

Chapter 1

A LITTLE BIT OF MAGIC

There is, according to the nice woman who ran the workshop on *the brain* at the last California Association of Independent Schools meeting I attended, a difference between the way males and females approach academics. According to her, women think globally whereas men think in pieces. I assume this is a gross over-generalization. There are obviously men out there who can view a new subject from a global perspective, and there are undoubtedly women who do just fine taking an algorithmic approach to learning.

Nevertheless, the research and its conclusion were significant for me as a physics teacher because physics has historically been taught in a step-wise fashion. In the past, it has evidently been inadvertently presented with a bias toward the way men learn.

This presentation approach is not completely without justification. It is difficult to look at a topic globally if you haven't yet been introduced to the bits and pieces that make up the whole. Still, it made me wonder, back in those heady days of gender enlightenment, whether I might not be able to do better for those of the global persuasion.

I am not completely sure I can, but I'm going to try.

A.) A Tiny Preamble:

There are several things to be aware of concerning this chapter.

First, the format you are seeing now before your eyes is not the format you will encounter in the main part of the book. Most students *underline* as they read because that is an easy way to break massive, complex ideas up into bite size chunks. From the third chapter on, the bite size chunks will come gratis. The format will be in *outline* form and, yes, this is a nod toward the piece-wise folks.

Second, I will begin each chapter with a very quick overview as to what the chapter at hand will attempt to accomplish. This is a nod toward the big picture people.

Lastly, although the beginning of this chapter is educational in the sense that it should allow you to see where we are going, most of the chapter is devoted to convincing you that you know very little about your world.

As such, the topics will be selective and presented only partially. My first inclination was to let it be a "for your own edification" kind of thing, but the more I thought about it, the more I figured you'd feel slighted if I didn't test you on, at the very least, the factual minutia that will make up the discussions. To that end, I have included at the end of this chapter a list of test-possible fact/questions for your amusement. It will be more memory than anything else, but that's life. We'll get to the math soon enough.

B.) A Little Background:

Physics is the study of the dynamics of the physical world. There are three general ways to do this study. This section will present those ways along with a few thoughts as to what you can expect of this course.

The first way to approach the study of physics is from the *physics for poets* perspective. This is a facts based approach that uses qualitative explanations to delve into our understanding of the physical world. At least for test preparation, this approach is fairly easy because it primarily requires memory work.

An example: White light is made up of a wide range of frequencies of electromagnetic radiation. This includes frequencies that show themselves collectively as blue light. When white light from the sun passes close to the earth without actually hitting it, its blue-light component is absorbed by nitrogen in the earth's atmosphere. Once absorbed, the blue light is then re-emitted in random directions. As such, we see blue light coming from the sky even though there is no apparent object emitting it.

A typical test question would be: *Why is the sky blue?*

Observation: There is little thinking required here, just a good memory.

The second way to approach the study of physics is through a *conceptual* perspective. This approach requires an understanding of the "laws" upon which the mathematical models associated with physics are predicated. It is challenging for students because it is not memory based. It focuses on the conceptual side of the theory, then expects the student to be able to use that understanding to qualitatively predict what would happen in unknown situations.

An example: According to Newton's First Law, objects in motion stay in motion with a constant velocity in a straight line unless impinged upon by a force.

A typical test question: You are walking on a flat, horizontal surface (i.e., not on an incline) with a constant velocity. As you walk, you hold a ball in your hand next to your body. As you continue to walk, you release the ball and it falls. When the ball hits the ground, does it hit (a) behind you, (b) next to you, or (c) ahead of you? You can assume (correctly) that air friction is negligible in this situation.

Observation: Think about it. When the ball is released, a gravitational force acts on it in the vertical. As such, the ball's vertical velocity component changes as it accelerates toward the ground, just as Newton's Second Law predicts.

In the horizontal, on the other hand, there *is* no force acting on the ball (friction is being ignored). The consequence is that the ball's horizontal velocity component does *not* change.

The ball's horizontal velocity and your walking velocity are initially the same, so if the ball's horizontal velocity *doesn't change*, the ball should hit right next to you as you walk. In other words, the answer to the question is *b*.

(Note: One of my friends over at Caltech pointed out that this is the reason why a low flying bomber will bank after dropping its payload. If it didn't, the bombs would stay directly beneath the plane as they fell and the plane would be right on top of the explosion when the bombs hit the target.)

