COMPILATION: Physics First at Rex Rice's school (Clayton High School)

Note by Jane Jackson: Rex Rice, of St. Louis, Missouri, is one of the best modelers in the nation. Rex Rice's school follows the science sequence promoted by Nobel Laureate Dr. Leon Lederman. All freshmen have a year of physics, and all sophomores have a year of chemistry. The juniors have biology, and they can take advanced physics.

In 1999, Rex and I had a long phone conversation about it. Below is my summary of our conversation. Later he proofread my summary and commented on it. His comments are in quotes.

Another post follows, in which Rex describes his school's regular and honors freshman physics course, and his regular junior/senior physics course and AP-B course.

Force Concept Inventory scores of students in Rex Rice's freshman classes and also in his colleague Bob Mullgardt's honors freshman classes are much higher than those of students who are taught conventionally.

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1) Types of students:
Rex's school is in a suburb of St. Louis. It is a comprehensive grades 9 - 12 public school, and 20% of the students are inner city African Americans. Some of these inner city kids won't do the work in Rex's freshman regular physics course, and so they are at the bottom of the class. Rex says, “many won't do the work. I have many that do, and as a result do fine in the course.”

2) Methodology:
Rex follows the modeling approach fully in his 2 sections of the regular freshman physics course. He likes some of the C3P activities (his wife, Debbie, is a C3P mentor) but says that modeling has a lot more to offer. But modeling is harder to teach freshmen than juniors, he says. The freshman honors teacher uses modeling, but the rest of the freshman physics teachers give more of a survey course. *When the students come into Rex's junior course, he can really tell the difference; his regular freshman students and the honors freshman students are much better prepared.*

Rex adds, “I do have a colleague, new to the school, who did modeling with the freshmen along with me this year. He and his students did reasonably well for a first-timer without the benefit of the formal modeling training.”

3) Why physics first?
Rex was instrumental in getting his school to change to the physics - chemistry - biology sequence several years ago, because the old sequence made no sense. He says *this sequence is MUCH better than the traditional one. The biology teachers are thrilled,* he says!

4) Why a full year of freshman physics, rather than chem/phys?
Rex says, *“In a chem/phys course, there is not much chance of doing much more than a survey. This course should be about teaching students to "do" science. I know of no better training for this than a freshman course in physics taught using a "lower math" modeling method."*

Date: Sat, 20 Mar 1999
From: Larry Dukerich <dukerich@ASU.EDU>
Subject: physics first
Hi Folks,

After Leon Lederman came to ASU to discuss his physics first initiative, I asked Rex Rice (Phase I participant and Phase IIa leader) to tell us a bit about what they do at his high school in Clayton, MO. I think you will find Rex's remarks thought-provoking, whether or not you are seriously considering 9th grade physics at your school.

I spoke with Rex Rice about the way they do physics first at Clayton HS in Missouri. Below is a compilation of three e-mails that Rex sent me to answer this question. You may find his account helpful should you wish to implement a physics-first approach.

LD: I was wondering if you could provide us a brief outline of what it is that you guys do with the 9th graders at your school.

RR: I try to do modeling, in a limited fashion, with my 9th graders. I teach the "regular" level freshman physics, so I am dealing with approximately the "lower" two-thirds of the student body.

With this group of mostly average to below average students, I use the modeling method and get through the following units:

Unit I (I don't include significant figures here... they just confuse the issue) In unit I, I am primarily interested in experimental design and analysis. We do the pendulum lab as three separate experiments, but do not, at this point worry about straightening graphs. We also do a spring
experiment, primarily to learn to do mathematical analysis of linear graphs. We do not use the computers for graphing at this stage. I want these guys to understand how to make a graph and particularly how to scale a graph before I turn them loose on the computers.

Unit II - This unit is done in its entirety. We actually do a total of three different uniform motion experiments. We start with the BB in the water-filled tube experiment (using two different angles for the tube), followed by the car experiment (using two different speed cars) and concluding with a glider on a level air track experiment (using two different "pushes" to cause different speeds). The glider experiment is videotaped and analyzed frame by frame. In each case both objects are
plotted on the same set of axes to emphasize the idea that the slope is related to the speed of the object. There is a good deal of concept development between each experiment with each one designed to reinforce the ideas developed prior to it. Students also use the motion detectors to try
to reproduce several different position vs. time graphs which contain only straight line segments.

