The data students take (in groups) shows the thermal energy is proportional to the amount of weight and to the distance the weight falls, all without any mention of mgh yet. Thus, the students are doing an experiment to map the relationship between mechanical energy (falling weight) and thermal energy (heat transferred to aluminum cylinder). The conclusion drawn is that the decrease in potential energy of the falling weight is directly proportional to the change in thermal energy of the aluminum cylinder. I still feel that it would be appropriate and honorable to show a picture of James Joule and to describe the way he did the similar experiment, giving the students a feeling of continuity.

Elastic potential energy is then examined using a stretched spring for the source of energy and measuring the change in temperature of the aluminum cylinder. By this time, students are starting to see that energy is "conserved" without using that word.

Kinetic Energy

So how does one introduce kinetic energy, if not via work done on an object? Again, thermal energy is the key as the heat gained by the aluminum cylinder is compared to the velocity of a falling weight attached to a bicycle wheel. After a wheel is spinning at a known (measured) rate, the energy needed to stop the wheel is measured by the temperature change of the aluminum cylinder. The faster the wheel turns, the hotter the cylinder gets; showing that by graph, the relationship is definitely NOT linear (Fig 7.9). In order to show that the mechanical (kinetic) energy is directly proportional to the square of the speed a graph is constructed plotting energy (Y) vs. square of speed (X) which results in a linear best fit. This might be about as far as 8/9th graders can reason mathematically, showing that the energy is directly proportional to the SQUARE of the speed of an object.

Free Fall

The next experiment looks at the relationship between kinetic energy and potential energy using a motion sensor and a falling softball, a traditional experiment often performed in a variety of ways. Finally, the Law of Conservation of energy is explained with some demonstrations of a weight moving up and down on the rim of a wheel.

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