Most students hate questions like this because it requires them to suspend their belief in "common sense" along with, in some cases, stepping away from everyday experience. In the case of the falling ball, it is easy to mistake this situation with the very visual situation of someone throwing a hamburger wrapper out of a moving car window. In that case, you *see* the wrapper hitting the ground *behind the window*. The problem is, the two situations aren't the same. Don't believe me? Try the falling ball problem. Assuming you don't push the ball one way or the other (i.e., just drop it clean), the ball will hit right next to you as you walk.

The point here is that doing "conceptual" problems requires you to think on your feet while trusting in a physics "law" that may seem counterintuitive at the time. This is usually what makes these kinds of problems difficult.

The third approach is to focus on the mathematics used to model the concepts that underlie physics. Ignoring the *straight memory* approach, and assuming there is no conceptual trickery going on, this is the easiest thing to do in physics . . . at least for some. Learn the equations, know how the variables in the equations work (i.e., know what they stand for), then use them intelligently.

An example: According to Newton's Second Law, the relationship between the force F_f on an object and the acceleration a of the object is $F = ma$, where m is the object's mass.

A typical test question: Given Newton's Second Law, what is the acceleration of a 2 kg mass under the influence of a 12 newtons force (note that a *newton* is a kg·m/s²)?

Observation: There is a very formal way to use Newton's Second Law in a problem. For the problem outlined above, that procedure is shown below.

$$\begin{aligned}\underline{\Sigma F}: \\ F_1 &= ma \\ \Rightarrow a &= \frac{F_1}{m} \\ \Rightarrow &= \frac{12 \text{ kg} \cdot \text{m} / \text{s}^2}{2 \text{ kg}} \\ \Rightarrow &= 6 \text{ m} / \text{s}^2.\end{aligned}$$

Easy, eh?

In a typical Honors Physics course, the conceptual and mathematical side of physics are paramount. Problem is, there is a lot of pretty amazing stuff about the way our world works that isn't usually delved into at this level unless you are in *physics for poets* class.

We aren't going anywhere (no AP test to take at the end of the year), and we have plenty of time to do the hard-core stuff, so for the next chapter and a half, we are going to be bad. We are going to get poetic and briefly delve into the question, "What do you really know about your world?"

C.) The Lowly Atom:

Look at the room in which you sit. Better yet, look at the palm of your hand. What you perceive is something that appears massive, substantive. In your world, substance is all around you . . . and yet it isn't.

The so-called *fundamental building block of matter* is the atom. So take an atom. What do we know about it?

...To begin with, it is small. The diameter of a typical atom is 10^{-10} meters across (that is .0000000001 meters, or one *angstrom*).

...It is made up of positively charged protons, neutral neutrons in the nucleus at the atom's center, and negatively charged electrons "orbiting" the nucleus.

...Assuming it isn't an ion (i.e., an atom that has gained or lost electrons), it is electrically neutral because it has as many positive protons as negative electrons in it.

...Its "type" is identified by the number of protons in its nucleus. What this means is that *all* hydrogen atoms have *one* proton; *all* helium atoms have *two* protons; *all* lithium atoms have *three* protons, etc.

...Its electrons orbit its nucleus moving at around 14,000 miles *per second*. (It is interesting to note that at that speed, given the size of the orbit, the electron orbits the nucleus approximately 10^{16} times every second--that's 10,000,000,000,000,000 times per second.)

Although the number of protons in a particular kind of atom is fixed, the number of neutrons is not. Normal hydrogen has one proton and no neutrons. Deuterium is the isotope of hydrogen (i.e., an oddball variant of hydrogen) that has one proton and one neutron. Tritium is another isotope of hydrogen that has one proton and two neutrons.

So let's take a closer look at a particular atom, the so-called "normal" hydrogen atom.

If we could take a hydrogen atom and do a little magic on it so that its nucleus expanded up to the size of a super ball with everything else expanding proportionally, what would we end up with?

We would end up with a 2.5 inch diameter super ball nucleus with a point sized electron orbiting the super ball approximately *four miles* away. That is to say, if the super ball were located here on Polytechnic School's campus, the electron would be located somewhere down in the middle of San Marino.

In other words, we would be left with a super ball sized proton, a point sized electron, and in between, four miles of *absolutely nothing*.