We do work with some of the early parts of PAS *Conceptual Kinematics* in this unit as well. I use most of the Unit II worksheets, but downplay the more algebraically involved problems. These kids seem to do fine until they are confronted with an equation that requires them to solve for a variable. At that time, kids who have been with you the whole way get the "deer in the headlights" look and unfortunately shut down. I learned in my first iteration that minimizing the algebra required (even though all of these students supposedly passed algebra as eighth graders) is a smart thing to do. Lots of good physics still happens with a minimum of algebra. I do not bypass this (algebraic problem solving) altogether, but I spend a minimum amount of time on it and count it fairly lightly on exams. Some of my kids can do it, but they are in the minority.

Unit III - This is treated very similarly to Unit II. We do three uniformly accelerated motion experiments. These include the wheel and axle experiment (in lieu of the ball down the ramp). This is done using a metronome as a timing device, so time is indeed the independent variable. The second experiment is a glider on an inclined air track which is videotaped and analyzed frame by frame. At the end of this unit we introduce free fall as an application of uniform acceleration. We make stroboscopic photographs of falling golf balls. Students analyze the photograph and prepare a formal lab report. More work is done in this unit with the motion detectors and students moving relative to them to try to reproduce v vs. t graphs and predicting what the corresponding position vs
time and acceleration vs. time graphs include.

Problem solving is again simplified to avoid scaring too many students off. 1-D Vectors ARE treated carefully in this unit and do not seem to be a major problem. We use more of *Conceptual Kinematics* and *Graphs and Tracks* in this unit.

Unit IV/V - We do no trig in this unit. We do the introductory demo from Unit IV and develop the concept of a force and force diagrams, the concept of net force, and the relation of net force to motion. We also do the Gravitational Force vs. Mass experiment and discuss the ideas of mass and
gravitational force carefully. We follow this with the Unit V paradigm lab in order to develop Newton's second law. We concentrate primarily on the effects of net force and mass on acceleration through the remainder of the unit.

Problems are chosen which have only one body, and for which the net force can be determined through the force diagram fairly easily. Again, no trig! No pulley problems like Atwood's or "half-Atwoods" machines are done.

Finally in this unit, we do the paradigm experiment for Newton's Third Law that Dave and I put together at UWRF. We make more use of the Hewitt book and its various review and think & explain questions in this unit.

And there you have it. The first semester of freshman physics as taught by me at Clayton HS.

This year, I really got bogged down and this took us an extra few weeks into the second semester to complete.

In the second semester, we go ahead and do some work on significant figures and scientific notation along with a little unit conversion. We then proceed to the Energy Unit. Two years ago, I used the "new" energy materials as they then existed with the freshmen. I was happier with their
understanding than I had ever been even with my juniors and seniors. Since then I have been using this approach with ALL of my classes, and feel that I am getting better at using this

approach all of the time. I am just starting this with this year's freshmen, and it is going well. I have designed a spring that attaches to the PASCO dynamics cart track that is easy enough to use and yields good enough results that I have reconsidered my earlier reservations about the energy labs.

Over the course of the past two weeks, the freshmen have successfully done three energy experiments and I have changed my mind. They did the spring experiment with only one spring and set up so that the F vs. x graph goes through the origin. We then did an experiment in which they stored energy in the new spring on the PASCO track, and measured, using a photogate and a flag on the dynamics cart, the velocity of dynamics cart launched on a level track by the spring. The energy vs. velocity squared graph had a slope that was typically within 10% of one-half the mass of the cart, and closer to 5% for the lab groups with really good technique. They then did an experiment where they released a weighted card set up as a pendulum from a series of heights (5 cm to 30 cm in 5 cm increments). They measured the speed of the card using the length of the card and the time for it to pass through a photogate placed at the bottom of the swing. They plotted a graph of gravitational energy (at the top of the swing, relative to the bottom of the swing) vs. height. They assumed that the gravitational energy at the top was equal to the kinetic energy at the bottom, which they were able to calculate. This graph (Eg vs. h) yields a slope that was well within 5% of the product of the mass of the card and 9.8 N/kg. With this series of experiments, we were able to develop mathematical models for elastic energy in a hookean spring, kinetic energy, and gravitational energy. Next I will see if they can apply these mathematical models with the energy relations they write from their bar graphs to solve for unknowns. I know this part will probably be less successful because of their horrible algebra skills. I think that the set of experiments will have been, nonetheless, fruitful.

With my juniors and seniors, I have done the experiment in which the spring is compressed and used to launch a glider up an inclined air track to relate gravitational energy to height, but the freshman do not have the math to relate the distance along the track and the angle to the height reached by the glider. The pendulum version seems to be a satisfactory substitute.