Put a little differently, of the approximately 35,000,000,000,000 cubic feet (that's thirty-five trillion cubic feet) making up the volume of that expanded spherical atom, only about 0.005 cubic feet would be occupied by what you and I would call *real matter*.

Conclusion: Atoms are made up *almost entirely of space*.

Consequence? Take an object, any object. Take your body, for instance. If we could somehow extract all the space from your body, we would be left with a tiny speck of matter that would probably take a microscope to see, and that would weigh one to two hundred pounds (i.e., your original weight).

Why? Because there is practically no physical substance in your body, yet your body doesn't appear to be so. You do not look at your hand and say, "Ah, yes. Space!" That is not what your hand is to you. Yet that is what it really is.

In my country, something that appears to be something it is not is called *an illusion*. And in fact, that is exactly what the physical world is.

D.) Time:

Still not convinced that your perception of the world is not as close to reality as you think? Let's try again.

Time is a measure of the rate at which the moment passes. You think time runs the same everywhere?

It doesn't!

Time at the sea shore runs more slowly than time in the mountains.

Poppycock you say? It's true. Sure, you'd need cesium clocks--clocks that are accurate to a ten-thousandth of a second over a thousand years--to measure the effect, but it is there.

In fact, scientists *have* used cesium clocks to show this phenomenon.

Two cesium clocks were set so that they were exactly alike. One of the clocks was put on the first floor of a building. The other clock was put on the third floor of the building. The two clocks were left alone for a couple of years, then brought back together for comparison. What was observed was that the clock on the first floor ran more slowly than the clock on the third floor.

This is not magic. Don't expect Penn and Teller to come popping out of your television set showing you the sleight of hand. This is a part of the reality of your world. You don't observe this kind of time variation because you are never in a situation in which it is obvious (i.e., you are never in a situation in which you are close to *extremely* massive objects), but it is nevertheless a part of the reality of your world.

In summary, *time*--a measure of the rate at which the moment passes--will always appear to be running normally to you, but time in one frame will not always be the same as time in another frame. The rate at which the moment passes depends upon *where* you are, and upon the massiveness of the objects that are around you in the space in which you reside. Time is not the same everywhere . . . and that's the truth (thank you, Ruth Buzzi!).

Note: The consequence of all of this is that in Relativity, space is not viewed as a nice, homogeneous, three-dimensional void. It is instead viewed as a *four-dimensional* structure with the fourth dimension being *time*. In other words, in Einstein's view of the world, *time* is quite literally a part of the fabric of space.

E.) Mass and Free Falling Objects:

A ten kilogram object weighs more than a one kilogram object (duh!). That is to say, a ten kilogram object is gravitationally pulled toward the earth with ten times the force of a one kilogram object. Put a little differently, if you drop a ten kilogram object on your right foot, then from the same height drop a one kilogram object on your left foot, I can guarantee that the experience of your right foot is going to be less pleasant than the experience of your left foot.

This is all very obvious, very reasonable. What is not so obvious and reasonable is the experimentally determined fact that if you take those two objects and drop them side by side from the same height, assuming air friction is the same for both, the two will reach the ground *at the same time*. That is, the two will drop side by side until they reach the ground.

In other words, even though the ten kilogram object is being pulled toward the earth with a greater force, it accelerates at the same rate as the lighter object.

So how can this be?

To understand what is going on, you need to understand what is going on with the idea of *mass*.

According to most sixth grade science classes, the mass of a body identifies how much *stuff* there is in the body. If a body's mass is big, there's a lot of stuff in it. If the body's mass is small, there is little stuff in it.

What is additionally pointed out in the sixth grade is that if you take an object to the moon, its weight will change because the moon will gravitationally pull at the object less than was the case on earth, but its mass--the amount of stuff in the body--will remain the same.

Unfortunately, this is a very simplistic view of mass. In fact, the idea of mass was originally devised to measure a couple of very specific somethings.

There are characteristics that are true of all material objects. For instance, all objects have a tendency to *resist changes in their motion*. A rock placed in space will not suddenly, spontaneously accelerate for no reason. It will sit in its place until a force makes it move.

The unwillingness of an object to spontaneously change its motion is called *inertia*. As the amount of inertia an object has is intimately related to how much "stuff" there is in the object and, hence, how much *force* will be required to *accelerate* the object, quantifying the idea of inertia is important.

Early scientists satisfied that need by defining an *inertia-related quantity* they called "inertial mass."

The idea is simple. A platinum-iridium alloy cylinder, currently housed in a vault at the *Bureau of Weights and Measures* in Sevres near Paris, France, is defined as having *one kilogram* of inertial mass. All other inertial mass values are measured relative to that cylinder. That is, an object with the same amount of *resistance to changing its motion* as does the standard is said to have "one kilogram of *inertial mass*." An object with twice the *resistance to changing its motion* is said to have two kilograms of *inertial mass*; one-half the resistance implies one-half kilogram of *inertial mass*, etc.

In other words, the inertial mass of a body gives us a numerical way of defining how much inertia an object has RELATIVE TO THE STANDARD. Put still another way, *inertial mass is a relative measure of a body's tendency to resist changes in its motion*.

Note: Although France is a beautiful country, it would be terribly inconvenient for laboratory scientists around the world if they had to travel to France every time they wanted to determine an *inertial mass* value, so scientists further generated a laboratory technique for measuring *inertial mass*. It utilizes what is called an *inertial balance*--a tray mounted on two thin blades that allow the tray to vibrate back and forth. The more mass that is placed in the tray, the slower the tray vibrates. A simple formula relates the tray's vibratory rate (its *period* of motion) to the amount of *inertial mass* there is in the tray.

Although it works, using an inertial balance is a VERY CUMBERSOME and time consuming operation.

Another characteristic that is true of material objects, at least in the standard Newtonian view, is that massive objects are attracted to other massive objects.

A measure of a body's *willingness to be attracted to another body* is related to what is called "gravitational mass."

Just as was the case with *inertial mass*, to provide a quantitative measure of *gravitational mass*, scientists have taken an agreed upon object as the standard against which all subsequent *gravitational mass measurements* are made (again, this standard is housed today in Sevres, France).

The technique for measuring *gravitational mass* utilizes a *balance* or *electronic scale*. The object is placed on a scale which consists of a spring-mounted pan. The gravitational attraction between *the object and the earth* pulls the object toward the earth and compresses the spring in the process. The scale is calibrated to translate spring-compression into gravitational mass (assuming that is what the scale is calibrated to read--in some cases, such

scales are calibrated to read force, hence American bathroom scales measure in pounds).

MEASURING *GRAVITATIONAL MASS* IS EASY.

Somewhere down the line, someone noticed a wholly unexpected and profoundly improbable relationship between *gravitational* and *inertial mass*. It was observed that if the same standard object were used for both, a second object with twice the *gravitational mass* relative to the standard would also have twice the *inertial mass*.

THIS DOES NOT HAVE TO BE THE CASE.

There is no obvious reason why a body with twice the *resistance to changing its motion* (relative to the standard) should also have twice the *willingness to be attracted to other objects*. The two characteristics are completely independent of one another, yet they appear to parallel one another to a high degree of precision.

In fact, the best comparisons to date have accuracy to around 2×10^{12} with *no discrepancy found* even at that order of magnitude.

Scientists could have called the units of *gravitational mass* anything they wanted (I'd have suggested *the Fletcher*, but I wasn't around when the discussion took place), but because they knew the parallel between *gravitational mass* and *inertial mass* existed, they decided to give *gravitational mass* the same units as *inertial mass*, or "kilograms" in the MKS (meters, kilograms, seconds) system of units.

That means that, as defined, a body with two kilograms of *gravitational mass* also has two kilograms of *inertial mass*.

We are now ready to understand the brain teaser I stated at the beginning of this section. Specifically, if a body whose *gravitational mass* is ten kilograms is attracted to the earth ten times as much as a body whose *gravitational mass* is only one kilogram, why will the two free fall toward the earth at the same rate?

The answer is simple. A body with ten times the *gravitational mass* also has ten times the *inertial mass*. That is, the body will have ten times the force on it, but it will also have ten times the *resistance to changing its motion*.

The net effect? It does not matter how massive an object is, its *inertia* coupled with its *willingness to be attracted to the earth* will always balance out making the object accelerate at the same rate as all other objects (again, assuming you ignore air friction).

Note: Close to the surface of the earth, that acceleration in the MKS system of units is 9.8 m/s^2 . In our system of units in the US, it's 32.2 ft/s^2 .