Last year, using rubber bands and a different spring arrangement, the best I was ever able to do on the slopes with excellent technique was an error of about 13%. It was very hard, even for bright kids to figure out whether the slope of the energy vs. velocity squared graph was supposed to be the mass of the glider or one-half the mass of the cart, since it was in the middle of the two. With this new spring, even on a dynamics cart track, the freshmen seemed to have no problem realizing that it was one-half the mass of the cart. I am pleased!

I need to tell you how I have modified the experiment using the air track to get GREAT results). In any event, I use the energy materials mostly qualitatively, and feel like if students can write an appropriate energy equation for various situations we have been successful. We do the experiment relating the gravitational energy of a pendulum at the top of its swing to the kinetic energy at the bottom quantitatively using photogates and it works great with them.

We do not include projectiles, momentum, circular motion, or SHM in our mechanics section.

I then follow mechanics with CASTLE. In the past I have followed the materials as presented by Steinberg fairly faithfully through section 6. This year I plan to try the modified CASTLE materials. This is a good unit for freshmen although they are pretty tired of it by the end of the third section.

The next unit is electrostatics using the Bob Morse materials. This is also a good unit for freshmen. We do not try to deal with this quantitatively at all.

By the time we have finished with the above, there are usually about six weeks left. I have traditionally done units on waves & sound and a little bit with light in the remaining time. I try to do things that are high interest to keep kids on task as the year draws to a close.

LD: Then, when you teach physics to juniors/seniors, you do revisit some of the topics, no?

RR: Before I answer this question, I should explain what Bob Mullgardt [Rex's colleague at Clayton HS] does with Honors Freshman Physics.

In this course which is taken by the top quarter to third of our freshmen, Bob teaches via what is basically a modeling method as well. The course sequence follows what we traditionally used in the previous course, which was called Quantitative Science.

The first semester of Honors Freshman Physics is primarily geometric optics. All of the major science skills are integrated into a fairly detailed investigation of geometric optics. Each unit begins with a paradigm experiment, and the models are developed in what is remarkably close to our modeling cycle. The fundamental model used is a particle model of light. No reference to a wave model.

The sequence includes:

- Pinholes
- The Law of Reflection and Plane Mirrors
- Curved Mirrors
- Refraction and Snell's Law
- Lenses

Students learn to do graphical analysis extremely well. Bob reserves computer graphing until the second semester.

During the second semester Bob has integrated very complete versions of Units II and III. He does a Newton's Laws unit which includes many of the elements of Units IV and V. He completes the year with an energy unit. His focus has traditionally run toward machines as an application and he
has spent loads of time on levers and pulleys and such. Last year I was able to convince him to consider the new energy materials and he is trying to incorporate them. I plan to work on him some more this year and hope to get him to buy into them more thoroughly. I think he will.

As you can see from the abbreviated set of topics, *students are allowed to investigate thoroughly and leave with what I consider is an excellent understanding of how to do science as well as the ability to properly apply many fundamental models in physics.*

Now on to your question, which is a complicated one.

First the easy answer.

In my AP class, virtually every student has completed the Honors Freshman Physics course. Some of the students are juniors, some are seniors. Bob keeps the student's laboratory portfolios until they get to the later physics course and I give these back to them at the start of the course. We make some serious time through kinematics and dynamics and require no review of graphical analysis techniques. We revisit experiments from the freshman year, and use these as a starting point. There are units in each of the major areas which are part of the AP Physics B syllabus, but Kinematics and Newton's Laws go fairly quickly. Students have a firm foundation for the rest of Mechanics. The other place that I gain ground from the freshman course is of course in Geometric Optics. I give them a two-day review of the full semester of optics that they have already had. I then give them a set of exercises to work over spring break and then a killer optics test after spring break. They do well.

That course is the only way that I am able to do an AP Physics B course that hits all of the topics on the syllabus and is still taught with the laboratory as the focus. The course has a definite modeling flavor, although whiteboarding (especially of problems) is minimized severely to save time.

More complicated is my regular (junior/senior level course)

This class has an interesting mixture of students, which makes figuring out what to do an extreme challenge. Some of the students in this class have had the Honors Freshman Physics course. Some of the students have had the regular freshman physics course, but most of them have had other teachers (not me). The rest of the students are those who entered the school from some other school after their freshman year and have had no introduction to physics. The result is that I feel compelled to do the complete modeling program with the classes, but at a pace that is faster than what I would do with students who had not had a previous course. What usually happens is that the resulting course is too slow for the kids that had the honors course, too fast for the kids that have had no physics, and about right for the kids from the regular freshman physics course.