Kindly note that the MKS system of units is not something that only pointy-headed scientists use (thank you, Sterl Phinney for that turn of phrase), it is what THE ENTIRE REST OF THE WORLD USES OUTSIDE AMERICA! In other words, *we* are the oddballs for using things like inches and pounds as our system of units.

This is an example of phenomenon that, at least on the surface, seems to make no sense. No sense, that is, until you understand better how your world works.

I'm tempted to stop here. A physical world made up of practically nothing of substance. Time running at different rates depending upon where you are. Objects of the same size but different masses falling at the same rate. These are all real characteristics of your world even if some are not immediately evident. Still, I am having fun. Maybe just one more bit of amusement.

F.) Energy in a Relativistic Sense:

Visualize an object sitting motionless out in space. Once you've got it, mentally apply a constant force to it. What changes?

Most people will say that the body's *position* will change.

Most people will say that the *time* will change.

Most people will say that the body's *velocity* will change.

And although it is wrong, at least some people will say that the body's *acceleration* will change (this is wrong because a constant force will produce a constant acceleration, and a constant acceleration doesn't change . . .).

WHAT MOST PEOPLE *WON'T* SAY, but what happens to be true, is that the other thing that changes is the body's *inertial mass*.

That's right, folks. As the body's velocity increases, so also will its *resistance to changing its motion--its inertial mass*. And for those of you who are still awake, YES, THIS IS VERY WEIRD.

If you wanted to do an experiment in which you observed this phenomenon, you would have to come up with a device that measures the mass of an object that is in motion, relative to you (actually, if the mass was charged, observing how the mass acted as it passed through a known magnetic field would do the trick). Let's assume you have done that. You have this clever device that measures a body's *resistance to changing its motion--its inertial mass--as it passes you by*. With that device, we are almost ready to do an interesting experiment.

First, though, there is one more minor bit of information you need to know. It has to do with the *idea* of energy.

In a very loose, hand waving, conceptual way, a body is said to have *energy* if it has the ability to affect (i.e., do *work* on) other objects. A speeding bullet, for instance, can affect a target when it hits. A speeding bullet, therefore, is said to have energy and the ability to *do work*.

If *energy* exists as a consequence of the object's motion, it is said to have *kinetic energy*. Kinetic energy is sometimes referred to as the *energy of motion*.

Kinetic energy is numerically equal to $(1/2)mv^2$, where m is the object's inertial mass and v is its velocity. (This expression assumes that the object is not going close to the speed of light.)

So now we are ready for the big experiment.

You are sitting still out in space. You have your mass detection device with you. You also have sitting next to you an object whose inertial *rest mass* is exactly $1.\bar{0}$ kilogram (the bar over the zero means the zeros repeat forever, and the term *rest mass* alludes to the inertial mass of the object as it sits still next to you in your frame of reference). A friend takes the object, moves far away from you, then applies a constant force to it.

In doing so, your friend does *work* on the object and the object accelerates to *100 miles per second*.

Observation #1: I should point out how absurdly fast this is. The Space Shuttle *in space* only goes *17 miles per second*, so we aren't talking about normal speeds, here. Still, let's assume you could do this.

Observation #2: Another way to frame this situation is to say that by doing *work* on the object (i.e., your friend *pushing* it), she puts *energy* "into the system." That *energy* shows itself as an increase in the body's *kinetic energy*--its energy of motion--as the body speeds up.

You are still sitting still, so as the object comes whistling by and you point your *inertial mass measuring device* at it, what will your device measure?

Common sense suggests that the mass will still be $1.\bar{0}$ kilograms. Unfortunately, that is not what you would read. In fact, as the body passed by at *100 miles per second*, the mass measuring device would measure the body's mass to be *1.000000145 kgs*. In other words, the mass would have *increased*.

Observation #1: Think about what this means. At *100 miles per second*, there is, evidently, inherent within the structure, more *resistance to changing its motion*--more *inertia*, more *mass* if you will--than there was when the body was sitting still.

THIS IS VERY, VERY FREAKY.

Put enough energy into the system to get the speed up to *100,000 miles per second* and the mass will measure *1.185 kg*.

Put enough energy into the system to get the speed up to *170,000 miles per second* and the mass will measure *2.46 kg*.

Put enough energy into the system to get the speed up to *185,999.9999 miles per second* and the mass will measure *30,496 kg*.

Conclusion: Evidently, if you do *work on* and put *energy into* a system (i.e., our object) in this way, it isn't just the energy of motion--the kinetic energy--that increases. The mass increases, also. And it's right about this point in the lecture that the classroom rebel gets a wild hair, stands up on the desk, and shouts at the top of his or her lungs, "WHAT THE HELL ARE YOU TALKING ABOUT? THIS MAKES NO SENSE AT ALL!!!"

Before we respond to the disruptive hooligan on the desk, though, there is just one more question I'd like to ask. "Looking at the data trend, what do you suppose the top speed of the object might be?"

If asked in class, someone usually notices that as the object's velocity gets closer and closer to the speed of light (i.e., $c = 186,000$ miles per second), the mass edges toward infinity.

In fact, this is the reason Einstein concluded that no massive object can ever be made to go the speed of light. To reach that speed, you would have to put an infinite amount of energy into the system, and at that speed the body would have infinite mass.

So what are our conclusions?

At low velocities, energy put into a system will show itself almost completely as an increase in kinetic energy--in energy of motion. *Very little* of the energy will show itself as an increase in the body's *resistance to changing its motion* (i.e., its mass).

We only experience low velocity phenomena in the "real world," so this is the scenario for which we are familiar.

At velocities close to the speed of light, energy put into a system will not show itself as an appreciable increase in kinetic energy. *Most* of the energy will show itself as an increase in the body's *resistance to changing its motion* (i.e., its mass).

How do we know all of this?

Our best particle accelerators--Fermilab, for instance, outside of Chicago--can accelerate protons up to .9999995 times the speed of light. It can

do this because the mass of a proton is only 1.67×10^{-27} kilograms, which is to say *small*, and because we have access to enormous amounts of energy. (In fact, to do one run, a typical accelerator uses somewhere around the amount of energy that the city of San Francisco burns in a day.)

The important point is that when particles accelerated in this way collide with whatever target they are aimed at, they hit with considerably more umph than they should have (yes, umph *is* a scientific term--you need to know its definition for the test . . . not).

Why does this happen? Because the inertial mass of the speeding particles is so enormous in comparison to their *rest mass*, their impact carries a wallop that is significantly larger than would have been the case if the relativistic effect hadn't been in evidence.

Without this phenomenon, we would never have been able to "split the atom."

So now it's time to quiet the heckler and find out what's going on. In fact, you've had the key to this mass/energy problem ever since you were wee small.

What is the first (and probably only) equation you ever learned having to do with Einstein and his Theory of Relativity?

That's right, it's $E=mc^2$.

What Einstein was really saying with $E = mc^2$ was that mass and energy are *two forms of the same thing*.

Put a little differently, Einstein maintained that at its most fundamental level, material is nothing more than "congealed" energy. In fact, he even called mass *frozen energy*.

Nature exhibits this mass/energy characteristic in some pretty spectacular ways.

Take a single deuterium atom (hydrogen isotope with one proton and one neutron) and put it on a scale (OK, we are being silly here--play along). Assume we find the mass of the atom to be x . Do the same thing with a second deuterium atom. Its mass will also read as x .

Now, take those two atoms and force them together to make a single entity. This will take close to a billion atmospheres of pressure and temperatures up around 10,000,000 degrees Centigrade, but do it anyway. When you are done fusing the two deuterium atoms into one single entity, you will end up with a helium atom.

Now put that Helium atom on the scale. What you will find is that the mass of this new atom will not equal the sum of the two deuterium atoms that

made it up (i.e., the mass will *not* equal $2x$). What you will find is that the helium atom's mass will be shy by 0.7% of that sum.

So where did the missing mass go? It was turned into pure energy a' la $E = mc^2$. Evidently, when we fuse small atoms to make bigger atoms, we get energy given off. This is the heart of the *hydrogen bomb*--small deuterium atoms making larger helium atoms.

Do we get a lot of energy out of the fusion process?

Take one gram of hydrogen and fuse it into as much Helium as you can. (How much Helium will that be? It will be .993 grams worth.)

The missing .007 grams will have been converted to pure energy.

How much energy is released when .007 grams of matter is converted into pure energy?

According to $E = mc^2$, the conversion of the .007 grams of matter into pure energy will produce enough energy to send 350, four-thousand pound Cadillacs 100 miles into the atmosphere. That's how much energy is released with the fusion of one gram of hydrogen.

And just so you know, the Sun, our star, converts 657,000,000 TONS of hydrogen into 653,000,000 TONS of helium *every second*.

Put a little differently, our star converts 4,000,000 TONS of matter into pure energy every second. This is part of the reason our star does such a nice job of heating the little bit of nothing we call *our planet*, even though we are 93,000,000 miles away from it.

So what *is* energy?

Feynman, a Nobel Laureate in physics from Caltech, was asked that question several years ago at a *California Association of Independent School* meeting by moi. Cool dude that he was, he didn't bat an eyelash. He simply said, "I have no idea." In so answering, he spoke for physicists around the world.

We know when a body *has* energy. We know how to *produce* energy. We know how to *store* energy. We know how to *use* energy. We know how to *transfer* energy long distances. What we *don't* know is exactly what energy is.

Having made that unsettling remark, it should be pointed out that there is a very useful approach used to analyze certain kinds of situations that incorporate the idea of energy into a model you are going to come to know and love. But that will come a little later.

For now, it is sufficient to simply marvel at how remarkable and surprising our physical universe is.

QUESTIONS & PROBLEMS

Note: Although it might be possible to tease a few math problems out of the reading, I'm not going to do that. What I am going to do is list a series of questions you could be asked on your test. As these are more research questions than anything else (all the answers *are* all found in the chapter), you will not find "solutions" to these questions at the end of the book. Sorry about that. Life's tough . . . and then you die.

1.1) Although I didn't intend to test you on any of the material found on the first *three and a half pages* (i.e., don't expect a question that asks what the *physics for poets* approach is all about), I can't help myself when it comes to fun facts. Soooo, why is the sky blue?

1.2) What is an *angstrom*? Also, what is the diameter of an atom?

1.3) What are atoms made up of (OK, this is really dumb--think of it as mercy points if I put it on the test)?

1.4) What determines the *kind* of atom you are looking at (i.e., whether it is hydrogen or lithium or what)?

1.5) How fast do electrons travel inside the atom?

1.6) If an atom were expanded up so that its volume were thirty-five trillion cubic feet, what part of its whole would be made up of solid matter?

1.7) If you had to put a word to the reality of the physical world, what would it be?

1.8) What is time?

1.9) Assuming you are observing from a frame of reference that is located somewhere "out there," what will the watch of a hiker do as the hiker descends from the top of a mountain to the bottom? (the effect might be small--be anally technical here)?

1.10) Who is Ruth Buzzi?

- 1.11) According to Einstein's view of the world, how is time related to the space?
- 1.12) What is inertia? What is *inertial mass* (be complete)? How, technically, is *inertial mass* measured?
- 1.13) What is *gravitational mass*, and how is *it* measured?
- 1.14) Do bodies with different masses have different gravitational forces on them, and if so, why do they accelerate at the same rate if allowed to freefall (ignoring frictional effects)?
- 1.15) What is the MKS system of units?
- 1.16) What is the acceleration of gravity in the MKS system of units?
- 1.17) If a body has *energy*, what does that mean?
- 1.18) What do you have to do to change a body's energy content?
- 1.19) What is *kinetic energy*? What is *work*? What is the difference between doing *positive work* and *negative work*?
- 1.20) At very low velocities (like the velocities you and I experience in our daily lives), what happens to a body when *work* is done to it?
- 1.21) At very high velocities (i.e., close to the speed of light), what happens to a body when *work* is done to it?
- 1.22) If you accelerated an object to 170,000 miles per second, by how much would its mass have grown?
- 1.23) Why did Einstein claim that you can never motivate an object to go the speed of light?
- 1.24) What relationship did Einstein come up with that explained all of this weirdness concerning energy? What do the symbols in the relationship mean?
- 1.25) What kinds of temperature and pressure are required to effect the fusion of hydrogen atoms?

- 1.26)** When hydrogen fuses, what percent is converted to pure energy?
- 1.27)** How much energy is released when *one gram* of hydrogen is fused into helium?
- 1.28)** To what speeds can the Fermilab accelerator accelerate protons?
- 1.29)** How much mass is converted into pure energy in the sun every second?
- 1.30)** So what *is* energy?

